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# SOURCES, CHARACTERISTICS AND TREATMENT AND DISPOSAL OF INDUSTRIAL WASTES CONTAINING HEXACHLOROBENZENE*

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## Summary

Hexachlorobenzene (HCB) is a hazardous component of certain industrial wastes. The hazardous characteristics of HCB stem from its toxicity, potential for bioaccumulation and environmental persistence. A study was conducted to identify the sources and characteristics of manufacturing wastes containing hexachlorobenzene and to review and document methods currently used for treatment and disposal of HCB wastes.

The chlorinated solvents and pesticide industries were found to account for nearly all HCB wastes produced (4,305 tons per year) by the 14 industries reviewed as sources of HCB wastes.

Waste storage methods which are used prior to ultimate disposal include storage of solid waste cubes under plastic cover and use of water-covered lagoons. Methods for transportation of HCB wastes include use of forklift, truck, pipeline, heated tank trucks and rail. Ultimate waste disposal methods include land disposal, incineration (with or without by-product recovery), resource recovery, discharge to municipal sewage treatment plants, and emission to the atmosphere. The majority of the HCB waste handled by the industrial facilities reviewed is currently disposed of in two industrial landfills using a soil cover of 4 to 6 ft. with a polyethylene film placed at approximately the mid-depth of the soil cover. Incineration at a sufficiently elevated temperature can effectively destroy HCB; HCl can be recovered as a by-product.

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

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## Introduction

In recent years there has been a growing concern on the potentially far-reaching environmental implications of a number of hazardous chemicals which are generated as waste products from industrial operations or are manufactured and used for industrial and agricultural purposes. One such chemical is

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hexachlorobenzene (HCB), which is generated as a waste product in the manufacture of a number of chemicals, including certain chlorinated solvents, pesticides, and chlorine. Based on the industry-furnished data, of the estimated 4,305 tons of HCB which are generated annually in the United States, approximately 210 tons are used as a peptizing agent in the manufacturing of styrene and nitroso rubber for tires and as a grain fungicide for seed treatment; the rest is discharged as wastes which are primarily disposed of on land or incinerated.

The hazardous characteristics of HCB stem from its toxicity [1], potential for bioaccumulation in the food chain [2,3], and environmental persistence due to physical, chemical, and biological stability [1]. Studies by Laseter *et al.* [3] have indicated that HCB is bioaccumulative in bass to levels 44,000 times the concentration of HCB in the surrounding aquatic environment. Based on tests with laboratory animals, HCB has been shown to have very low acute toxicity [4,5]. Subacute and chronic toxicity of HCB can be significant, with the most pronounced effect being that of dysfunction of the liver [6]. HCB sublimes when exposed to air. In connection with storage and disposal operations, the rate of sublimation of HCB can be reduced (but not eliminated) by use of cover materials such as soil, water and polyethylene film. Some general and hazardous properties of HCB are summarized in Table 1.

An outbreak of HCB poisoning in man occurred in Turkey during the 1950's as a result of human consumption of seed grain which had been treated with HCB and distributed by the Turkish Government [8,9]. As many as 5,000 people are believed to have sustained poisoning, 80 percent of these being children between 4 and 14 years of age. Effects observed included liver deterioration, acute skin sensitivity and blistering, uncontrolled hair growth, and ultimately, tremors, convulsions and death. The victims had taken doses ranging from 50 to 200 mg/day for a long period of time.

Mismanagement of HCB wastes and use of products containing HCB have already resulted in several serious incidents of environmental contamination [10]. A major HCB contamination episode occurred in southern Louisiana (U.S.A.) in 1972 [8,11], where the U.S. Department of Agriculture (USDA) detected HCB levels in beef cattle far in excess of the tolerance level of 0.3 ppm in beef fat then in effect. As a result, up to 20,000 head of cattle were quarantined by the Louisiana Department of Agriculture. The total direct economic losses resulting from the incident have been estimated by the U.S. Environmental Protection Agency at $ 380,000 [8].

Investigations as to the source of the HCB in the Louisiana cattle revealed that the contamination had originated primarily from industrial plants in the area which were engaged in the production of perchloroethylene, carbon tetrachloride, synthetic rubber, and agricultural chemicals (atrazine, simazine, and propazine herbicides). HCB wastes from at least two of these plants had also been carelessly transported to and dumped in off-site landfills. At one landfill HCB waste had been used as a fly repellant by spreading the material in thin coats over the entire landfill. The spillage of HCB from haul trucks

TABLE 1

General and hazardous characteristics of HCB

Physical constants [1]:

| | |
|---|---|
| Melting point: | 230° C |
| Boiling point: | 326° C |
| Flash point: | 116.7° C |
| Density: | 1.5 |

Stability: highly stable and unreactive; is not hydrolyzed in aqueous solutions [1].

Volatility: sublimes and evaporates readily when exposed to air [1].

Vapor pressure of HCB [7]:

| Temperature (° C) | Vapor pressure (mmHg) |
|---|---|
| 15 | $4.47 \times 10^{-6}$ |
| 25 | $1.91 \times 10^{-5}$ |
| 35 | $6.36 \times 10^{-5}$ |
| 45 | $2.09 \times 10^{-4}$ |

Solubility:

(i) in distilled water: 6.2 μg/l at 23.5° C [7]
(ii) in landfill leachate: 5.1 μg/l at 23.5° C [7]

Experimental results on volatilization of HCB at 25° C through various types of cover materials [7]:

| 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) |

en route to the landfill and improper handling of the waste at the landfill sites were identified as the major sources for the widespread contamination of land and air.

