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Survey of Methods Used to Control Wastes Containing Hexachlorobenzene

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SURVEY OF METHODS USED

TO CONTROL WASTES CONTAINING HEXACHLOROBENZENE

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1976

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PREFACE AND ACKNOWLEDGEMENTS

This report presents the results of a survey of methods used to control wastes containing hexachlorobenzene (HCB). The survey was conducted by TRW Systems under Contract BOA 68-01-2956, Task Order 68-01-3203, for the EPA Office of Solid Waste Management Programs, (OSWMP). The project is deeply indebted to the EPA Project Officer, Mr. Thomas Leshendok, Hazardous Waste Management Division, OSWMP, for his continuing advice and guidance during the course of the study. Thanks are also due to other staff members of the Office of Solid Waste Management Programs for their critical review of the draft final report.

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1. SUMMARY

Under a contract with the EPA Office of Solid Waste Management Programs, Hazardous Waste Management Division, TRW conducted a survey of methods used to control wastes containing hexachlorobenzene (HCB). The specific objectives of the study were to identify the sources and characteristics of manufacturing wastes containing HCB, to review and document methods used for treatment and disposal of HCB wastes, and to evaluate the environmental adequacy of the treatment and disposal methods.

The data collected and used in this study were obtained from the following sources: (a) published literature; (b) telephone contacts and formal correspondence with industrial firms; (c) visits to production sites and waste disposal facilities; and (d) discussions and interviews with technical staffs in academic institutions, research establishments, trade organizations, and State and Federal agencies. The initial phase of the program concentrated on the identification of all possible sources for the generation of HCB wastes. Based on a literature search and some contact with industry, the following fourteen industries/operations were initially identified as possible sources of HCB wastes.

Industry/Operation	Potential Origin of HCB Wastes
Basic HCB production	HCB production operation
Chlorinated solvents production	Reaction side-product in the production of chlorinated solvents, mainly, carbon tetrachloride, perchloroethylene, trichloroethylene, and dichloroethylene
Pesticide industry	Reaction side-product in the production of Dacthal, simazine, mirex, atrazine, propazine, and pentachloronitrobenzene (PCNB)
Electrolytic chlorine production	Chlorine attack on the graphite anode or its hydrocarbon coating

Industry/Operation	Potential Origin of HCB Waste
Ordnance and pyrotechnics production	Use of HCB in the manufacture of pyrotechnics, and tracer bullets and other ordnance items
Sodium chlorate production	Similar to electrolytic chlorine production, where graphite anodes are used
Aluminum manufacture	Use of HCB as a fluxing agent in aluminum smelting
Seed treatment industry	Use of HCB in seed protectant formulations
Pentachlorophenol production	Reaction by-product of PCP production by chlorination of phenol
Wood preservative industry	Use of HCB as a wood preserving agent
Electrode manufacture	Use of HCB as a porosity control in the manufacture of graphite anodes
Cyanogen chloride production	Cyanogen chloride production process
Vinyl chloride monomer production	By-product in the manufacture of vinyl chloride monomer
Synthetic rubber production	Use of HCB as a peptizing agent in the production of nitroso and styrene rubbers for tires

Subsequent to the identification of the above listed industries, a number of firms in each industry were contacted and inquiries made regarding HCB waste generation and quantities. Of the total of 232 firms reported for the above listed industries, 80 firms (34 percent) were contacted in this survey. Of these 80 firms, 21 (26 percent) indicated that their waste streams contained HCB, 40 (50 percent) indicated that their waste streams did not contain HCB, and 19 (24 percent) either indicated that they did not know or that they preferred not to discuss the matter. The percentage distribution of the three types of response varied for the various industries. Based on the survey results, chlorinated solvents and pesticide industries were identified as the major sources of HCB wastes and were subsequently subjected to in-depth evaluation from the standpoint of waste generation and treatment and disposal methods.

Based on the data collected in this survey, of the estimated 3,900 metric tons of HCB waste* which is generated annually in this country, 2,400 metric tons (2,650 tons) is produced as a by-product waste in the production of chlorinated solvents. Of the 16 companies manufacturing chlorinated solvents, 5 representing 7 production sites and accounting for an estimated 37.3 percent of the total U.S. chlorinated solvents production capacity, indicated that HCB was a constituent of their waste streams and provided data (in some cases very limited) on waste quantities and treatment and disposal methods. These production sites are designated in this report as Plant Sites A, B, C, D, E, F and J.† HCB waste quantities generated at three production sites (Plant Sites G, H, and I) were estimated based on data provided by an off-site disposal contractor which had previously handled HCB waste from Plant Site G and the data collected for similar production operations at other plant sites. Plant Sites G, H and I account for an estimated 21.2 percent of the total U.S. chlorinated solvents production capacity.

Five additional chlorinated solvents production plants representing an estimated 41.5 percent of the total U.S. chlorinated solvents production capacity responded in one of the following ways: (a) they use the CS_2 process which does not generate HCB waste; (b) they have not detected HCB in their waste streams; and (c) they have not analyzed their waste stream for HCB content. For the plants surveyed, HCB-containing waste streams are usually in the form of heavy ends waste liquids from various distillation or purification processes within the manufacturing operation. Two plants

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* Except when noted as "HCB-Containing Waste", throughout this report all quantitative data on HCB wastes refer to the HCB content of the wastes (i.e., the amount of HCB contained in the waste stream).

† Many of the companies participating in the present study submitted data to TRW on a proprietary basis. To protect the proprietary interests, where appropriate the participating companies (plant sites and waste disposal contractors) are referred to in this report by designated letters of alphabet (e.g., Plant Site A or off-site waste disposal contractor OC-1, etc.). Tables A-1 and A-2 in the Appendix identify the states in which the production sites and off-site contractors are located.

recover HCB from chlorinated solvents wastes. Each year approximately 240 metric tons (265 tons) of HCB is recovered for sale. This quantity, however, accounts for only 10 percent of the total HCB generated by the chlorinated solvents industry; the other 90 percent is discharged in the waste streams which are disposed of on land or are incinerated.

In the pesticide industry, the production of Dacthal, PCNB, mirex simazine, atrazine, and propazine result in the generation of HCB wastes. At the present, Dacthal, PCNB, and mirex each is produced at only one production site and by a different company. Simazine, atrazine and propazine are produced at one site by one company. Pesticide production sites are designated as Plant Sites Q, R, S and T. The estimated total quantity of HCB waste generated in the pesticide industry is 1,499 metric tons (1,655 tons) per year with wastes from Plant Sites R and Q accounting for 84.5 percent and 15.1 percent of the total, respectively. The HCB is present mainly in tars and still bottoms from manufacturing operation.

For a total of 2,870 metric tons (3,168 tons) per year of HCB waste for which data were obtained from industry on waste handling methods, the currently used waste storage methods and the percentage of waste handled by each method are: storage of solid cubes under plastic cover, 44.2 percent; water-covered open storage lagoons, 33.1 percent; drums which may or may not be lined, 14.3 percent; insulated and heated storage tanks, 8.2 percent; and nitrogen-blanketed steel tank, <0.1%. Methods used for waste transportation and the percentage of waste handled by each method are: truck, 38.4 percent; forklift, 35.7 percent; pipeline, 19.1 percent; heated tank trucks, 6.6 percent; and rail, 0.1 percent. Loading, storage and transportation of waste can result in environmental contamination if the operation is not managed properly or in cases of accidents and spills.

At some HCB waste generation and disposal sites some form of treatment is utilized prior to ultimate waste disposal. These treatment methods include use of storage lagoons to effect settling of HCB solids, distillation to effect waste volume reduction and material recovery, heating to effect fluidization during storage and bulk transportation by pipeline and trucks, solidification and shaping into cubes for storage, dewatering for waste concentration, and dilution and suspension by mixing with other wastes prior to deep well injection.

Methods currently used for the ultimate disposal of HCB wastes include land disposal (sanitary landfill, industrial landfill, deep well injection and drying ponds), incineration (with or without by-product recovery), open pit burning, resource recovery, discharge to municipal sewage treatment plants, and emission to the atmosphere. Both on-site disposal and off-site contract disposal are used. Based on a total waste quantity of 2,444 metric tons (2,647 tons) for which data were obtained on waste disposal methods, land disposal is currently the most prevalent method for ultimate disposal of HCB wastes. Nine of the 22 sites surveyed use land disposal; approximately 1,389 metric tons (1,483 tons) of HCB wastes (56 percent of the total) are disposed of by this method each year. Among land disposal methods, industrial landfill is the most widely used method, accounting for the disposal of 39.7 percent of all HCB wastes. Ranked next to land disposal is incineration which is used at nine of the sites surveyed for the destruction of 1,055 metric tons (1,164 tons) per year of HCB wastes. One incineration site handling 680 metric tons (750 tons) of HCB waste per year, recovers hydrochloric acid as a by-product. No data were available on the quantity of HCB wastes which is used at one site as a chemical feedstock for the production of low-molecular weight aliphatic halogenated hydrocarbons. Compared to land disposal and incineration, the quantities of waste discharged to sewage treatment plants and to the atmosphere appear to be very small. Of the 22 sites surveyed, 6 use the services of commercial off-site disposal contractors for the disposal of a total of 655 metric tons (723 tons) per year of HCB wastes.

Methods for the ultimate disposal of HCB wastes were evaluated in terms of three levels of technology representing the prevalent practice (Level I), the best technology available in current commercial practice (Level II), and technology currently known and assessed as providing adequate health and environmental protection (Level III). Based on the quantity of HCB wastes handled, industrial landfill on a suitable geological formation and with a cover consisting of 1.2 to 1.8 m (4 to 6 feet) of soil and a 0.025 cm (10-mil) thick polyethylene film placed at approximately mid-depth of the soil cover would be the Level I technology. However, based on the number of sites which use a disposal method, incineration without by-product recovery but with emission control would be the Level I technology. Incineration with emission control and by-product recovery is considered as Level II and Level III technology. Data for operating sites indicate that HCB can be effectively destroyed by incineration with little emission of pollutants to the atmosphere. An incineration system of proprietary design at Plant Site G is reported to effect 99.94 percent destruction of HCB and allows for recovery of HCl as a by-product.

Not all industries and waste disposal facilities which were contacted furnished information on the costs for handling and disposal of HCB wastes. Some of the companies and waste disposal facilities indicated that they cannot break down their total cost to arrive at any meaningful estimate of the portion of the cost which can be attributed to the handling of HCB wastes, which accounts for a small fraction of the total waste handled. The cost charged to waste generators by four off-site waste disposal contractors employing landfill, incineration and deep-well injection range from $22 to $35 per metric ton ($20 to $32 per ton) of HCB-containing wastes. At one plant site, the cost for the operation of a pretreatment lagoon, removal and transport of waste from the lagoon to an industrial landfill, and equipment maintenance is estimated at $11 per metric ton ($10 per ton).

2. CONCLUSIONS

- Of the 14 industries/operations identified as possible sources for HCB waste generation, chlorinated solvents production and pesticide manufacturing are the two major sources of HCB wastes accounting for nearly all of the reported HCB waste generation quantities.

- HCB has been detected in waste effluents from electrolytic chlorine production, pyrotechnic and ordnance manufacture and seed treatment industries. Adequate analytical data are not available to assess the magnitude of HCB generation and specific operations resulting in HCB production in these industries.

- The largest current use of HCB is as a peptizing agent in the manufacture of nitroso and styrene rubber for tires. The use of large quantities of HCB in the manufacturing of synthetic rubber is very new and quantitative and qualitative data are not available on waste generation possibilities and environmental implications associated with such a usage.

- Based on contacts with a number of firms/plants in the aluminum manufacturing, pentachlorophenol production, electrode manufacture, and vinyl chloride monomer production industries, HCB wastes are not associated with these industries.

- Adequate data are not available to assess the magnitude of HCB problem in the wood preservative industry, cyanogen chloride production, and sodium chlorate production.

- The hauling of HCB wastes in open drums and the dumping of the drums in a normal sanitary landfill operation can present a significant potential for contamination of air, land, water and wildlife.

- Disposal of HCB in sanitary or industrial landfills can be environmentally acceptable if an adequate soil cover which includes an intermediate layer of plastic is provided and the geology of the site is suitable for waste and leachate containment.

- Incineration with emission control and by-product recovery appears to be the most desirable and environmentally acceptable technology for the destruction of HCB wastes. Design data, operating conditions and cost data are not available on the only unit of this kind currently in operation at one plant site.

- Very limited actual disposal cost data are available on existing facilities handling HCB wastes.

- At most facilities which generate HCB wastes, these wastes account for only a fraction of the total waste effluent. At these facilities, the handling of HCB wastes cannot be considered as an isolated problem requiring a separate solution, but rather should be viewed as an element in the total waste management plan for the facility.

4. METHODOLOGY

The data collected and used in this study were obtained from the following sources: (a) published literature; (b) telephone contacts and formal correspondence with industrial firms; (c) visits to production sites and waste disposal facilities; and (d) discussions and interviews with technical staffs in academic institutions, research establishments, trade organizations, and State and Federal agencies. In the body of the report, the source or sources of data are identified, where appropriate.

The first step in data gathering was a preliminary literature survey in which industries, plants, and operations suspected of generating HCB wastes were identified. This was then followed by telephone inquiries and submission of formal requests for data to the company headquarters and plants. The specific data which were requested from some industries/plants contacted are illustrated in the questionnaire form shown as Table A-4 in the Appendix. The requested data included information on source(s) of HCB wastes; commodity production and HCB generation rates; physical and chemical characteristics of waste streams containing HCB; and waste handling, treatment, and disposal methods and associated costs. Overall, a total of 80 companies (some operating more than one production site) were contacted. A listing of the non-industrial agencies contacted are presented in Table A-5 in the Appendix.

Six site visits were made for data collection. These included visits to two major waste generation sites (designated as plants B and F in Table A-1 in the Appendix), two visits to waste disposal sites (designated as OC-1 and OC-4 in Table A-2 in the Appendix), one trip to New Orleans, Louisiana, for discussions with the personnel at the Louisiana State Health Department (Section of Solid Waste and Vector Control, and Air Control Section), and one trip to the University of California at Riverside (California) to discuss research findings on control of HCB volatilization at land disposal sites.

The data which were collected in the survey were collated and evaluated, and are presented (in summary form) and discussed in the sections of this report which follow.

5. RESULTS AND DISCUSSION

This Chapter presents and discusses the data obtained on industries and operations which produce HCB-containing wastes, quantities and characteristics of the wastes, and methods and procedures used for handling, treatment, and disposal of the wastes. A discussion of the environmental adequacy of waste treatment/disposal methods is also presented in the pertinent sections of this Chapter.

5.1 HCB WASTE GENERATION SURVEY

The following 14 industries/operations were identified as possible sources for the generation of HCB wastes:

(1) Basic HCB production

(2) Chlorinated solvents production

(3) Pesticide industry

(4) Electrolytic chlorine production

(5) Ordnance and pyrotechnics production

(6) Sodium chlorate production

(7) Aluminum manufacture

(8) Seed treatment industry

(9) Pentachlorophenol production

(10) Wood preservative industry

(11) Electrode manufacture

(12) Cyanogen chloride production

(13) Vinyl chloride monomer production

(14) Rubber manufacturing

A number of firms in each of the industries listed above were contacted and inquiries were made regarding the presence of HCB in their waste streams. The number of firms in the first 13 industries listed above which were contacted, the estimated number of firms in each industry, and the number of responses received from the firms contacted are summarized in Table 1. (It is only very recently that large quantities of HCB have been used in the manufacturing of synthetic rubber. Very little data are available on HCB use, and waste generation and treatment in the rubber manufacturing industry. Although identified here as a possible source of HCB wastes, the synthetic rubber industry was not included in this survey.) Relative to the estimated total number of firms in the various industries, the number of firms contacted in general represent an adequate sampling of the industries reviewed. Indeed, for some industries, more than 50 percent of the estimated total number of firms were contacted (e.g., for chlorinated solvents production and vinyl chloride production). Some of the firms contacted own and operate more than one plant; some of these firms provided information on more than one or all of their facilities. Of the total of 80 firms surveyed, 21 (26 percent) indicated that their waste streams contained HCB, 40 (50 percent) indicated that their waste streams did not contain HCB, and 19 (24 percent) either indicated that they did not know or that they preferred not to discuss the matter. The percentage distribution of the three types of response varied for the various industries. Thus, for chlorinated solvents production, of the 11 firms contacted, 6 (55 percent) indicated that they generated HCB-containing wastes, and 5 (45 percent) indicated that they did not generate HCB-containing wastes; whereas for electrolytic chlorine production, 2 (14 percent) of the 14 firms contacted indicated that they generated HCB-containing wastes and 7 (50 percent) indicated that they did not know or that they preferred not to discuss the matter. The survey results shown in Table 1 indicate that not all plants (firms) within a given industry generate HCB wastes. This may be explained in a number of ways including:(a) that there are differences in processes/operations utilized, and (b) not all plants monitor their waste streams for HCB or utilize the analytical procedures with the same detection levels.

Based on the survey results and the data on waste quantities (which are presented and discussed in Section 5.4), the chlorinated solvents and pesticide industries are the major sources of HCB wastes. The electrolytic chlorine industry can be considered as a minor source of HCB wastes. (See

TABLE 1
HCB WASTE GENERATION SURVEY, NUMBER OF FIRMS CONTACTED AND RESPONSES RECEIVED

Industry	No of Firms Contacted in Each Industry*	Total No of Firms Reported For the Industry†	No of Contacted Firms Generating HCB Wastes	No of Contacted Firms Not Generating HCB Wastes	No of Contacted Firms Not Sure/Would Not Disclose
Basic production/ Distribution	3	3	1	2	0
Chlorinated Solvents Production	11	11	6	5	0
Pesticide Industry‡	4	4	4	0	0
Formulation/Distribution	2	46	2	0	0
Electrolytic Chlorine Production	14	34	2	7	5
Ordnance and Pyrotechnics Production	7	§	3	1	3
Sodium Chlorate Production	5	9	0	0	5
Aluminum Manufacture	4	10	1	3	0
Seed Treatment Industry					
Production	3	8	0	3	0
Formulation/ Distribution	3	8	1	2	0
Seed Treatment Houses, Nurseries	1	4	0	0	1
PCP Production	5	6	0	3	2
Wood Preservatives Industry	2	52	0	2	0
Electrode Manufacture	5	23	1	4	0
Cyanogen Chloride Production	0	2	n.a.	n.a.	n.a.
VCM Production	11	12	0	8	3
(Total)	(80)	(232)	(21)	(40)	(19)

* Some of the firms operate more than one production facility.
† Based on data in references 9 through 12.
‡ Includes only those firms involved in production/formulation of Dacthal, mirex, simazine, atrazine, propazine and PCNB. These pesticides and operations related to their production/formulation are suspected sources of HCB waste.
§ No exact estimates available due to fluctuations in munitions needs which involve activation and deactivation of many military production sites.
n.a. Indicates not applicable.

also the discussion below for the individual industries.) Because of this consideration, only these three industries were subsequently subjected to in-depth evaluation from the standpoint of waste quantities generated and treatment/disposal methods employed.

The following section briefly reviews the industries which were surveyed as possible sources of HCB wastes. The information presented is based on (a) response to inquiries which were directed to various companies, (b) literature search and (c) in some cases, field visits and discussions with plant technical personnel.

5.2 INDUSTRIAL OPERATIONS PRODUCING HCB WASTES

5.2.1 Basic Production of HCB

Although there are known methods for direct synthesis of HCB (e.g., by chlorination of benzene or treatment of isomers of hexachlorocyclohexane with sulfuryl chloride), the current industrial production of HCB involves recovery of HCB from wastes generated in the production of chlorinated solvents (see below).

The 1975 Stanford Research Institute Directory of Chemical Producers[10] and the Oil, Paint and Drug Chemical Buyers Directory[13] list Dover Chemical Company (Dover, Ohio) and Hummel Corporation (South Plainfield, New Jersey) as manufacturers of HCB. In 1974, the Dover facility in Ohio produced approximately 50 metric tons (55 tons) of HCB.[14] The production process involves recovery of HCB from chlorinated solvent wastes.[14] Hummel is only an HCB supplier/distributor, handling primarily Dover's product.[15]

Wastes in the production of HCB are expected to originate from the actual manufacturing operations and from equipment and spill clean-up activities. Using a carbon absorption/solvent extraction method for sample concentration, followed by gas chromotographic analysis of the concentrate, no HCB has been detected in the aqueous waste streams from the Dover plant at a detection level of 0.1 ppm.[16]

5.2.2 Chlorinated Solvents Production

Based on industry-furnished data (see Section 5.4), over half of the 3,909 metric tons (4,316 tons) of HCB which is generated annually in the country is produced as a by-product waste in the production of chlorinated solvents (mainly, carbon tetrachloride, perchloroethylene, trichloroethylene, and dichloroethylene). In the production of chlorinated solvents, HCB is formed as a reaction side product in the course of thermal chlorination, oxychlorination and cracking operations. HCB-containing waste streams are usually heavy ends waste liquids from various distillation or purification processes within the manufacturing operations. As will be discussed in Section 5.4.2, because of differences in the manufacturing processes, not all chlorinated solvent producers generate HCB in their waste streams.

Table 2 lists companies, domestic sites and annual production capacities (or quantities) for the production of carbon tetrachloride, perchloroethylene, ethylene dichloride and trichloroethylene. Carbon tetrachloride is produced by seven companies at 12 different locations; perchloroethylene is produced by eight firms at 11 different production sites; ethylene dichloride is manufactured by 12 firms at 18 sites; and trichloroethylene is produced by 5 companies at 5 different sites. Of the total of 16 companies manufacturing chlorinated solvents, only one recovers HCB from its waste streams at one of its facilities (Plant Site A). Each year approximately 190 metric tons (210 tons) of HCB is recovered at this site for sale. When this quantity of HCB is added to the 50 metric tons (55 tons) per year of HCB produced at the Dover Plant (see Section 5.2.1), the total quantity of HCB recovered from chlorinated solvent waste is 240 metric tons (265 tons) per year which accounts for only 10 percent of the estimated 2401 metric tons (2650 tons) per year of HCB waste which is generated annually in the production of chlorinated solvents. The other 90 percent of HCB which is not recovered is discharged in the waste streams which are disposed of on land or are incinerated (see Section 5.5).

5.2.3 Pesticide Industry* (Excluding Seed Treatment Industry)

Based on the data collected in this study, approximately 38.6 percent of the total HCB generated annually in the U.S. is produced by the pesticide

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*See Section 5.2.8 for a discussion of the seed treatment industry.

TABLE 2
COMPANIES, DOMESTIC SITES AND PRODUCTION RATES OR CAPACITIES FOR CARBON TETRACHLORIDE, PERCHLOROETHYLENE, TRICHLOROETHYLENE, AND DICHLOROETHYLENE

Company	Site	Production Rate or Capacity* Metric Tons/Year (Tons/Year)	Reference
Carbon Tetrachloride			
Allied Chemical Corp.	Moundsville, W.V.	3,630, (4,000)	10
Dow Chemical U.S.A.	Freeport, Tx.	59,000, (65,000)	10
Dow Chemical U.S.A.	Pittsburg, Ca.	20,400, (22,500)	10
Dow Chemical U.S.A.	Plaquemine, La.	45,400, (50,000)	10
E. I. duPont de Nemours & Co., Inc.	Corpus Christi, Tx	227,000, (250,000)	10
FMC Corp.	So. Charleston, W.V.	136,000, (150,000)	10
Inland Chemical Corp.	Manati, P.R.	(Not available)	10
Stauffer Chemical Co.	Louisville, Ky.	22,700, (25,000)**	17
Stauffer Chemical Co.	LeMoyne, Al.	90,600, (100,000)	10
Stauffer Chemical Co.	Niagara Falls, N.Y.	68,000, (75,000)	10
Vulcan Materials Co.	Geismar, La.	16,000, (17,500)	10
Vulcan Materials Co.	Wichita, Ka.	18,000, (20,000)	10
Perchloroethylene			
Diamond Shamrock Corp.	Deer Park, Tx.	73,100, (?0,500)**	18
Dow Chemical U.S.A.	Freeport, Tx.	54,500, (60,000)	10
Dow Chemical U.S.A.	Pittsburg, Pa.	9,100, (10,0??)	10
Dow Chemical U.S.A.	Plaquemine, La.	68,100, (75,000)	10
E. I. duPont de Nemours & Co., Inc.	Corpus Christi, Tx.	72,600, (80,000)	10
Ethyl Corp.	Baton Rouge, La.	22,900, (25,000)	10
Hooker Chemical Co., Subsid. Occidental Petroleum Corp.	Taft, La.	22,900, (25,000)	10
PPG Industries, Inc.	Lake Charles, La.	91,000, (100,000)	10
Stauffer Chemical Co.	Louisville, Ky.	25,000, (27,500)	17
Vulcan Materials Co.	Geismar, La.	68,000, (75,000)*	10
Vulcan Materials Co.	Wichita, Ks.	22,900, (25,000)	10

* Unless marked by ** these figures are the production capacities reported in Reference (10); the figures marked by ** are the actual production rates as supplied by the industry.

TABLE 2
COMPANIES, DOMESTIC SITES AND PRODUCTION RATES OR CAPACITIES FOR CARBON TETRACHLORIDE, PERCHLOROETHYLENE, TRICHLOROETHYLENE, AND DICHLOROETHYLENE (CONT'D)

Company	Site	Production Rate or Capacity* Metric Tons/Year (Tons/Year)	Reference
Trichloroethylene			
Diamond Shamrock Corp.	Deer Park, Tx.	13,300, (14,600)**	18
Dow Chemical U.S.A.	Freeport, Tx.	68,100, (75,000)	10
Ethyl Corp	Baton Rouge, La.	68,100, (75,000)	10
Hooker Chemical Co., Subsid (Occidental Petroleum Corp.)	Taft, La.	18,200, (20,000)	10
PPG Industries, Inc.	Lake Charles, La.	127,100, (140,000)	10
Dichloroethylene			
Allied Chemical Corp.	Baton Rouge, La.	295,000, (325,000)	10
Continental Oil Co. (Conoco Chemicals)	Westlake, La.	513,000, (565,000)**	19
Diamond Shamrock Corp.	Deer Park, Tx.	118,000, (130,000)	10
Dow Chemical U.S.A.	Freeport, Tx.	590,000, (650,000)	10
Dow Chemical U.S.A.	Oyster Creek, Tx.	499,000, (550,000)	10
Dow Chemical U.S.A.	Plaquemine, La.	527,000, (580,000)	10
Ethyl Corp.	Baton Rouge, La.	249,200, (275,000)	10
Ethyl Corp.	Pasadena, Tx.	117,800, (130,000)	10
B. F. Goodrich Co.	Calvert City, Ky.	408,600, (450,000)	10
PPG Industries, Inc.	Lake Charles, La.	454,000, (500,000)	10
PPG Industries, Inc	Guayanilla, P.R.	379,000, (417,500)	10
Stauffer Chemical Co.	Carson, Ca.	136,000, (150,000)	10
Shell Chemical Co.	Deer Park, Tx.	545,000, (587,500)	10
Shell Chemical Co.	Norco, La.	529,000, (587,500)	10
Texaco, Inc.	Port Neches, Tx.	32,000, (35,000)	10
Union Carbide Corp.	Taft, La.	68,000, (75,000)	10
Union Carbide Corp.	Texas City, Tx.	68,000, (75,000)	10
Vulcan Materials Co.	Geismar, La.	109,000, (120,000)	10

* Unless marked by ** these figures are the production capacities reported in Reference (10), the figures marked by ** are the actual production rates as supplied by the industry.

industry, primarily in the manufacturing of Dacthal, mirex, simazine, atrazine, propazine, and pentachloronitrobenzene (PCNB). HCB is produced as a waste product and is also present in the product as an impurity. Based on industry-furnished data, it is estimated that 99.4 percent of the estimated 1,509 metric tons (1,666 tons) per year of HCB associated with the pesticide industry is contained in the process waste streams (tars, still bottoms, etc.) from production operations, and 0.6 percent (9 metric tons or 10.5 tons per year is contained in the product as an impurity. HCB contained in the wastes from the manufacturing of simazine, propazine, and atrazine has been attributed to the presence of HCB impurities in the cyanogen chloride which is used as a raw material. Direct use of, and formulation operations involving HCB-containing pesticides can result in the introduction of HCB into the environment. Table 3 lists the producers, production sites, formulators and the number of distributors for each of the above-mentioned pesticides. The list of formulators and the number of distributors are based on the data published in the Farm Chemicals Handbook.[(11)] Some of the formulators operate more than one formulation site.

5.2.4 Electrolytic Chlorine Production

The electrolytic processes for the production of chlorine (diaphragm and mercury cells) generate HCB (and other hydrocarbon wastes) in the crude chlorine gas when graphite electrodes are used as the anode.[(9)] HCB production is believed to result from direct attack of chlorine on the graphite and/or from the reaction of chlorine with the hydrocarbon oils (e.g., linseed oil) which are used as anode coatings. When crude chlorine is liquified and purified by distillation, most of the chlorinated hydrocarbons (including HCB) are separated from chlorine and remain as components of the "heavy ends." Some HCB may also be present in the recycled spent brine and in the brine purification mud. Some manufacturers do not purify chlorine on site. The undistilled product is used in a number of industrial applications (e.g., as a flux in aluminum smelting) not requiring a highly pure chlorine gas. When the unpure liquified chlorine is vaporized at the application site prior to use, HCB and other hydrocarbon impurities remain as residuals in the storage tank and/or vaporization equipment. Thus, industrial sites where unpurified chlorine is used may be regarded as secondary potential sources for HCB waste generation.

TABLE 3
PRODUCERS, FORMULATORS AND THE NUMBER OF DISTRIBUTORS FOR MIREX, DACTHAL, SIMAZINE, ATRAZINE, PROPAZINE AND PCNB (10, 11)

Pesticide	Producer	Production Site	Formulator	Location of Company Headquarters	Number of Distributors*
Dacthal	Diamond Shamrock Corporation	Greens Bayou, Tx.	Agway, Inc.	Syracuse, N.Y.	22
			Brockville Chemical Industries, Ltd.	Montreal, Quebec	
			Lebanon Chemical Company	Lebanon, Pa.	
PCNB	Olin Corporation	McIntosh, Al.	Woodbury Chemical of Homestead	Princeton, N.J.	10
			Woolfolk Chemical Works, Ltd.	Ft. Valley, Ga.	
Mirex	Nease Chemical	State College, Pa.	Hooker Chemical Company	Niagara Falls, N.Y.	2
			Allied Chemical Company	Morristown, N.J.	
Simazine Atrazine Propazine	Ciba-Geigy Corporation	St. Gabriel, La.	-	-	33

* A complete listing of these distributors and their locations can be found in the Farm Chemicals Handbook (11)

Electrolytic chlorine production operations which use metallized anodes, such as the so-called dimensionally stable anodes (DSA's), do not generate HCB. Since about 1969, many modern plants have been converted to the use of the DSA's. In the present survey, 67 plants were identified as sites for the electrolytic production of chlorine; graphite anodes are currently used at 32 of the sites (see Table 4); the remaining 35 sites (see Table 5) currently use or are scheduled to use DSA's or other types of non-graphite electrodes.

5.2.5 Ordnance and Pyrotechnics Production

HCB is used in the manufacture of various pyrotechnics (e.g., signal flares) for military and civilian use and in the production of certain ordnance items (e.g., tracer bullets). Some HCB-containing wastes are thus expected to be generated at pyrotechnic and ordnance manufacturing/loading facilities which handle HCB-containing raw materials or products. Except for the major facilities which are identified below, all of the pyrotechnic/ordnance production sites which may generate HCB wastes could not be idenified because of the limited data available (mainly due to the classified nature of munitions production operations).

HCB has been used in the manufacture of Navy Mark 13 Day and Night Distress Signals, Mark 99 Marine Markers, Army hand signals (eliminators) and commercial highway emergency flares by Kilgore Corporation (Toone, Tennessee). Between 1962 and 1975, approximately 2.7 metric tons (3 tons) of HCB was loaded for Army hand signals, 0.6 metric tons (0.65 tons) HCB for commercial flares, and an additional undisclosed quantity for the Navy Marine Mark Series at this site.[20] Mark 99 Marine markers have also been loaded at the Crane Naval Ammunition Product Engineering Center (Crane, Indiana). Three other pyrotechnic and ordnance manufacturers (Apache, Benson, Arizona; Aerojet-General, El Monte, California; and Security Signals, Cordova, Tennessee) which are involved in the production of similar items may also generate HCB wastes. Longhorn Army Ammunition Plant (Marshal, Texas) and Crane Naval Ammunition Center are reportedly using or have used HCB in pilot scale testing of certain ordnance/pyrotechnic items.[21,22]

TABLE 4
ELECTROLYTIC CHLORINE PRODUCERS USING GRAPHITE ANODES AND PRODUCTION SITES*

Company	Site(s)
Allied Chemical Corp.	Brunswick, Ga., Baton Rouge, La., Syracuse, N.Y., Acme, N.C.
BASF Wyandotte Corp.	Wyandotte, Mi.
Champion International Corp.	Houston, Tx.
Dow Chemical U.S.A.	Midland, Mi., Plaquemine, La., Freeport, Tx., Pittsburg, Ca.
E. I. duPont de Nemours & Co., Inc.	Niagara Falls, N.Y., Memphis, Tn.
Ethyl Corp.	Baton Rouge, La., Houston, Tx.
Ft. Howard Paper Co.	Green Bay, Wi.
Hooker Chemical Corp., Subsid. (Occidental Petroleum Corp.)	Montague, Mi., Taft, La., Tacoma, Wa.
Hooker-Sobin Chemicals, Inc.	Niagara Falls, N.Y.
Inland Chemical Corp.	Newark, N.J.
Jefferson Chemical Co.	Port Neches, Tx.
Linden Chlorine Products, Inc.	Linden, N.J.
Mobay Chemical Corp.	Cedar Bayou, Tx.
Olin Corp.	Augusta, Ga., McIntosh, Al., Niagara Falls, N.Y., Charleston, Tn.
Oregon Metallurgical Corp.	Albany, Or.
PPG Industries, Inc.	Barberton, Oh., Corpus Christi, Tx.
RMI Company	Ashtabula, Oh.
Stauffer Chemical Co.	Henderson, Nv.
Vicksburg Chemical Co.	Vicksburg, Ms.

* Based on data in Reference 9, supplemented by direct contact with industry; seven of the companies listed were contacted in the survey.

TABLE 5
ELECTROLYTIC CHLORINE PRODUCERS USING DSA'S OR OTHER NON-GRAPHITE ELECTRODES, AND PRODUCTION SITES*

Company	Site(s)
Aluminum Company of America	Ft. Comfort, Tx.
Allied Chemical Corp.	Moundsville, W.V.
BASF Wyandotte Corp.	Fort Edwards, Wi., Geismar, La.
Brunswick Pulp and Paper Co.	Brunswick, Ga.
Champion International Corp.	Canton, N.C.
Diamond Shamrock Corp.	Painesville, Oh., Deer Park, Tx., Delaware City, De., Muscle Shoals, Al., Mobile, Al.
Detrex Chemical Industries, Inc.	Ashtabula, Oh.
Georgia-Pacific Corp.	Billingham, Wa.
B. F. Goodrich Co.	Calvert City, Ky.
Hercules, Inc.	Hopewell, Va.
Hooker Chemical Corp.,Subsid. (Occidental Petroleum Corp.)	Niagara Falls, N.Y.
Kaiser Aluminum & Chemical Corp.	Gramercy, La.
Monsanto Co.	E. St. Louis, Il., Pisgah Forest, N.C.
Pennwalt Corp.	Calvert City, Ky., Tacoma, Wa., Portland, Or., Wyandotte, Mi.
FMC Corp.	S. Charleston, W.V.
PPG Industries, Inc.	New Martinsville, W.V., Lake Charles, La.
Shell Chemical Co.	Deer Park, Tx.
Sobin Chemicals, Inc.	Orrington, Me.
Stauffer Chemical Co.	LeMoyne, Al., St. Gabriel, La.
Vulcan Materials Co.	Denver City, Tx., Wichita, Ks., Geismar, La.†
Weyerhaeuser Co.	Longview, Wa.

* Based on data in Reference 9, supplemented by direct contact with industry; nine of the companies listed were contacted in this survey.

† Not yet on stream.

HCB wastes generated by the ordnance/pyrotechnic industry are relatively small in quantity and are primarily in the form of HCB scrap and contaminated containers. At the Kilgore plant in Toone, Tennessee, approximately 1.5 percent of drummed dry scrap waste generated in the manufacturing of HCB-containing products is HCB. The total amount of scrap generated is not known.

5.2.6 Sodium Chlorate Production

Sodium chlorate is manufactured by the electrolysis of saturated brine solutions containing sodium dichromate and acidified with hydrochloric acid. As with the electrolytic chlorine production, two types of electrodes are commonly used as the anode: graphite and metallized anodes (such as the DSA). Because of the use of graphite anode, sodium chlorate production by the electrolytic process can be a potential source of HCB production. Waste streams from the process which may contain HCB are the mud wastes (graphite stub residue) from spent cell liquor.

Table 6 presents a list of the 15 sodium chlorate manufacturing facilities in the U.S. Five companies representing seven sites (four sites using graphite anodes and three sites using non-graphite anodes) were contacted in this survey and inquiries were made about HCB production. The companies contacted indicated that they had not tested their waste streams for HCB and had no qualitative or quantitative data available on HCB. Based on contact with industry and the information contained in a recent publication[9], all sites which currently use graphite electrodes will soon convert to DSA's or other types of non-graphite electrodes. Accordingly, the sodium chlorate industry is expected to be eliminated as a potential source of HCB production.

5.2.7 Aluminum Manufacture

HCB has been reported to be used as a fluxing agent in the smelting operating associated with the primary manufacture of aluminum. In the present survey, four of the ten major aluminum manufacturing companies which were contacted (see Table 7 for a complete list of domestic aluminum

TABLE 6
SODIUM CHLORATE PRODUCERS, PRODUCTION
SITES AND TYPE OF ANODE USED*

Company	Site	Type of Anode Used
Brunswick Pulp and Paper Company	Brunswick, Ga.	Graphite
Huron Chemicals of America, Inc.	Butler, Al.	N.A.
Georgia-Pacific Corp.	Bellingham, Wa.	DSA
Kerr-McGee Chemical Corp.	Hamilton, Ms.	Graphite
	Henderson, Nv.	Graphite
Hooker Chemical Corp., Subsid. of Occidental Petroleum Corp.	Columbus, Ms.	N.A.
	Niagara Falls, N.Y.	DSA
	Taft, La.	N.A.
Pacific Engineering and Production Company of Nevada	Henderson, Nv.	Graphite
Penn-Olin Chemical Co.	Calvert City, Ky.	DSA
Pennwalt Corp.	Portland, Or.	DSA Scheduled
	Wyandotte, Mi.	Not Disclosed
PPG Industries, Inc.	Lake Charles, La.	N.A.
Riegel Paper Corp.	Naheola, Al.	N.A.
	Riegelwood, N.C.	N.A.

*Based on the data in References 9 and 10, supplemented by direct contact with industry; five of the companies listed were contacted in this survey.

N.A. indicates not available.

TABLE 7
ALUMINUM MANUFACTURERS (SMELTERS) AND COMPANY HEADQUARTERS*

Company	Headquarters
Kaiser Aluminum & Chemical Corp.	Oakland, Ca.
Howmet Corp.	Brunswick, Ct.
Olin Corp.	Stanford, Ct.
Batchelder, Charles E.	Newton, Ct.
Manufacture Systems Inc.	Great Lakes, Mn.
Martin Marietta	New York City, N.Y.
Revere Copper and Brass	New York City, N.Y.
Ormet	Hannibal, Oh.
Reynolds Metals	Richmond Va.
Aluminum Co. of America	Pittsburgh, Pa.

* Based on data in Reference 12; four of the companies listed above were contacted in this survey.

manufacturers) indicated that they do not use HCB as a fluxing agent and they envisioned no likelihood for the generation of HCB in the smelting or fabrication of aluminum by the currently used technology. Alcoa is currently conducting pilot plant tests on a new proprietary smelting process. To date, tests conducted on waste streams from the pilot plant have failed to indicate the presence of HCB.

As was indicated above in Section 5.2.4, aluminum manufacturing plants which use impure chlorine (alone or in combination with other gasses as a flux in smelting) may be a source of HCB waste, since any HCB present in the liquified chlorine feed tank may accumulate as residue which may require disposal.

5.2.8 Seed Treatment Industry

In the past, the principal use of HCB has been as a seed protectant or as an ingredient in seed protectant formulations for the control of wheat bunt and smut fungi of other grains.(9) (Currently, HCB is mainly used as a peptizing agent in the manufacturing of certain types of synthetic rubber.) In 1971, an estimated 6.2 metric tons (6.9 tons) of HCB were used as a grain fungicide primarily in California, Washington and Oregon.(1) HCB is also used in quarantine centers and in seed certification.(23) Seed treatment formulation houses which formulate HCB-containing seed protectants, and quarantine and seed treatment houses, as well as the use of treated seeds (particularly the cotton seed) are sources for HCB waste generation and introduction of HCB into the environment.

According to the Farm Chemicals Handbook,(11) there are at least eight major seed treatment formulators in the country (and at least four seed treatment nurseries(24)). Each of the companies and nurseries presumably formulate and operate at more than one site. Three of the seed treatment formulators were contacted in the present survey. Two of the formulators indicated that they do not use HCB in any of their seed treatment formulations. One formulator (Production Site AD) indicated that it uses HCB in two formulations but declined to identify the products or provide data on their compositions. This formulator formulates about 45.3 metric tons (50 tons) per year of each product. According to California State Department of Food and Agriculture,[23] HCB is also an ingredient of Grannox, a specific seed treatment formulation, which is imported from United Kingdom and distributed for use in this country by ICI America. ICI reports no waste generation in the distribution of the product.[25]

5.2.9 Pentachlorophenol (PCP) Production

According to one report,[9] HCB is produced as a by-product in the production of pentachlorophenol (PCP). This assertion, however, is not supported by the industry-furnished data collected in this survey.

There are six reported major domestic producers of PCP.[10] These are listed in Table 8. Based on the plant analytical data,[26,27] HCB is not generated at two sites (Vulcan Materials Co., Wichita, Kansas; and Reichold Chemicals, Inc., Tacoma, Washington) which produce PCP by the chlorination of phenol. This same PCP synthetic route is also used by Monsanto Co. at its Sauget, Illinois plant and by Dow Chemical U.S.A. at its Midland, Michigan facility. No analytical data have been obtained at the Sauget plant to assess the presence of HCB in the waste streams.[28] The fifth producer of PCP, Dover Chemical Company, which is also an HCB producer, may produce PCP through hydrolysis of HCB. As discussed in Section 5.2.1, at a detection level of 0.1 ppm, no HCB has been detected in the effluent discharges from the Dover plant. The sixth reported domestic producer of PCP, Sonford Chemical Company, has indicated it is only a representative for PCP manufacturers.[29]

5.2.10 Wood Preservative Industry

HCB has been reported to be used as a wood preservative.[9] There are at least 52 domestic sites for wood preservation treatment.[24] Two companies (J.H. Baxter Co., San Mateo, California, and Honolulu Wood Treatments Company, Honolulu, Hawaii) which were contacted in this survey, reported that HCB is not used at any of their treatment sites and that to the best of their knowledge HCB is not in use domestically, at least not in large

TABLE 8
PENTACHLOROPHENOL (PCP) PRODUCERS AND PRODUCTION SITES*(10)

Company	Site
Dover Chemical Company (Subsidiary of Ansul Company)	Dover, Oh.
Dow Chemical U.S.A.	Midland, Mi.
Monsanto Company	Sauget, Il.
Reichhold Chemicals, Inc.	Tacoma, Wa.
Sonford Chemicals Company	Houston, Tx.
Vulcan Materials Company	Wichita, Ks.

*With the exception of one, all of the above companies were contacted in this study.

wood treatment centers.[30,31] According to one industry contact,[30] the apparent confusion regarding the use of HCB as a wood treatment agent may stem from the fact that HCB is often confused with γ-BHC (gamma-benzene hexachloride or gamma-hexachlorocyclohexane) which has been used both in this country and in Europe as a wood preservative. (Note: the British Wood Society Register of Wood Preservatives, also does not list HCB as a wood preservative.[30])

Pentachlorophenol (PCP) is used as wood preservative in this country. If it is assumed that technical grade PCP produced by hydrolysis of HCB contains HCB as an impurity, the use of PCB for wood preservation may constitute a source for the generation of HCB wastes. However, no analytical data are available on the HCB content of technical grade PCP to test the validity of this assertion.

In wood treatment operations, the wood is steamed in the presence of treatment chemicals or is pressure-treated with solutions containing such chemicals. The wood is then drained and the residual liquid is removed by the application of a vacuum. If PCP contaminated with HCB is used in these processes, probable sources of HCB-containing wastes may include the non-recyclable spent liquor, mechanical losses, spills and overflows, equipment clean-up, etc.

5.2.11 Electrode Manufacture

HCB has been reported to have been used as a porosity control agent in the manufacture of graphite anodes for industrial uses.[9] There are 23 domestic manufacturers of carbon and graphite products, including electrodes (see Table 9). Five of the electrode manufacturers were contacted in this survey. One manufacturer (Stackpole Carbon Company, St. Marys, Pennsylvania) indicated that the company has stopped using HCB in its electrode manufacturing operations.[32] Two other companies (Carborundum Corporation, Sanbornne, New York and Airco-Speer Corporation, St. Marys, Pennsylvania) indicated that they do not use HCB in their operations, but suggested that HCB may be an ingredient of the heat transfer materials, primarily chlorinated organic compounds, such as chlorinated biphenyls, which are used by the industry.[33,34] These sources, however, added that the use of

TABLE 9
ELECTRODE MANUFACTURERS AND COMPANY HEADQUARTERS*(24)

Company	Headquarters
Airco Speer Co., Carbon-Graphite Division	St. Marys, Pa.
Becker Bros. Carbon Co.	Cicero, Il.
Carbone Corp.	Boonton, N.Y.
Carborundum Co.	Sanborne, N.Y.
Electro-Nite Co.	Philadelphia, Pa.
Great Lakes Carbon Corp.	New York, N.Y.
Helwig Carbon Products, Inc.	Milwaukee, Wi.
Kennametal Inc.	Milwaukee, Wi.
Keystone Carbon Co.	St. Marys, Pa.
Kirkwood Commutator Co.	Cleveland, Oh.
Lukens Steel Co.	Coatesville, Pa.
Morganite Incorporated	Dunn, N. C.
Ohio Carbon Co.	Cleveland, Oh.
Pure Carbon Co., Inc.	St. Marys, Pa.
Saint Marys Carbon Co.	St. Marys, Pa.
Stackpole Carbon Co.	St. Marys, Pa.
Superior Carbon Products, Inc.	Cleveland, Oh.
Teeg Research, Inc.	Easton, Md.
Textool Products, Inc.	Irving, Tx.
Ultra Carbon Corp.	Bay City, Mi.
Union Carbide Canada Limited	Toronto, Canada
Union Carbide Corp.	New York, N.Y.
United States Graphite Co.	Saginaw, Mi.

*Five of the companies listed were contacted in this survey.

chlorinated organic compounds as heat transfer materials is apparently becoming outdated in the industry. Of the remaining two firms, one (Keystone Carbon Company, St. Marys, Pennsylvania) indicated that it now makes metal anodes, rather than graphite anodes.[35] The other firm (Helwig Carbon Products, Inc., St. Marys, Pennsylvania) indicated that it is not involved in the manufacturing of electrodes.[36]

5.2.12 Cyanogen Chloride Production

As discussed in Section 5.2.3, HCB contained in the wastes from the manufacture of three pesticides (simazine, atrazine, and propazine) has been attributed to the HCB impurities in the cyanogen chloride which is used as a raw material. At one site, HCB emission was significantly reduced when a higher purity cyanogen chloride was used in the process. The presence of HCB in cyanogen chloride suggests that cyanogen chloride manufacturing may be a potential source of HCB generation. This possibility for HCB generation was not discussed with the two reported domestic manufacturers of cyanogen chloride (Nilok Chemicals Inc., Memphis, Tennessee[10] and DuPont and Co., Inc., Wilmington, Delaware).[37]

5.2.13 Vinyl Chloride Monomer (VCM) Production

According to one report,[9] HCB may be produced as a by-product in the production of vinyl chloride monomer (VCM). The industry-furnished data collected in this study, however, do not support such a possibility.

There are 12 major producers of VCM and 17 production sites in this country (see Table 10). Based on industry-furnished analytical data (and some independent testing by one state laboratory), tests with ppm (parts per million) sensitivities, have indicated no detectable amount of HCB in the waste streams at 5 of the 17 sites. At four of the sites HCB has been detected in waste streams containing VCM wastes, but in these cases the VCM wastes are in combination with wastes from chlorinated solvent production which may be the real sources of HCB. The data supplied by one company for two production sites indicate that at a detection level of 10 ppm, no HCB was found in its waste streams.

TABLE 10
VINYL CHORIDE MONOMER PRODUCERS AND PRODUCTION SITES*(10)

Company	Site(s)
Allied Chemical Corp.	Baton Rouge, La.
American Chemical Corp. (Stauffer Chemical Co.)	Carson, Ca.
Continental Oil Co.	Westlake, La.
Dow Chemical U.S.A.	Oyster Creek, Tx. Freeport, Tx. Plaquemine, La.
Ethyl Corp.	Baton Rouge, La. Pasadena, Tx.
B. F. Goodrich Co.	Calvert City, Ky.
PPG Industries, Inc.	Lake Charles, La. Guayanilla, P. R.
Shell Chemical Co.	Deer Park, Tx. Norco, La.
Tenneco, Inc.	Houston, Tx.
Union Carbide Corp.	Texas City, Tx.
Borden, Inc.	Geismar, La.
Monochem, Inc.	Geismar, La.

* Except for one, all companies listed were contacted in this survey.

Of the remaining six VCM production sites, two reported they are phasing out of production. Information was not available for the remaining two companies representing four production sites.

5.2.14 Synthetic Rubber Production

According to a 1975 publication,(9) the largest supplier of HCB in the U.S., has committed its entire HCB production output on a multi-year contract basis for use as a peptizing agent in the production of nitroso and styrene type rubber for automobile tires. The use of HCB on such a large scale in the manufacture of synthetic rubber is very new and very little information is available on sites using HCB, processes involved, and pollutant emission quantities.

5.3 CHARACTERISTICS OF HCB-CONTAINING WASTES

Table 11 summarizes the data collected in this survey on HCB waste characteristics. As indicated in this table, in most cases HCB is present as a constituent of the distillation residue and heavy ends (tars) from product purification operations. The HCB content of the waste mixtures varies, depending on the nature of the operation and the specific products produced. In general, as discharged from the process, HCB-containing wastes are viscous organic fluids containing little or no water. When cooled to ambient temperature, HCB solidifies and separates from the mother liquor. Depending on the nature of the liquid component, some HCB may remain in solution in the liquid phase. (See Table A-3 in the Appendix for properties of HCB.)

As indicated in Table 11, HCB-containing wastes from chlorinated solvents production also contain hexachlorobutadiene (HCBD) as a major ingredient. Indeed, HCBD for commercial use was formerly produced as a recovered by-product in the production of perchloroethylene.(9) (In 1974, all commercial quantities of HCBD, 91 to 227 metric tons or 100 to 250 tons per year, were imported from Germany(9)). HCBD is liquid at ambient temperature (melting range -19 to 22°C; boiling range 210 to 220°C), is considerably more volatile than HCB (vapor pressure 1.5 mm Hg at 40°C) and

TABLE 11
GENERAL CHARACTERISTICS OF HCB-CONTAINING WASTE STREAMS FOR CHLORINATED SOLVENT AND PESTICIDE MANUFACTURING INDUSTRIES, BASED ON DATA FOR SPECIFIC PRODUCTION SITES

Industry (and Products)	Site Designation	Process Waste Source	HCB-Containing Waste Composition	Miscellaneous Waste Stream Characteristics
Carbon tetrachloride, perchloroethylene, chloroethane solvents	A	Heavy ends from solvent recovery system (recycle, stripping)	74% HCB, 14% hexachlorobutadiene (HCBD), 10% hexachloroethane (HCE)	Grayish or whitish in color
Carbon tetrachloride, perchloroethylene, ethylene dichloride	B	Heavy ends from purification stills	15% HCB,* 75% HCBD, 10% HCE	Grayish-white solid settles out when cooled (with viscous red-brown liquid supernatant containing concentrated organics)
Perchloroethylene, trichloroethylene, ethylene dichloride	J	Still bottoms, ("heavies") from purification stills	1.6% HCB, 79% HCBD, 3.5% HCE, 3.5% tetrachlorobutadiene, 3.4% pentachlorobenzene, 3.3% trichlorobenzene, 2.4% perchloroethylene, 0.9% tetrachlorobenzene, 0.8% pentachlorobutadiene, 1.6% sand and carbon	Viscous tars, vapor pressure <690 newtons/m^2 absolute (0.1 psia) at 38°C (100°F); viscosity (at 24°C or 75°F) = 0.025 newton-second/m^2; density = 1.6 g/cm^3
Perchloroethylene, trichloroethylene	F	Heavy ends	6% HCB, 80-90% HCBD, 4-14% C_4-C_6 chlorinated organic compounds	Viscous tar, black in color; density = 1.8 g/cm^3
Ethylene dichloride	D	Distillation tars and residue	10-40 ppm HCB, 15% 1,2-trichloroethylene, 41% chlorinated C_4,C_5, compounds 4% miscellaneous solids	Similar to above
Pesticides	Q	Distillation residue	75% HCB, 25% product	Viscous yellow liquid when discharged (hot); yellow crystalline solid formed at ambient temperature
Pesticides	R	Liquid still bottoms	80% HCB, 20% lower chlorinated benzenes	Grayish-white; HCB separates from mother liquor as an opaque solid when cooled
Pesticides	S	Distillation tars	1% HCB	No data available
Pesticides	T	Stack emissions	No data available	No data available

* Independent analysis of this waste has indicated an HCB content of as high as 75%. (38)

has some of the toxic and biological properties of HCB. The present survey has concerned itself primarily with the HCB which originates in the production of a greater number of chemicals. General information and sources and characteristics of HCBD waste can be found in Reference 9.

In one pesticide production site, HCB is emitted from the process in the scrubber emission which is vented to the atmosphere. These HCB emissions, however, are from cyanogen chloride which is used as a raw product and which contains HCB as an impurity (see Section 5.2.12). No data (qualitative or quantitative) could be obtained on possible HCB emissions to the atmosphere for other production operations.*

5.4 ESTIMATED HCB WASTE QUANTITIES

5.4.1 Total Waste Quantities and Comparison of Estimates with Those Made in an Earlier Study

Under a contract with EPA Office of Toxic Substances, Midwest Research Institute (MRI) conducted a study of hexachlorobenzene and hexachlorobutadiene (HCBD) in U.S. industrial wastes, by-products, and products.(9) The study identified the following 11 industrial/agricultural chemicals which contain HCB and/or their production results in the generation of HCB

*With the exception of one plant site producing pesticides, the possibility of direct HCB discharges to the air has not been documented. Several of the firms contacted in this survey indicated that measurements of HCB levels in gaseous emissions and other process waste streams have been made and no HCB has been detected. For example, at Plant Site B, stack gases had been monitored several times monthly since the 1973 episode of HCB contamination in the Southern Lousiana area. The periodic monitoring has since been discontinued, since only 1-2 parts per billion (ppb) HCB has been the maximum ever detected. At Plant Site F, a spot check of miscellaneous effluent streams showed 2.2 ppb of HCB in the "No. 3 Outfall." The firm also indicated it does not normally check its effluent waste streams for HCB. Thus, if HCB has been detected in miscellaneous plant effluent and stack discharges in the chlorinated solvents and pesticide industries, it would appear to be the exception rather than the rule, and is not likely to be documented.

wastes: perchloroethylene, trichloroethylene, carbon tetrachloride, chlorine, Dacthal, vinyl chloride, atrazine, propazine, simazine, pentachloronitrobenzene, and mirex. These chemicals fall into the "chlorinated solvents production," "electrolytic chlorine production," "pesticide industry", and "vinyl chloride monomer production" which were discussed in Sections 5.2.2, 5.2.4, 5.2.3 and 5.2.13, respectively. Although in the present survey 14 industries/operations were identified as sources of HCB wastes, based on the discussion in Section 5.2, only three industries, namely, chlorinated solvents production, electrolytic chlorine production, and pesticide industry can be regarded as significant sources for HCB waste generation. Data obtained in the present survey on the vinyl chloride monomer industry indicate that this industry is probably not an important source of HCB production (five production sites which were contacted indicated that they had not detected any HCB in their waste streams).

Based on reported or estimated chemical commodity production capacities for the U.S., some waste composition data obtained from selected production sites, and assuming that the quantity of waste generated is proportional to production capacity, estimates were made by MRI of the total quantity of HCB waste generated in 1972 in the U.S. by each of the major HCB waste producing industries.[9] The MRI data which are reproduced in Table 12, consist of "high" and "low" estimates with the "low" values generally assumed to be 50 percent of the "high" estimates. The industry-furnished data on waste quantity collected in the present survey are also presented in Table 12. At some plant sites where more than one of the three listed chlorinated solvents are manufactured, the waste streams are not segregated and only the combined plant effluent is sampled and analyzed for HCB content. Accordingly, the industry-furnished waste quantity data for chlorinated solvents shown in the Table, represent the total for perchloroethylene, trichloroethylene, and carbon tetrachloride production. These waste quantities are from selected sites which participated in the present survey and do not include waste from all production sites. Comparison of the industry-furnished data with the MRI estimate indicates that, with few exceptions, the industry-furnished data are significantly higher than the "high" estimates reported in the earlier study by MRI. Of particular interest is pentachloronitrobenzene production for which the "high" estimate is

TABLE 12

HCB WASTE QUANTITIES*

(A COMPARISON OF THE EARLIER MRI ESTIMATES (9) AND THE DATA COLLECTED AND ESTIMATES MADE IN THE PRESENT STUDY)

Industry/Product	MRI Data for 1972: 1972 Production Rate	MRI Data for 1972: Estimated Total HCB Quantity		1975 Production Rate	Industry-Furnished Waste Quantities		Projected Waste Quantity for the U S	Projected Waste Quantity Adjusted to 1972 Products Level
		High	Low		HCB Waste	HCB-Containing Waste		
Chlorinated Solvents								
Perchloroethylene	332,000 (367,000)	1,585 (1,750)	793 (875)					
Trichloroethylene	193,400 (213,500)	204 (275)	104 (115)					
Carbon tetrachloride	451,600 (498,500)	181 (200)	91 (100)					
Subtotal	977,000 (1,079,000)	1,970 (2,175)	988 (1,090)	1,530,000 (1,689,000)	2,401 (2,650)	21,440 (23,665)	3,937 (4,345)	2,514 (2,775)
Pesticides								
Dacthal	900 (1,000)	45 (50)	36 (40)	2,300 (2,500)	226 (250)	302 (333)	226 (250)	91 (100)
Simazine, Atrazine, and Propazine	50,700 (56,000)	4.1 (4 5)	2 3 (2.5)	**	25 kg (55 lb)	N.A.	25 kg (55 lb)	N C
PCNB	1,350 (1,500)	2 7 (3)	1 4 (1 5)	N A.	1,268 (1,400)	1,585 (1,750)	1,268 (1,400)	N C
Mirex	450 (500)	0.9 (1)	0.4 (0.5)	†	5 0 (5 5)	500 (550)	5 0 (5.5)	N.C.
Subtotal	53,400 (59,000)	53 (59)	40 (45)	1,532,000 (1,692,000)	1,499 (1,655)	2,387 (2,633)	1 499 (1,655)	91 (100)
Electrolytic Chlorine Mfr	8,940,000 (9,868,000)	180 (195)	72 (80)	10,872,000 (12,000,000)	2 7 kg (6 lb)	141 (156)	‡	‡
Vinyl Chloride	2,305,000 (2,544,000)	12 (13)	0	3,162,000 (3,490,000)	0	0	‡	‡
Total	-	2,215 (2,442)	1,100 (1,215)		3,900 (4,305)	(23,968 (26,454)	5,323 (6,000)	2,605 (2,875)

* Except as noted, values not enclosed in parenthesis are metric tons, those enclosed in parenthesis are tons All HCB waste values indicate the amount of HCB contained in the waste and not the total waste stream quantities which would be significantly larger.

** Production data is not available, since U S Tariff data does not cover products manufactured at only one site

† Production of Mirex at the one domestic production site (Nease Chemical Co) was stopped in mid-1974.

‡ No valid projection can be made from the one available data point.

N A indicates Not Available N C Indicates Not Calculable from the given data

2.7 metric tons (3 tons) per year of HCB whereas the industry-furnished data indicate an HCB waste generation rate of 1,268 metric tons (1,400 tons) per year. Since a greater number of plants were surveyed in the present study and the industry-furnished data represent those collected through actual sampling and waste analysis, the industry-furnished waste quantities shown in the table, are probably closer to actual values than those estimated in the earlier study. Indeed much higher values would be obtained, if, using the earlier approach, the industry-furnished waste data are projected to a national level using the total estimated national production capacity and assuming that the quantity of waste generated is proportional to production capacity, (see the last two columns in Table 12).

The present survey indicates that approximately 3,909 metric tons (4,316 tons) per year of HCB is produced at major industrial plants and that major sources of HCB are chlorinated solvents production (2,401 metric tons or 2,650 tons per year), pentachloronitrobenzene manufacture (1,268 metric tons or 1,400 tons per year) and Dacthal production (226 metric tons or 250 tons per year). A more detailed description of the data collected in this survey on waste quantities and waste generation rates follows.

5.4.2 Chlorinated Solvents

In the present survey, seven companies representing 10 chlorinated solvents production sites indicated that HCB was a constituent of their waste. These plant sites which are designated as Sites A through J and the reported or estimated waste quantities for these sites are listed in Table 13. With the exception of Plant Site D, where only one product (ethylene dichloride) is manufactured, more than one type of chlorinated solvent are manufactured at the production sites listed in Table 13. Since at most sites waste streams from all chlorinated solvent production operations are combined and the combined effluent is tested for HCB, HCB waste quantities shown in the table are not broken down for the individual products. Although ethylene dichloride is included in the HCB waste data for the majority of the sites, based on the data for Site D, ethylene dichloride production is not a significant source of HCB wastes.

TABLE 13
PRODUCTION SITES AND HCB WASTE QUANTITIES FOR CHLORINATED SOLVENTS PRODUCTION*

Site Designation	Products	Quantity of HCB Waste Metric Tons/Year (Tons/Year)
A	Carbon tetrachloride, perchloroethylene, (methyl chloride, chloroform, dichloromethane)	378 (418)
B	Carbon tetrachloride, perchloroethylene, ethylene dichloride (EDC)	734† (810)
C	Carbon tetrachloride, perchloroethylene	217 (240)
D	Ethylene dichloride	0.35 (0.39)
E	Perchloroethylene, trichloroethylene, ethylene dichloride	0.14‡ (0.16)
F	Perchloroethylene, trichloroethylene, ethylene dichloride	236 (260)
G	Carbon tetrachloride perchloroethylene, ethylene dichloride	680§ (750)
H	Carbon tetrachloride, perchloroethylene, trichloroethylene, ethylene dichloride	770¶ (850)
I	Carbon tetrachloride, perchloroethylene	317¶ (350)
J	Ethylene dichloride, perchloroethylene, trichloroethylene	157 (173)
	Total	3,489 (3,851)

* All waste quantities refer to the amount of HCB contained in the waste and not the total waste mixture which would be significantly larger.

† Based on industry-furnished data that waste contains 15% HCB.[38] However, a recent independent analysis of the waste has found 75% HCB.

‡ Estimated based on waste generation data for Plant Site D.

§ Based on 1971 data on the quantity of waste hauled away from the site.

¶ Estimated based on plant production capacity and the calculated waste generation factor for Plant Site G.

The data in Table 13 indicate that approximately 2,401 metric tons (2,650 tons) of HCB wastes are generated each year at plant sites for which industry has supplied waste generation quantities. For Plant Sites H and I, for which no industry-supplied data were available, estimates were made of the waste generated based on production capacities. When the estimates for these two major production sites are included, the total industry-supplied and estimated waste quantities would be 3,489 metric tons (3,851 tons) per year of HCB. The plant sites listed in Table 13 represent an estimated total chlorinated solvents production capacity of 892,000 metric tons (985,000 tons) and account for 58.5 percent of the total U.S. production capacity for 1975.

Table 14 lists a number of additional plant sites for which data on HCB waste production quantities were solicited in the present survey. These sites represent 41.5 percent of total U.S. chlorinated solvents production capacity. Three of the sites representing a production capacity 294,500 metric tons (325,000 tons) per year of carbon tetrachloride use the CS_2 process which reportedly does not generate HCB as a by-product.[9] One small plant (production capacity 3,624 metric tons or 4,000 tons per year of carbon tetrachloride) has not detected any HCB in its waste stream. According to the company representing Plant Site L, the waste from this plant probably contains HCB at parts per million (ppm) concentration levels; the waste, however, has not been tested for HCB content. No quantitative data were available on wastes from Plant Site P, which, according to one source,[37] contains "small quantities" of HCB.

5.4.3 Pesticide Industry

Pesticide industry is the second most important source of HCB wastes. As was indicated in Section 5.2.3, production of Dacthal, PCNB, mirex, simazine, atrazine and propazine result in the generation of HCB wastes. At the present, simazine, atrazine and propazine are produced at one production site by only one company and each of the remaining three pesticides is produced by a different company at only one production site. The four production sites, designated as Plant Sites Q through T, and industry-furnished data on HCB waste quantities generated at these sites, are

TABLE 14
CHLORINATED SOLVENTS PRODUCERS REPORTING NO HCB WASTE GENERATION OR HAVING NO ANALYTICAL DATA

Site Designation	Product	Production Capacity[10] Metric Tons/Year (Tons/Year)	Comments
K	Carbon tetrachloride	3,624 (4,000)	None detected
L	Carbon tetra-chloride	226,500 (250,000)	HCB may be generated in ppm quantities; wastes have never been analyzed
	Perchloro-ethylene	72,500 (80,000)	
M	Carbon tetra-chloride	135,900 (150,000)	Uses CS_2 method
N	Carbon tetra-chloride	90,600 (100,000)	Uses CS_2 method
O	Carbon tetra-chloride	67,950 (75,000)	Uses CS_2 method
P	Perchloro-ethylene	22,650 (25,000)	Produces HCB in "small quantities"[37]
	Trichloro-ethylene	18,120 (20,000)	

presented in Table 15. The data indicate a total HCB waste quantity of 1,499 metric tons (1,655 tons) per year with wastes from Sites R and Q accounting for 84.5 percent and 15.1 percent of the total, respectively.

As was discussed in Section 5.2.3, both Dacthal and PCNB contain HCB as an impurity (estimated at 9 metric tons or 10.5 tons per year in the final products) which should be considered as a potential source for the introduction of HCB in the environment. No quantitative data were obtained in this study on the HCB content of wastes generated at formulation plants which handle these products.

5.4.4 Electrolytic Chlorine Production

As indicated in Section 5.2.4, electrolytic chlorine production using graphite anodes generate HCB wastes. Of the 67 domestic electrolytic chlorine production sites, 32 have been identified as using graphite anodes (see Table 4). Table 16 lists eight sites which use graphite electrodes and which were contacted during this survey.

As indicated in Table 16, HCB has been detected in the waste stream from at least two sites (designated as U and W). At Plant Site U, HCB has been determined to be close to the 20 ppm level in the still bottoms from chlorine distillation operation. Because of the small volume of the waste, however, the quantity of HCB generated is very small (2.7 kg/year or 6 lb/year). At Plant Site W, HCB has been detected in the product chlorine which is not purified but sold directly. No qualitative data are available on HCB waste for this site. No HCB has been detected in waste from two other plant sites (V and X). The waste from Plant Site Y has never been analyzed for HCB. Three other plants (G, H and I) which did not discount the possibility for the presence of HCB in their waste stream did not submit data on HCB quantities.

Based on the waste generation data for Site U, the HCB produced in the electrolytic chlorine industry should be very small relative to the waste quantity in the chlorinated solvents and pesticide industries. Since data were not available on production capacities for the 32 plants which use

TABLE 15
QUANTITIES OF HCB WASTES FROM PESTICIDE MANUFACTURE

Site Designation	Quantity of HCB in Discharged Wastes Metric Tons/Year (Tons/Year)
Q	226 (250)
R	1,268 (1,400)
S	5 (5.5)
T	0.02 (0.03)

TABLE 16
ELECTROLYTIC CHLORINE PRODUCERS USING
GRAPHITE ANODES WHICH WERE CONTACTED
IN THIS SURVEY

Site Designation	Industry-Furnished Data
U	20 ppm HCB in distillation tars (2.7 kg/yr or 6 lb/yr)
V	No HCB detected using gas chromatography
I	No data submitted
H	No data submitted
G	No data submitted
W	HCB detected in unpurified chlorine product. No quanti- tive data submitted
X	No HCB detected using infrared spectroscopy
Y	Never analyzed for HCB

graphite anodes, no projection could be made of the total quantity of HCB produced on a nation-wide level. Some of the sites which currently use graphite anodes plan to convert to DSA anodes which do not generate HCB wastes.

5.5 WASTE HANDLING, TREATMENT, AND DISPOSAL

5.5.1 Waste Handling (Storage and Transportation)

Loading and temporary storage of HCB wastes in containers, tank trucks and lagoons, and the transportation of HCB wastes from the point of waste generation to loading/storage or ultimate disposal facilities provide potential for environmental contamination through possible accidental spills, mismanagement of the operation and use of inadequate environmental safeguards. Accordingly, as part of the present survey, data were collected on methods of HCB waste storage and transportation. These data which are summarized in Table 17, are briefly discussed below. (The information contained in Table 17 on methods of waste treatment will be discussed in Section 5.5.2.)

Based on the data in Table 17, for the total of 2,870 metric tons (3,168 tons) per year of HCB waste for which data were obtained from industry on waste handling methods,* the currently used waste storage methods and the percentage of waste handled by each method are as follows:

Storage of solid cubes under plastic cover	44.2 percent
Water-covered open storage lagoons	33.1 percent
Drums which may or may not be lined	14.4 percent
Insulated and heated storage tanks	8.2 percent
Nitrogen-blanketed steel tank	<0.1 percent

*This quantity of HCB represents 74.4 percent of the estimated total national HCB waste production quantity based on data furnished by industry (see Table 12).

TABLE 17
METHODS OF HCB WASTE TREATMENT, HANDLING, AND TRANSPORT BASED ON DATA FOR SPECIFIC PRODUCTION SITES

Site Designation	HCB Quantity metric tons/year (tons/year)	Treatment	Handling and Storage Methods	Transportation Method
A	188 (208)*	No pre-treatment for bulk HCB wastes; spills washed to a collection pit	Drums covered with plastic bags; drums stored in a metal truck body with other dry trash	Trucks used to haul truck body containing drummed waste to a disposal site 16 kilometers (10 miles) away
B C	734 (810) 217 (240)	Storage lagoon for solid-liquid separation	Open concrete pit with water cover; waste dredged with a crane or clam-type shell equipment	Trucks used to haul waste to an on-site burial site
D	0.35 (0.39)	Distillation for waste concentration and resource recovery; heating to effect waste fluidization	Nitrogen blanketed steel storage tank	Waste hauled to Site E in tank trucks
Z	Not Disclosed	Distillation for waste concentration and resource recovery	Storage tank	Waste hauled by ship to Site E
E	0.14 (0.16)	Distillation for waste concentration and resource recovery	Not known	Piped to incinerator (prior to pipeline construction, trucks were used to transport waste to onsite storage tank, then to incineration)

* Does not include 190 metric tons (210 tons) per year which is recovered and sold.

TABLE 17
METHODS OF HCB WASTE TREATMENT, HANDLING, AND TRANSPORT BASED ON DATA FOR SPECIFIC PRODUCTION SITES (CONT'D)

Site Designation	HCB Quantity metric tons/year (tons/year)	Treatment	Handling and Storage Methods	Transportation Method
F	236 (260)	Distillation for waste concentration; heating to effect fluidization; spills washed off to a collection sump; waste dilution and suspension by the off-site disposal contractor prior to deep well injection	Heated, insulated storage tank, with 3-m (10-ft) pipeline for truck hook-up	Heated tank trucks
G	680 (750)	Not disclosed	Not disclosed	Piped to incinerator; metal truck bodies were used in 1970-71 to haul the waste to off-site disposal
Q	227 (250)	Not disclosed	113-liter (30-gal) "fiber-pak" drums	Truck transport to off-site disposal site
R	1,268 (1,400)	Solidification and shaping into cubes	Cubes stored under plastic cover	Waste forklifted to storage area
S	5 (5.5)	Distillation for waste reduction and material recovery	Not disclosed	Rail and/or truck transport to a neighboring state, by an off-site disposal contractor
AA	Not available	Not disclosed	Drums	Truck transport
AB	Not available	Dewatering by filtration	Not disclosed	Not disclosed

At pesticide production Site R, heavy still bottom tars containing 80 percent HCB from the distillation operation are discharged into a 1-cubic yard mold and allowed to cool to the ambient temperature. The cooling results in the solidification of the waste into 1-ton blocks which are then removed and transported by a forklift to a storage area. As of the date of this survey, approximately 3,171 metric tons (3,500 tons) of the HCB-containing waste blocks (2,537 metric tons or 2,800 tons of HCB) have been accumulated at this storage site. The blocks are covered with a plastic tarpaulin sheet as a rain cover. The company is currently evaluating a number of possible alternatives, including incineration and material recovery, for disposal of the accumulated wastes. The handling and storage of the waste blocks can involve some environmental contamination (e.g., resulting from possible fragmentation and dust formation during handling, and volatilization through sublimation during handling and storage).

Three-meter (10-foot) deep rectangular concrete lagoons are used for temporary storage of HCB-containing wastes at Plant Sites B and C. At these sites waste discharges from process operations enter the lagoons through steam-jacketed fiber-cast pipes. The waste is not pumped and flows through the pipe by means of process-generated pressure. The waste is distributed along the length of the lagoon by a submerged mobile discharge pipe. Ordinarily, a water cover of 0.3 to 0.6 meter (1 to 2 feet) is maintained above the waste to minimize volatilization. Periodically, a portion of the HCB waste is "scooped" and removed from the lagoon (using a crane or a clam-type shell equipment) and transported by a dump truck to an on-site land-fill location. Since some water is also scooped out with the waste, this water acts as a seal in the dump truck during transportation.

The operation of lagoons at Sites B and C provides some potential for environmental contamination. Although compared to soil and polyethylene film, a water cover has been shown to be most effective to reduce HCB volatilization and loss to atmosphere[38], it is difficult to maintain an effective layer of water cover at all times. Moreover, HCB is soluble to some extent in the aqueous cover (6.2 μg.1 for distilled water at 23.5°C)[38] and can be lost to atmosphere through evaporation and wind action. Mass balance calculations around the lagoon at Plant Site B have indicated leaching into the subsurface soil,[38] possibly due to deterioration of concrete lining.

Both lined and unlined drums are used for temporary storage/ transportation of HCB wastes. In some cases, a drum containing HCB is placed in a thin plastic bag which also serves to cover the open drum. During handling, transportation and land disposal of these drums, there is a strong possibility for spillage, generation of dust, and volatilization. Some actual photographs of the drums containing HCB wastes as delivered to a sanitary landfill are shown in Figure 1.

At Plant Site F, HCB waste is stored on-site in a 41,600-liter (11,000-gal) insulated and steam-jacketed tank. The waste is maintained in a fluid state by heating to 116°C (240°F). The waste is removed from the tank and transferred to heated tank truck via 3-meter (10-foot) discharge pipe to which the trucks can connect their intake. The 3-meter (10-foot) distance between the storage tank and the tank truck intake pipe is considered an adequate safety measure. The tank sits on a concrete base and any spillage flows to a collection sump and the contaminated area is washed with water which also flows to the collection area. The material collected in the sump is removed, the organic material is recovered by steam stripping and the aqueous portion is discharged to an on-site waste treatment facility which discharges its treated effluent to a receiving water.

Figure 2 presents a schematic flow diagram for the HCB waste concentration and storage at Site D. The storage tank at this facility is a nitrogen blanketed 226,800-liter (60,000-gal) steel tank. Environmental safeguards provided include: (a) use of dike around the storage tank, (b) return of truck loading vent to the storage tank, (c) collection and discharge of all the surface drains which might accidentally contain tars to plant secondary waste treatment system, and (d) use of personnel safety equipment including full-face shield and rubber gloves by personnel while handling the tars.

As indicated in Table 17, the methods currently used for the transportation of HCB wastes include trucks (for drummed or bulk solid waste), heated tank trucks (for bulk liquid), pipeline (for in-plant transportation and transfer to handling trucks), forklift (for solidified blocks of HCB waste), ship (for bulk fluid), and rail (for tars). Based on the data

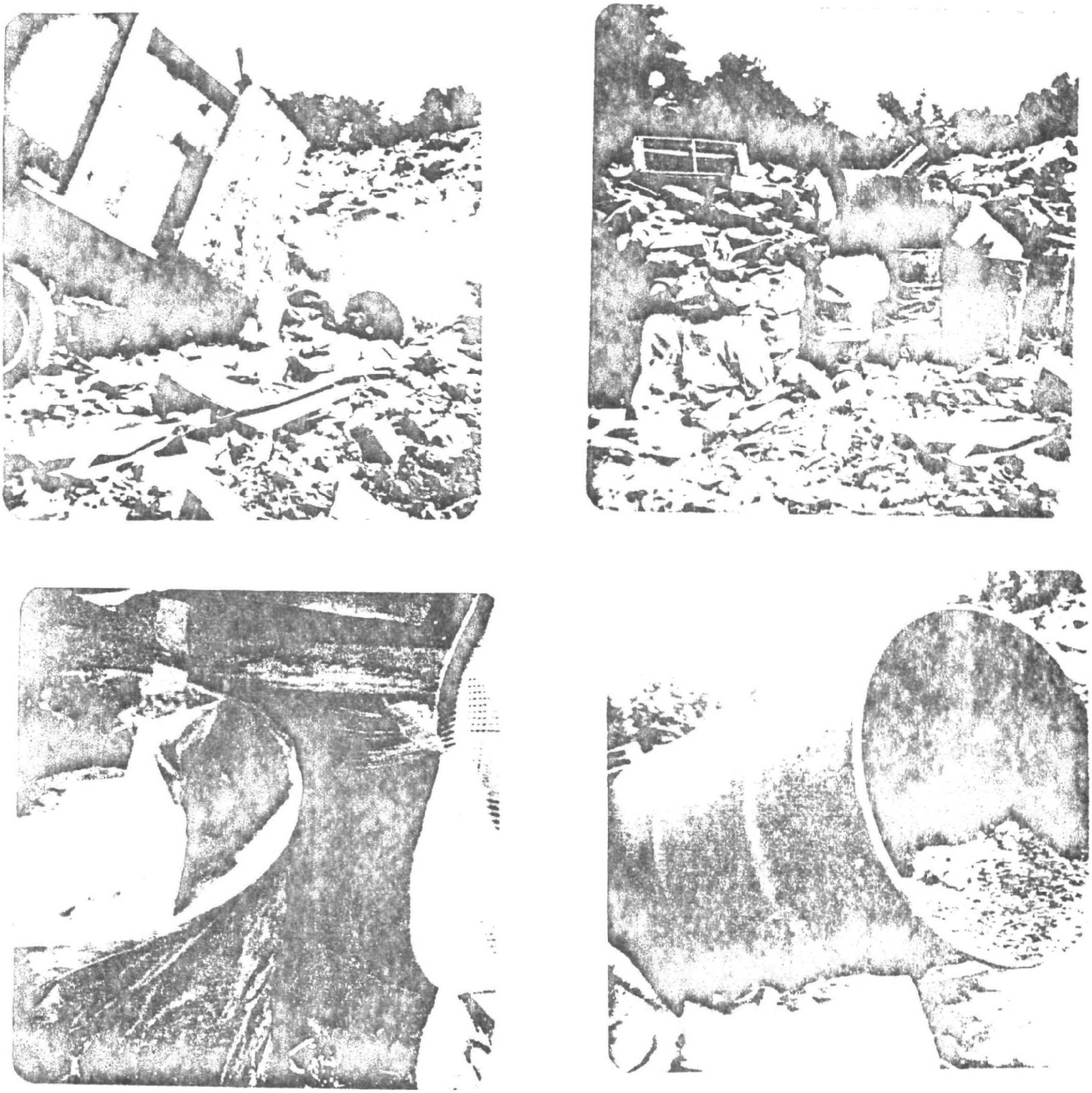

Figure 1. Photographs of Drummed HCB Wastes at a Sanitary Landfill

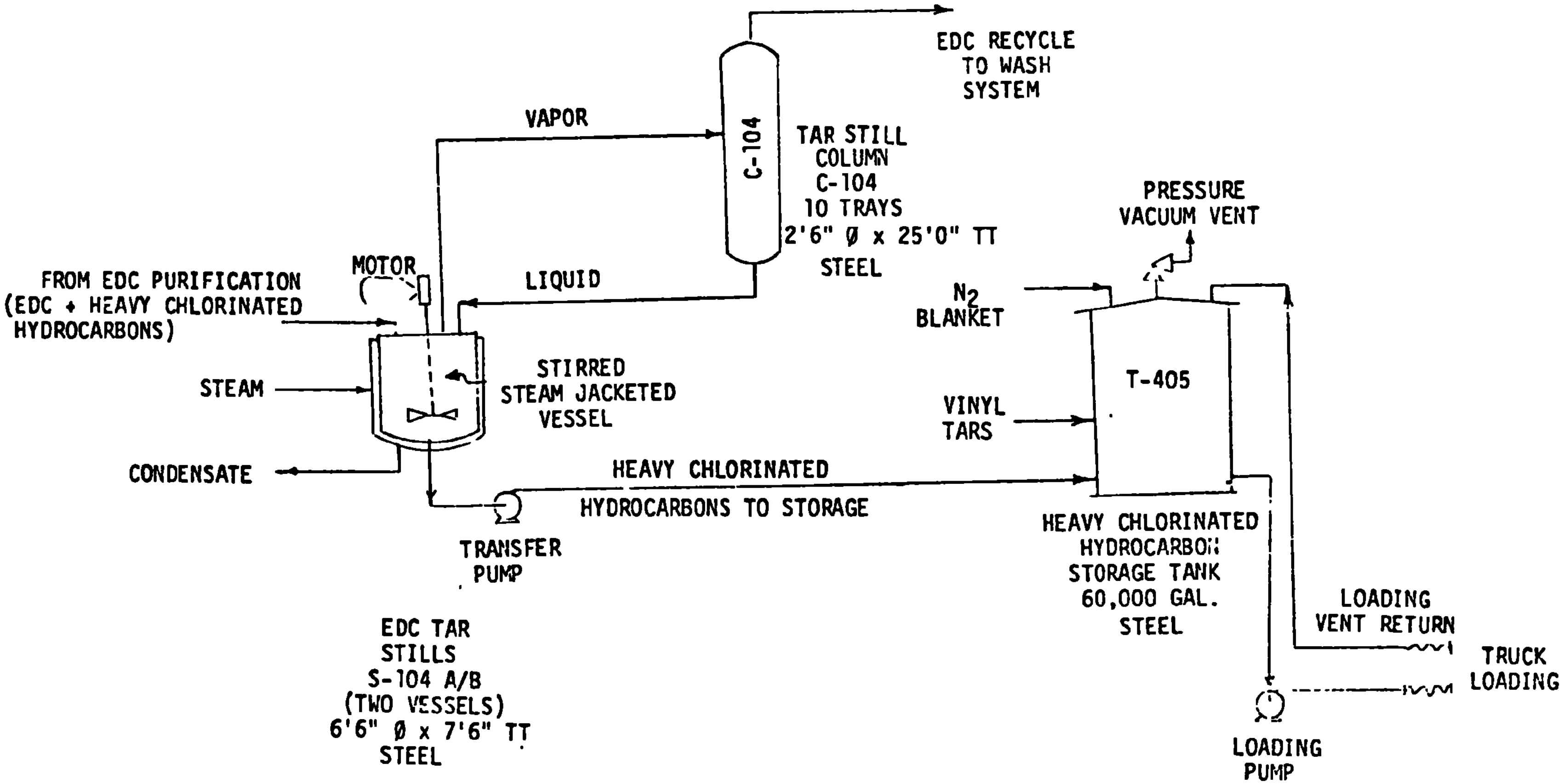

Figure 2. Tar Concentration and Storage Facility At Plant Site D

shown in Table 17, for the total of 3,555 metric tons (3,924 tons) per year of HCB wastes for which data were obtained from industry on waste transportation method,* the percentages of the total HCB waste quantity handled by the above-listed methods are as follows:

Truck	38.4 percent
Forklift	35.7 percent
Pipeline	19.1 percent
Heated tank trucks	6.6 percent
Rail	0.1 percent

Although no documented incidents of accidents involving transportation of HCB by the above methods have been reported, the possibility of such accidents occuring in the future cannot be ruled out. Because of the hazardous nature of the HCB-containing wastes, precautions should be taken to avoid spillage and losses due to wind action during transportation. During site visits in this survey, it was observed that some waste haulers use open trucks to transport open drums or drums enclosed in loose plastic bags containing HCB waste. This method of transportation presents a definite potential for environmental contamination. A major episode of HCB contamination in cattle occurred in southern Louisana in 1973 due partly to the spillage of HCB from the sides of open dump trucks as the trucks crossed railroad tracks, hit bumps in the country roads, etc., on the way to a landfill.[7] Pipelines used to transport HCB waste are usually heated to permit fluid flow. Any malfunction in the heating system can result in waste solidification and accidental discharge (flow-back-up) due to system failure.

*This quantity of HCB represents 91.1 percent of the estimated total national HCB waste production quantity based on data furnished by industry (see Table 12).

5.5.2 Waste Treatment

A number of sites for which data were collected in this survey utilize some form of treatment prior to ultimate disposal of HCB wastes. These treatment methods which are listed in Table 17 include use of storage lagoons to effect solidification and settling of HCB (Sites B and C), distillation to effect waste volume reduction and material recovery (Sites D, E, F, S, Z); heating to effect fluidization during storage and bulk transportation by pipeline and trucks (Sites D and F); solidification and shaping into cubes for storage (Site R); dewatering for waste concentration (Site AB); and dilution and suspension by mixing with other wastes prior to deep well injection (Site OC-3, see Section 5.5.3.3).

The use of storage lagoons, solidification, and heating systems were discussed above in connection with waste handling. At one off-site disposal site (OC-3, see Section 5.5.3.3) HCB waste from Plant Site F is mixed with a range of liquid wastes (chlorinated solvents, acids, alkali, rinse waste, etc.) from other industrial clients prior to deep well injection. At an electrolytic chlorine production facility (Plant Site AB), the mud from brine purification operation which contains graphite stub residues is dewatered by vacuum filtration prior to contract disposal. Based on the data in Table 17, for the total of 2,649 metric tons (2,924 tons) per year of HCB for which data on waste treatment were obtained from industry,* the percentage of total HCB waste quantities handled by the above-mentioned methods are as follows:

Solidification and shaping into cubes	47.9 percent
Storage in lagoons to effect solidification and settling	35.9 percent
Distillation to effect volume reduction and material recovery and/or heating to effect fluidization	9.0 percent
No treatment	7.1 percent

*This quantity of HCB represents 68.7 percent of the estimated total national HCB waste production quantity based on data furnished by industry (see Table 12).

No data were available on methods of pretreatment (if any) used at Site G where approximately 680 metric tons (750 tons) per year of HCB waste is disposed of by incineration.

5.5.3 Ultimate Disposal

Based on the industry-furnished data, methods currently used for the ultimate disposal of HCB-containing wastes include land disposal (sanitary landfill, industrial landfill, deep well injection and drying ponds), incineration, open pit burning, resource recovery, discharge to municipal sewage treatment plants, and emission to atmosphere. Both on-site disposal and off-site contract disposal are used. The prevalence of various disposal methods are shown in Table 18 in terms of the quantity of HCB (and HCB-containing wastes) handled and the number of facilities (on-site and off-site) which utilize the disposal methods.

The data in Table 18 indicate that based on the total quantity of waste handled, currently land disposal is the most prevelant method for ultimate disposal of HCB wastes. Nine of the sites surveyed use land disposal; approximately 1,389 metric tons (1,483 tons) of HCB waste (56 percent of the total) which is contained in a waste mixture of 17,362 metric tons (19,164 tons) is disposed of by this method each year. Among land disposal methods, use of industrial landfills is the most prevalent method, accounting for the disposal of 39.7 percent of all HCB wastes. Ranked next to land disposal is incineration which is used at nine of the sites surveyed for the destruction of a minimum of 1,055 metric tons (1,164 tons) per year of HCB contained in a waste mixture in excess of 4,763 metric tons (5,257 tons) per year. Compared to land disposal and incineration, the quantities of waste discharged to sewage treatment plants and to atmosphere are very small. No data were available on the quantity of HCB waste which is used at one site (Site L) as a chemical feedstock for the production of low-molecular weight aliphatic halogenated hydrocarbons. Of the 22 sites listed in Table 18, six use the services of off-site disposal contractors, which handle 655 metric tons (723 tons) per year of HCB wastes. A discussion of the various disposal methods follows.

TABLE 18
PREVALENCE OF METHODS USED FOR ULTIMATE DISPOSAL OF HCB WASTES

Disposal Method	HCB Waste		HCB - Containing Waste		Plant Sites	
	Quantity metric tons/year (tons/year)	% of Total	Quantity metric tons/year (tons/year)	% of Total	Number	% of Total
Land Disposal						
Sanitary Landfill	188 (208)	7.8	254 (281)	1.1	1	4.5
Industrial Landfill	997 (1,050)	39.7	6,544 (7,223)	29.6	5	22.7
Deep Well	204 (225)	8.5	10,564 (11,660)	47.7	2	9.1
Drying Pond	Not available	-	Not available	-	1	4.5
(Subtotal)	1,389 (1,483)	56.0	17,362 (19,164)	78.4	9	40.8
Incineration						
Without by-product recovery	375* (414)	15.6	3,857* (4,257)	17.4	8†	36.4
With by-product recovery	680‡ (750)	28.3	906‡ (1,000)	4.1	1	4.5
(Subtotal)	1,055 (1,164)	43.9	4,763 (5,257)	21.5	9	40.9
Open Pit Burning	13 kg (29 lb)	<0.1	165 kg (365 lb)	<0.1	1	4.5
Resource Recovery (excluding incineration)	Not available	-	Not available	-	1	4.5
Discharge to Waste Treatment Plants	Small, data on exact quantity not available	-	Not available	-	1	4.5
Emission to Atmosphere	25 kg (55 lb)	<0.1	Not available	-	1	4.5
Total	2,444§ (2,647)	100%	22,125§ (24,421)	100%	22	100%

* Includes an estimated 0.50 metric tons (0.55 tons) per year of HCB from plant sites D and E. These wastes are extremely dilute (10 to 40 ppm HCB content) and were not included in the total waste quantities to avoid gross distortion of percent of "HCB-Containing Waste" handled by incineration.

† Includes sites H and I for which data on actual waste quantities were unavailable

‡ Waste quantities is for 1970-71, data supplied by the off-site waste disposal contractor then handling the waste. Waste assumed to contain 75 percent HCB based on data for other plants.

§ Does not include 1,268 metric tons (1,400 tons) per year of HCB waste (1,586 metric tons or 1,750 tons of HCB-containing waste) temporarily stored under cover at Plant Site R. Also does not include 190 metric tons (210 tons) of HCB which is recovered for sale from 257 metric tons (284 tons) of HCB-containing wastes at Plant Site A.

5.5.3.1 Land Disposal

The data collected in this survey on sites employing land disposal and the quantity of HCB wastes handled at each site are summarized in Table 19.

As used in this report, sanitary landfills are those off-site landfills which accept both municipal refuse and industrial wastes. Industrial landfills are those which accept only industrial wastes. Industrial landfills may be located on-site or off-site. The American Society of Civil Engineers defines sanitary landfill as: "a method of disposing of refuse on land without creating nuisance or hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical area, to reduce it to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each day's operation or at such more frequent intervals as necessary."(39) Not all landfills which are commonly referred to as sanitary landfills conform to this definition or meet the high operating standards which are implied. Industrial landfills are generally waste burial sites consisting of pits or trenches which are excavated in suitable ground and into which the waste is deposited and subsequently covered with dirt. To provide protection against possible infiltration of leachate into the subsurface soil and contamination of groundwater, the burial sites may be lined with impervious materials such as dense clay, concrete or plastic liners.

The data collected in this survey on sites using sanitary landfills, industrial landfills, deep well injection, and drying ponds are presented below.

Sanitary Landfill

HCB wastes from Plant Site A are handled by an off-site contractor (designated as OC-1) which operates a 603-hectare (244-acre) sanitary landfill and handles household refuse and manufacturing wastes from a metropolitan area. Approximately 255 truck loads of wastes are received at the site each day, including seven to ten loads of HCB wastes per month from Plant Site A which is located about 16 kilometers (10 miles)

TABLE 19
METHODS AND SITES FOR LAND DISPOSAL OF HCB WASTES

Method of Land Disposal	Disposal Site Designation	Quantity of HCB Waste metric tons/year (tons/year)	Source of Waste (Plant Site Designation)
Sanitary Landfill	Off-site: OC-1	188 (208)	A
Industrial Landfill	Off-site: OC-2	45 (50)	Q
	On-site: B	734 (810)	B
	On-site: C	217 (240)	C
	On-site: P	Not available	P
	On-site: U	2.7 kg (6 lb)	U
Deep Well Disposal	Off-site: OC-3	47 (52)	F
	On-site: J	157 (173)	J
Drying Pond	On-site: AC	Not available	AC

away from the landfill. The HCB wastes are received in open drums, some enclosed in plastic bags. The disposal contractor's haul trucks containing the drums merely "dump" their loads at the site. These drums along with other loads of refuse and industrial trash are then compacted on a 4.7 meter (15-foot) high slope by a bulldozer. A 15-centimeter (6-inch) earth cover is provided at the end of each working day. Since the plastic bag enclosures for the drums do not provide a tight seal, in some cases the wastes are spilled from the drums and physically mixed with other wastes during the dumping and bulldozing operation. Because of the powdery nature of the waste, some of the HCB material may be blown away by wind action and this constitutes a potential health hazard to the equipment operators and presents possibilities for the contamination of air and adjacent land. (See Figure 1 and discussion in Section 5.5.1). HCB wastes from Site A have been hauled to this landfill since early 1974; it is estimated that about 282 metric tons (311 tons) of HCB has been deposited at this landfill to date.

The operation at the OC-1 waste disposal site was started about 24 years ago. The area was originally an uncleared swamp which has since been cleared and filled with dirt and sections of it used for waste disposal. The section which is in operation currently has an anticipated service life of 3-5 more years. The drainage ditches which pass through the property provide water for waste compaction and dust suppression during the operation. A hydrogeological study conducted by an independent consulting engineering firm has indicated that the site is suitable for use as a sanitary landfill and that the soils and bedrock are essentially impermeable to water (run-off) infiltration. The State Department of Health has been conducting periodic sampling of the ambient air in the vicinity of the site and of the drainage ditches above and below the operating dump.

Industrial Landfills

Based on the data collected in this study, five industrial landfills accept HCB wastes. Four of the sites are on-site landfills and one is operated by an off-site disposal contractor. The off-site disposal facility (designated as OC-2) receives HCB wastes from Plant Site Q. Prior to the current use of landfill, HCB wastes were incinerated at OC-2 disposal site along with other industrial wastes. However, because of certain operational difficulties and high cost of supplementary fuel, the incineration as a method of ultimate disposal was abandoned in favor of landfill operation. The site is located on a 593-hectare (240-acre) parcel and is classified as a Texas Class I site which, under Texas Water Quality Control Board regulations, is suitable for the disposal of hazardous chemicals. Approximately 20 percent of the HCB waste from Plant Site Q is hauled to this facility by the disposal contractor. (The other 80 percent is sent to another off-site facility, OC-5, for incineration; see below.) Since Plant Site Q is expected to join a regional waste disposal authority which will use incineration as the disposal method, no HCB waste will be taken to the OC-2 site after about 1976.

Although the practice has been stopped, during 1970-71, approximately 680 metric tons (750 tons) of HCB waste from Plant Site G was disposed of in an off-site disposal facility (OC-4). The waste was originally deposited in two 38 x 38 meter (125 x 125 foot) pits. One of the pits, which had become full, was subsequently covered with 0.61 meter (2 feet) of soil and 0.61 meter (2 feet) of dry trash. The other pit in which HCB had been deposited was still active receiving other industrial wastes. During the HCB contamination episode in Louisiana in 1973 (see Section 3), the operation at this site was suspected as a possible source for environmental contamination. This suspicion was later confirmed when samples of the soil from selected locations at the site were tested. A cleaning operation which was financed by the company representing Plant Site G was then initiated which included removal of the dirt and trash covers from the first pit and their replacement with a new cover consisting of a total of 1.9 meters (6 feet) of fresh soil with a 0.025-centimeter (10-mil) sheet of polyethylene film placed approximately at the middle of the soil cover.

On-site industrial landfill is used for the disposal of HCB wastes at Plant Sites B and C. The HCB wastes are scooped from the settling lagoons and brought to the burial site in dump trucks. The disposal sites at the two facilities are essentially identical. The landfill at Plant Site B, which is the larger of the two landfills, was visited during this survey.

HCB wastes are deposited in excavated pits 3.1 to 3.7 meters (10 to 12 feet) deep and roughly 6.2 x 9.3 meters (20 x 30 feet) in size. Each pit is of sufficient capacity to handle all the waste which is scooped from the settling pond in a lagoon emptying operation. The deposited waste is covered with 1.2 to 1.9 meters (4 to 6 feet) of soil and a 0.025-centimeter (10-mil) thick polyethylene film placed approximately at the mid-depth of the soil cover. The subsurface structure at the site includes impermeable strata which are considered adequate to prevent groundwater contamination. Soil boring tests have indicated that the top soil down to a depth of about 19 meters (60 feet) consists of a clay-silt mixture with very little sand. Periodic sampling and analysis of water from several wells in the area have indicated no contamination of groundwater with HCB.

Prior to the use of on-site land disposal, HCB wastes from Plant Site B were handled by a private off-site contractor and deposited in a nearby sanitary landfill. The landfill received 500 to 600 m^3 of material every three months for 2.5 years ending in January 1973. During much of this time the HCB waste was spread in a thin coat over the entire dump to serve as a fly repellent. This operation was later identified as the major source of environmental contamination in the Louisiana HCB contamination episode of 1973 (see Section 3). The site has since been closed and the wastes buried under polyethylene sheeting in an isolated section of the landfill.

Two other sites which utilize on-site landfills for the disposal of HCB wastes are Plant Sites P and U. According to the Louisiana State Health Department,[37] the on-site facility at Plant Site P has been in operation for a number of years. The quantity of HCB waste generated at this site is considered very small. Tars and still bottoms from the chlorine purification operation at Plant Site U contain a very small quantity of HCB (20 ppm or 2.7 kg/yr). These wastes are buried on-site in the desert land.

5.5.3.2 Deep-Well Injection

At the off-site waste disposal facility OC-3, deep-well injection is used for the disposal of certain types of industrial wastes. Among the wastes handled is approximately 780 metric tons (860 tons) per year of tars containing 6 percent HCB from Plant Site F. The waste is hauled to the site by the contractor in 18,900-liter (5000-gallons) vacuum tank trucks. The HCB-containing tars are mixed and diluted with wastes from other industrial sources prior to deep-well injection. The disposal stratum is about 1.6 kilometers (1 mile) below the surface and the average injection rate is 522 liters per minute (138 gpm). Depending on the nature and quantity of the wastes, some wastes are injected underground as soon as received at the site; other wastes may be stored for a period of several days prior to injection. The injection operation meets all requirements for deep-well disposal set by the Texas Water Quality Board and is carried out under a Board permit.

Deep-well disposal is also employed at an on-site facility (Plant Site J) in Louisiana for the disposal of HCB wastes from a chlorinated solvents production plant. No data are available on the actual disposal operation at this site.

5.5.3.3 Drying Pond

At Plant Site AC, the graphite stub residue from the electrolytic sodium chlorate production is dewatered by filtration and the filter cake which consists of the graphite stub loss, perlite filter aid, and insoluble calcium sulfate is taken to on-site drying ponds. In addition to the filter cakes, these ponds receive a number of other process wastes. When a pond is full, the operation is transferred to a new pond. Although the dried material in some of the abandoned ponds is not currently covered, the company plans to cover the dried material with dirt in the future.

5.5.3.4 Incineration

Incineration as a method for ultimate disposal of HCB wastes is used at six facilities listed in Table 20, along with the sources and quantity of waste handled at each site. The largest quantity of HCB wastes is handled at Plant Site G, which uses an on-site incinerator of proprietary design. The system reportedly effects 99.94 percent destruction of HCB and recovers hydrochloric acid as a by-product. The incinerator is equipped

TABLE 20
SITES FOR THE INCINERATION OF HCB WASTES

Disposal Site Designation		Quantity of Waste metric tons/year (tons/year)	Source of Waste (Plant Site Designation)
On-site:	G	680 (750)	G
Off-site:	OC-5	189 (208)	F
		182 (200)	Q
On-site:	E	Min 0.45 (0.5)	E, D, Z
Off-site:*	OC-6	5.0 (5.5)	S
On-site:	AD	Not available	AD
On-site:	Y	Not available	Y

* No HCB waste has been hauled to the site since mid-1974.

with scrubbers to minimize emissions to the atmosphere. Prior to the installation of the incinerator, HCB wastes were stored in metal drums; the stored wastes are now fed to the incinerator. The company plans to install similar incinerators at its facilities at two other locations.

The OC-5 off-site disposal contractor handles HCB wastes from Plant Sites F and Q. The wastes are hauled from these plants in heated tank trucks and stored in storage tanks prior to incineration. The incineration is essentially a destruction operation and does not include any by-product recovery. The solid and semi-solid wastes are handled in a Bartlett Snow rotary kiln incinerator which has a rated capacity of 1.8 metric tons (2 tons) per hour and operates at a temperature of 816 to 1,093°C (1,500 to 2,000°F) or higher. Low to medium viscosity waste liquids are fed at a rate of up to 3,780 liters (1,000 gallons) per hour to a Loddby liquid incinerator which operates at a burner temperature close to 1,093°C (2,000°F). All exhaust gases from the rotary kiln incinerator and the liquid waste burner are mixed and passed through an afterburner which operates at 1,316°C (2,400°F). The combustion gases are then cooled in a water quench chamber, scrubbed with an alkali solution and discharged to the atmosphere through a stack. Gases exist the stack at 77°C (170°F) and at a linear velocity of 539 meters (1770 fpm) per minute. When Plant Sites Q and F join a regional waste disposal authority (possibly in 1976), they will no longer use the services of the off-site contractor (OC-5) for the disposal of the HCB wastes.

The incinerator at Plant Site E handles HCB-containing wastes from chlorinated solvents production at this site and at two other production sites (D and Z). The incinerator is a Thermal Research unit having two trains, one for the destruction of gases and one for the combustion of liquids. The liquid train was designed to incinerate 19 metric tons (22 tons) per day of waste tars containing 98.5 percent chlorinated hydrocarbons. The gas train was designed to incinerate 48 metric tons (53 tons) per day of waste gases containing 20 percent chlorinated hydrocarbons. The incinerator is equipped with water and alkali scrubbing systems for the removal of acids from combustion gases. The scrubbed gases are exited to the atmosphere through a 1.2-meter (4-foot) diameter stack at a temperature of about 57°C (135°F) and an exit velocity of 3 meters per second (10 fps). Monitoring of stack gases has indicated the following emission rates:

Pollutants	Emission Rate, kg/hr (lb/hr)
HCl	2.8 (6.2)
CO	1.5 (3.2)
NO_x	5.7 (12.6)
Cl_2	0.3 (0.6)
Particulates	3.3 (7.2)

Up until mid-1974, the off-site contractor OC-6 in New York, handled approximately 5.0 metric tons (5.5 tons) per year of HCB from Plant Site S in Pennsylvania. No HCB wastes have since been handled at this site because of the discontinuation of the production of an HCB waste producing chemical at Plant Site S.

At Plant Site AD, liquid waste from formulation of HCB-containing pesticides are destructed, along with wastes from some other process sources, in an incinerator designed for pesticide wastes. The incinerator is bottom-fed, refractory-lined, and of up-right design. The dimensions for the lower section of the combustion chamber are 2.4 m I.D. x 7.5 m long (8 x 25 feet). Above this, the combustion chamber tapers to 1.2 meters (4 feet) I.D. at the top. The exhaust gases are quenched to less than 121°C (250°F) by means of water sprays and are scrubbed in a Venturi scrubber which normally operates with a pressure drop of about 1.4×10^4 Newtons/m^2 (2 psi). The incinerator is pressurized with a forced air feed (125 percent excess air) and is designed for a heat release of 3.2×10^{10} Joules/hr (30×10^6 Btu/hr). There are two spray nozzles at the bottom of the incinerator for introducing wastes and a gas burner at the pilot flame level. The quantitative rate at which supplementary fuel gas is used can be adjusted to obtain desired temperatures. Ordinarily, the incinerator is operated at 871°C (1600°F). The residence time in the combustion chamber is 2 to 3 seconds, based on an exit gas volume of 1,528 actual cubic meters per minute (54,000 ACFM) at the operating peak load. Under normal operating conditions, the exit gas flow rate is 764 actual cubic meters per minute (27,000 ACFM) and the gas exits at 85°C (185°F). The residence time is reduced to 1 to 1.5 seconds under maximum loadings. From the Venturi, the gases pass through a "disengager" where the scrubbing solution is separated and recycled to the quench tower and the Venturi scrubber. A sodium hydroxide solution is used as make-up which also adjusts the pH to 9.5 to 10.0.

All brine wastes from the electrolytic production of chlorine at Plant Site Y are destroyed in an on-site incinerator. Detailed information on this incinerator was not available.

5.5.3.5 Miscellaneous Disposal Methods

Miscellaneous methods which are currently in use for the disposal of HCB wastes include resource recovery (discussed in Section 5.5.4), open-pit burning, discharge to sewage treatment plants, and stack discharge to the atmosphere. Except for resource recovery, the quantity of HCB wastes handled by these miscellaneous methods is very small.

As at most munitions manufacturing sites, the combustible production wastes generated at Plant Site AA, are disposed of by open-burning; the scrap containing HCB is placed in waste cans which are covered with fuel and burned in an open pit. The open pit burning at this site is conducted under a State permit.

At Plant Site AE wastewater from the clean-up of equipment used for pesticide formulation enters a local sewage treatment plant which discharges its treated effluent to a receiving water. Beacuse of the refractory (resistant to biodegradation) nature of HCB,[1] it is doubtful that biological treatment per se can result in destruction of HCB in wastewaters.

At Plant Site T, a small amount of HCB (25 kg/year or 55 lb/year) which originates from the use of impure raw material (see Sections 5.2.3 and 5.2.12) is emitted to the atmosphere through stack discharges.

5.5.4 Resource Recovery

If a waste can be processed to recover energy or salable products, or if it can be directly used as a chemical feedstock in the production of commercial products, such resource recovery methods would be preferred to waste disposal such as incineration aimed solely at the destruction of organic wastes or landfilling. Table 21 lists a number of resource recovery methods which are currently used in connection with processing HCB-containing wastes. Because of the proprietary nature of the resource recovery operations currently in use, detailed information could not be obtained on raw material requirements, operating conditions, system efficiencies, and costs associated with various resource recovery methods. In general, the applicability of a specific resource recovery method to the processing of HCB-containing wastes would be dependent on the waste characteristics (HCB concentration, nature of other constituents, and total waste quantity) and should be evaluated on a case-by-case basis. As indicated in Table 21, at two Plant Sites (A and AF) HCB is recovered for sale from processing HCB-containing wastes generated in the manufacturing of chlorinated solvents. The recovered HCB is now largely used as a peptizing agent in the manufacture of nitroso and styrene rubber for tires. The incineration system at Plant Site G reportedly effects 99.94 percent destruction of HCB and recovers hydrochloric acid as a by-product. At Plant Site L, the wàstes from chlorinated solvent production are used as a raw material in a process for the production of freon. The freon process apparently includes recovery of HCl as a salable product. The inorganic waste from freon production operations (silica gel, metallic salts, etc.) are encapsulated in concrete in a landfill.

5.6 ULTIMATE DISPOSAL TECHNOLOGY CLASSIFICATION AND EVALUATION

The technology of waste disposal for the management of hazardous wastes is often described on the basis of the following classification standards:

Level I Technology:	The typical broad average practice for the industry or product group (i.e., prevalent practice).
Level II Technology:	The best technology available in current commercial practice.

TABLE 21
RESOURCE RECOVERY METHODS FOR PROCESSING HCB
CONTAINING WASTES

Resource Recovery Method	Plant Site Where Method Used	Quantity of HCB Handled metric tons/year (tons/year)
Recovery of HCB for sale from chlorinated solvent wastes	A AF	190 (210) 50 (55)
Use of recovered HCB for seed treatment	Seed treatment houses	6.2 (6.9)
Use of recovered HCB in the manufacture of synthetic rubber	Data not available	190 (210)
Incineration including recovery of HCl	G	680 (750)*
Use in production of freon, including HCl recovery	L	Not available

*This method is also scheduled for use at Plant Sites H and I which generate 770 metric tons (850 tons) and 317 metric tons (350 tons) of HCB waste, respectively.

Level III Technology: Technology currently known and assessed as providing adequate health and environmental protection.

Depending on the technology and the nature of the industry or specific waste stream, in some cases the three levels of technology may be the same or there may not be significant differences between Level I and Level II, or Level II and Level III technologies.

The quantitative data on the prevalence of various methods used for the disposal of HCB wastes are presented in Table 18 and were discussed in Section 5.5.3. Land disposal and incineration appear to be of equal prevalence from the standpoint of the total number of sites using each of the two disposal methods. However, based on the quantity of HCB waste handled, a greater quantity of waste (56.0 percent of the total) is disposed of on land, as compared to that destroyed by incineration (43.9 percent of the total). When the land disposal method is subdivided and considered as four separate technologies (sanitary landfill, industrial landfill, deep well injection and drying pond), and the incineration is considered as technologies with and without by-product recovery, incineration without by-product recovery (but with emission control) is the most prevalent method in terms of its usage at different plant sites. In terms of the quantity of HCB wastes handled, however, a greater quantity of HCB wastes is handled by industrial landfills than by an other single disposal method. The industrial landfills at Plant Sites B and C are designed and operated with due consideration to abatement of environmental contamination. The subsurface structure at the sites includes impermeable strata which are considered adequate to prevent groundwater contamination. Subsequent to waste deposition, the wastes are covered with 1.2 to 1.8 meters (4 to 6 feet) of soil with a 0.025-centimeter (10-mil) thick polyethylene film placed approximately at the mid-depth of the soil cover.

Incineration with emission control and by-product recovery is considered to correspond to both Level II and Level III technologies as defined above. The incinerator at the Plant Site G is reported to effect 99.94 percent destruction of HCB and to permit recovery of HCl as a by-product. The system is of a large capacity and handles about 680 metric tons (750 tons) per year of HCB. Based on the very limited data which are available on the operation of this particular incinerator, the applicability of the system for handling smaller quantities of HCB wastes (at other production sites) cannot be determined. The incinerator used at Plant Site E handles 7,112 metric tons (7,350 tons) per year of tars containing 314 pounds of HCB. Based on the stack monitoring data presented in Section 5.5.3 for this incinerator, emissions of HCl, CO, NO_x, Cl_2 and particulates are estimated at 0.002, 0.001, 0.005, 0.0002, and 0.003 kg/kg of tar input, respectively.

Table 22 summarizes the technology levels identified for the disposal of HCB wastes. The technology classification levels identified in this table are subject to certain limitations which should be considered in interpretation of the data and in developing regulations for the control of HCB wastes. The wide variety of systems which are in current use for the disposal of HCB-containing wastes reflect the differences in: (a) waste stream characteristics; (b) manufacturing and formulating methods; (c) size and geographic location of the plants; and (d) applicable environmental regulations. Because of the differences in waste quantities of characteristics and in plant locations and operations, it is almost impossible to arrive at a "broad average" HCB waste disposal method representative of the current practice at a "typical" plant. An equally impossible task is to define or prescribe a disposal system which would be applicable to the management of wastes at all HCB waste generation sites. At some large chemical production facilities or at off-site disposal sites, HCB wastes are only a very small portion of the total waste handled. In such facilities, the management of waste from a specific production operation is not usually an isolated problem requiring a separate solution, but rather an element in the total waste management plan for the facility.

5.7 WASTE HANDLING AND DISPOSAL COSTS

Not all industries and waste disposal facilities which were contacted in this survey furnished information on the costs for handling and disposal of HCB wastes. In some cases where cost data were supplied, the information

TABLE 22
DISPOSAL TECHNOLOGY CLASSIFICATION

Technology Level	Technology
Level I	Industrial landfills with a 1.2 to 1.8 m (4 to 6 ft) of soil cover and a 0.025 cm (10-mil) thick polyethylene film placed approximately at mid-depth of the soil cover (based on the quantity of HCB handled) Incineration without by-product recovery but with emission control (based on the prevalence of number of sites)
Level II and Level III	Incineration with emission control and by-product recovery

was fragmented and inconclusive. Some of the companies and waste disposal facilities indicated that although they can probably provide data on their overall cost of waste handling and disposal, they cannot break down the cost to arrive at any meaningful estimate of the portion of the cost which can be attributed to the handling of HCB waste which accounts for a small fraction of the total waste handled.

Table 23 presents the cost charged to waste generators by four off-site waste disposal contractors employing landfill, incineration and deep-well injection. The data indicate a disposal fee ranging from $22 to $35 per metric ton ($20 to $32 per ton) of HCB-containing wastes. The range in the disposal fee is understandable in the light of differences in the quantities of waste handled, method of disposal, haul distance, and labor costs in different locations.

Table 24 presents the very limited data which were furnished by two Plant Sites (B and E) on on-site waste disposal by landfill and incineration. The $11 per metric ton ($10 per ton) operating cost at Plant Site B includes costs for the operation of pretreatment lagoon, removal and transport of waste from the lagoon to the landfill site and equipment maintenance. No data were available on the cost of lagoon construction, and value of land used for lagooning and landfilling. The waste which is incinerated at Plant Site E is a chlorinated solvent waste containing a very small concentration of HCB (10-40 ppm).

The most comprehensive cost data collected in this study are for the ethylene dichloride (EDC) waste concentration and storage facility at Plant Site D (see Figure 2 for schematics of the operation). The system handles 8,833 metric tons (9,750 tons) per year of waste containing 40 ppm of HCB. The concentrated tar is hauled by tank trucks to Plant Site E for incineration. A breakdown of the cost for the EDC concentration and storage system are shown in Table 25. The system was installed in 1967, and the cost data are in 1967 dollars.

TABLE 23
COSTS FOR OFF-SITE DISPOSAL OF HCB WASTES

Disposal Method and Disposal Contractor	Source of Waste (Plant Site)	Quantity metric tons/year (tons/year)	$/metric ton ($/ton) of HCB Waste	$/metric ton ($/ton) of HCB-Containing Waste
Landfill: OC-1	A	188 (208)	$57 ($52) [$33 ($30) for users fee, and $24 ($22) for container rental]	$35 ($32) [$20 ($18) for users fee, and $15 ($14) for container rental]
Landfill: OC-4	G	680 (750)	$40* ($36)	$30 ($27)
Deep Well Injection: OC-3	F	47 (52)		$22 to $33 ($20 to $30) for all chlorinated solvent wastes including those containing HCB.
Incineration: OC-5	F,Q	371 (408)		$22 ($20) for all chlorinated solvent wastes

* Data are for 1971 operation and the costs were adjusted to 1975 dollars assuming an escalation factor of 8% per year.

TABLE 24
COSTS FOR ON-SITE DISPOSAL OF HCB WASTES

Plant Site	Disposal Method	metric tons/year (tons/year)	Costs
B	Industrial Landfill	734 (810)	Operating Cost: $11/metric ton ($10/ton) of HCB waste
E	Incineration	142 (157)	$2,000,000 investment cost for incinerator

TABLE 25
COSTS FOR EDC TARS CONCENTRATION AND STORAGE SYSTEM
AT PLANT SITE D (SEE FIGURE 2)

Major Equipment	1967 Cost
EDC Tar Stills (S-104A and B)	$28,562
Tar Still Column and Condenser (C-104)	13,294
Transfer and Loading Pumps	14,000
Tars Storage Tank (T-405)	15,000
1967 Major Equipment Cost	$70,856
Installed Cost (Estimated: 3X Major Equipment Cost)	$213,000
Utilities Requirements	
Steam (1.03 x 10^6 Newtons/m^2 gage; 150 psig) — 634 kg (1400 pounds) per hour	
Cooling Water — 794 liters per minute (210 gpm)	
Pumps (2) — 3.7 kW (5 hp) each	
Agitators (2) — 15 kW (20 hp) each	
Maintenance (Estimated at 6% of Installed Cost Per Year)	$12,800
Insurance and Taxes (1.5% of Installed Cost)	$2,700
Operating Labor	$6,000

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7. APPENDIX

TABLE A-1
KEY TO PLANT SITES, THEIR LOCATIONS AND SOURCES OF WASTES

Plant Site Designation	Location (State)	Operations Producing or Likely to Produce HCB Waste
A	Ky.	Chlorinated solvents production
B	La.	Chlorinated solvents production; electrolytic chlorine production
C	Ks.	Chlorinated solvents production; PCP production; electrolytic chlorine production
D	La.	Chlorinated solvents production; VCM production
E	La.	Chlorinated solvents production; electrolytic chlorine production; sodium chlorate production
F	Tx.	Chlorinated solvents production; electrolytic chlorine production
G	La.	Chlorinated solvents production; electrolytic chlorine production; VCM production
H	Tx.	Chlorinated solvents production; electrolytic chlorine production; VCM production
I	Ca.	Chlorinated solvents production; electrolytic chlorine production
J	La.	Chlorinated solvents production; electrolytic chlorine production; VCM production
K	W.V.	Chlorinated solvents production; electrolytic chlorine production
L	Tx.	Chlorinated solvents production; electrolytic chlorine production
M	W.V.	Chlorinated solvents production
N	Al.	Chlorinated solvents production; electrolytic chlorine production
O	N.Y.	Chlorinated solvents production
P	La.	Chlorinated solvents production; electrolytic chlorine production; sodium chlorate production

TABLE A-1
KEY TO PLANT SITES, THEIR LOCATIONS
AND SOURCES OF WASTES (CONT'D)

Plant Site Designation	Location (State)	Operations Producing or Likely to Produce HCB Waste
Q	Tx.	Pesticide production
R	Al.	Pesticide production
S	Pa.	Pesticide production
T	La.	Pesticide production
U	Nv.	Electrolytic chlorine production
V	Oh.	Electrolytic chlorine production
W	Al.	Electrolytic chlorine production
X	Wa.	Electrolytic chlorine production
Y	Or.	Electrolytic chlorine production
Z	P.R.	Chlorinated solvents production
AA	Tn.	Ordnance and pyrotechnics production
AB	Or.	Sodium chlorate production; electrolytic chlorine production
AC	Ms.	Sodium chlorate production
AD	Ca.	Seed treatment chemicals formulation
AE	N.Y.	Pesticide production; electrolytic chlorine production; sodium chlorate production
AF	Oh.	HCB production; PCP production

TABLE A-2
KEY TO OFF-SITE WASTE DISPOSAL CONTRACTORS HANDLING
HCB WASTES, THEIR LOCATIONS
AND PLANT SITES SERVED

Contractor Disposal Site Designation	Location (State)	Waste Disposal Method Used	Plant Site(s) Served
OC-1	Ky.	Sanitary landfill	A
OC-2	Tx.	Industrial landfill	Q
OC-3	Tx.	Deep well injection	F
OC-4	La.	Industrial landfill	G
OC-5	Tx.	Incineration	F, Q
OC-6	N.Y.	Incineration	S

TABLE A-3
GENERAL AND HAZARDOUS CHARACTERISTICS OF HCB

Synonym: perchlorobenzene

Appearance (Pure HCB): monoclinic prisms (white needles)

Formula: C_6Cl_6

Physical constants:[9]

Molecular weight:	284.80
Melting point:	230°C
Boiling point:	326°C
Flash point:	116.7°C
Density:	1.5
Vapor pressure:	1.089×10^{-5} mm Hg, 20°C 1 mm Hg, 114.4°C
Vapor density:	9.8

Stability: highly stable and unreactive; is not hydrolyzed in aqueous solutions[9]

Volatility: sublimes readily and evaporates readily when exposed to air[9]

Vapor pressure of HCB:[38]

Temperature (°C)	Vapor Pressure (mm Hg)
15	4.47×10^{-6}
25	1.91×10^{-5}
35	6.36×10^{-5}
45	2.09×10^{-4}

Heat of vaporization: 23.4 kcal/mole[38]

Solubility

(i) in distilled water: 6.2 μg/l at 23.5°C[38]

(ii) in landfill leachate: 5.1 μg/l at 23.5°C[38]

Bioaccumulation: accumulative in aquatic and terrestrial organisms[1,9]

Environmental persistence: resistant to biological degradation[1,9]

Experimental results on volatilization of HCB at 25°C through various types of cover materials:[38]

Type of Cover	Volatilization Rate kg/ha/yr
No cover	317
Polyethylene film, 0.15 mm	255
Soil, 1.9 cm	4.56
Composite soil and polyethylene film, 1.915 cm	3.29
Water, 1.43 cm	0.38
Soil, 60 cm	0.13 (calculated)

TABLE A-4
HCB WASTE DATA REQUESTED FROM SOME INDUSTRIAL PLANTS

CHARACTERISTICS OF WASTES

1. General Information

   a. Quantities of HCB/HCB-containing wastes handled

   b. Sources of waste (company and location)

   c. Characteristics of wastes:

      - physical description
      - concentration
      - chemical composition/analysis (BOD, COD, pH, etc.)

   d. Quantities and characteristics of other types of wastes (non-HCB) handled (in conjunction with HCB wastes).

2. Waste Pretreatment Facilities and Processes

   a. Process types (sedimentation, chemical treatment, filtration, etc.). Describe.

   b. Costs associated with waste pretreatment (i.e., capital investment costs, direct and indirect operating costs).

3. Materials Recovered

   a. Form, characteristics, quantities, etc.
   b. Residues generated (quantities, characteristics)
   c. Cost analysis of resource recovery methods:

      - capital investment costs
      - direct operating costs
      - indirect operating costs

4. Waste Handling and Storage Facilities and Methods

   a. Description of methods and facilities
   b. Costs associated with waste handling and storage

DISPOSAL METHODS

1. Incineration of Wastes

   a. Historical background (start-up date, etc.)

   b. Type of incinerator used

TABLE A-4
HCB WASTE DATA REQUESTED FROM SOME INDUSTRIAL PLANTS (CONT'D)

c. Process and equipment description (copies requested, if available)
   - process flow diagram
   - sketch or picture of incinerator layout
   - controls schematic
   - sampling points

d. Safety provisions used
   - Equipment, controls, interlocks, etc.
   - Standard operating procedures. Description.

e. Equipment or methods for controlling pollution from off-gases
   - afterburner? Describe.
   - stack gas cleaning? Describe.
   - characteristics and treatment/disposal of scrubber solutions.

f. Sampling and instrumentation capabilities
   - has any HCB been determined in burner off-gases?
   - has any HCB been detected in other sampling positions?

g. Costs associated with incineration
   - capital investment costs (i.e., equipment, facilities, land, etc.)
   - direct operating costs (i.e., power, labor, chemicals, equipment for related pollution abatement methods)
   - indirect operating costs (equipment depreciation, taxes, insurance, etc.)

2. Landfill Operations Associated with HCB-Containing Wastes or Residues

   a. Site characteristics and historical background (size, depth, location, topography, geological formation, distance to groundwater, start-up date, etc.)

   b. Quantities of wastes handled

TABLE A-4
HCB WASTE DATA REQUESTED FROM SOME INDUSTRIAL PLANTS (CONT'D)

c. Costs associated with landfill

- capital investment costs (i.e., equipment, land, facilities, etc.)
- direct operating costs (i.e., power, labor, chemicals, equipment)
- indirect operating costs (equipment depreciation, taxes, insurance, etc.)

d. Disposal fee associated with waste handling

e. Safety provisions: shower, eyewash, etc.

f. Registration (reporting requirements to regulatory agencies)

g. Environmental safeguards: leachate collection? monitoring systems, etc.

3. Any other disposal processes associated with HCB-containing wastes: deep well injection, lagooning, ocean dumping, etc.

a. Description

b. Cost analysis, as above.

TABLE A-5
NON-INDUSTRIAL AGENCIES CONTACTED FOR DATA ACQUISITION

Agency Name	Location	Person(s) Contacted	Telephone
EPA, Pesticide and Toxic Effects Laboratory	Research Triangle Park, N.C.	J.B. Mann	(919)-549-8411
Louisiana State Health Dept.	New Orleans, La.	G. Von Bodungen	(504)-527-5115
Chlorine Institute	New York City, N.Y.	Mr. Lowbush	(212)-MU2-4322
State of California, Dept. of Food and Agriculture	San Francisco, Ca.	Mr. Colstrum; B. Rollins	(916)-445-2742 (916)-322-5130
Aluminum Association of America	New York City, N.Y.	Dr. Balgord	(212)-972-1800
Midwest Research Institute	Kansas City, Mo.	Dr. Spigarelli	(816)-561-0202
Edgewood Arsenal	Baltimore, Md.	A. Hillsmeyers	(301)-671-3133
Frankford Arsenal	Philadelphia, Pa.	Dr. P. Brody	(215)-831-6130
Picatinny Arsenal	Dover, N.J.	G. Escalin	(201)-328-3906
Surgeon General, Medical R&D Command, Sanitary Engineering Research Branch	Washington, D.C.	Col. L.H. Reuter	(202)-693-8061
Crane Naval Ammunition Center	Crane, In.	K. Whorral; Mr. Fitch, Industrial Hygenist	(812)-854-1603 (812)-854-1847
Lone Star Army Ammunition Plant	Texarkana, Tx.	J. Alexander	(214)-838-1626
Naval Ship Parts Control Center	Mechanicsburg, Pa.	O. Wagner	(717)-766-8511
Naval Civil Information Laboratory	Port Hueneme, Ca.	T. Culbertson	(865)-982-5071
Longhorn Army Ammunition Center	Cornak, Tx.	D. Maley, Chief Engineer	(214)-679-3181
ARMCOM, Installation and Services Group, Rock Island Arsenal	Rock Island, Il.	T. Walsh Chief of Environmental Group	(309)-794-6244
Texas Water Quality Board	Houston, Tx.	B. Taylor	(512)-475-2500