The study described in this paper has had the following objectives: (1) development of detailed information on sources and locations* of manufacturing waste containing HCB; (2) identification of methods currently used for treatment/disposal of HCB-containing wastes, and location of ultimate disposal sites; and (3) collection of industry-furnished cost data on HCB waste treatment/disposal.

* Some of the companies participating in this study indicated that they preferred not to be identified in any technical publications. To respect this desire, company names and locations of the plants are not disclosed in this paper; plant sites and waste disposal contractors/sites are referred to by general industry type only.

## Methodology

Based on a preliminary literature search and contact with industry, fourteen industry types were initially identified as possible sources of HCB wastes. These industries and the reported source of HCB wastes for each industry are listed in Table 2. This initial effort was followed by inquiries to a number of firms in each industry, and submission of formal requests for data to company headquarters and plants. Additional information was obtained by visits to production sites, waste disposal facilities and by discussions and interviews with technical staffs in academic institutions, research establishments, trade organizations and State and Federal agencies. Six site visits were also made. These included visits to two major waste generation sites and two waste disposal sites, one trip to New Orleans, Louisiana, for discussions with the personnel at the Louisiana State Health Department and one trip to the University of California at Riverside to discuss research findings on control of HCB volatilization at land disposal sites.

## Results and discussion

*HCB waste quantities and major sources*

Table 3 lists the 14 industry types which were initially identified as sources of HCB wastes, the total number of firms reported for each industry, the number of firms contacted in each industry and the responses received. Of the total of 260 firms in the fourteen industries, 80 firms (31 percent) were contacted. 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 results of this study, the chlorinated solvents and pesticide productions were identified as the major sources of HCB wastes with the electrolytic chlorine industry being a very minor source. For the remaining 11 industries which were initially identified as potential sources of HCB, some of the sites contacted indicated that HCB is not a constituent of their wastes. Some plants indicated that they had not analyzed their wastes for HCB content. A limited number of sites indicated that they do generate HCB wastes, but based on the data submitted, the quantity of HCB waste generated was judged to be insignificant. Of the 3 companies identified in Table 3 as basic producers of HCB, two were found to be only product distributors, and one recovers HCB from wastes generated in chlorinated solvents production. The quantity of HCB handled by this producer is included in the chlorinated solvents industry. The use of HCB in the production 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.

Data on waste quantities for the chlorinated solvents, pesticide and electro-

TABLE 2

Industries identified as possible HCB sources and potential origin of HCB wastes

| Industry/type | Potential origin of HCB wastes |
|---|---|
| Basic HCB production/distribution | HCB production operation |
| Chlorinated solvents production | Reaction side-product in the production of chlorinated solvents, mainly, carbon tetrachloride, perchloroethylene, trichloroethylene, and dichloroethylene |
| Pesticide production | Reaction side-product in the production of Dacthal, simazine, mirex, atrazine, propazine, and pentachloronitrobenzene (PCNB) |
| Pesticide formulation/distribution | Formulation, packaging and distribution of HCB-containing pesticides |
| Electrolytic chlorine production | Chlorine attack on the graphite anode or its hydrocarbon coating |
| 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 (PCP) production | Reaction by-product of PCP production by chlorination of phenol |
| Wood preservatives industry | Use of HCB as a wood preserving agent |
| Electrode manufacture | Use of HCB as a porosity control in the manufacture of graphite anodes |
| 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 |

lytic chlorine production are summarized in Table 4. A brief discussion of these industries follows.

Based on the data collected in this study, of the estimated 4,305 tons of HCB waste* which are known to be generated annually in this country, 2,650 tons is produced as a by-product in the production of chlorinated solvents. Of

* Except when noted as "HCB-Containing Waste", throughout this paper 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).

TABLE 3

Number of firms contacted and responses received on HCB waste generation

| Industry | Total no. of firms reported for the industry* | No. of firms contacted in each 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 production*** | 4 | 4 | 4 | 0 | 0 |
| Pesticide formulation/ distribution | 46 | 2 | 2 | 0 | 0 |
| Electrolytic chlorine production | 34 | 14 | 2 | 7 | 5 |
| Ordnance and pyrotechnics production | ‡ | 7 | 3 | 1 | 3 |
| Sodium chlorate production | 9 | 5 | 0 | 0 | 5 |
| Aluminum manufacture | 10 | 4 | 1 | 3 | 0 |
| Seed treatment industry | | | | | |
| Production | 8 | 3 | 0 | 3 | 0 |
| Formulation/distribution | 8 | 3 | 1 | 2 | 0 |
| Seed treatment houses, nurseries | 4 | 1 | 0 | 0 | 1 |
| PCP production | 6 | 5 | 0 | 3 | 2 |
| Wood preservatives industry | 52 | 2 | 0 | 2 | 0 |
| Electrode manufacture | 23 | 5 | 1 | 4 | 0 |
| VCM production | 12 | 11 | 0 | 8 | 3 |
| Synthetic rubber production | 30 | 0 | — | — | — |
| TOTAL | 260 | 80 | 21 | 40 | 19 |

*Based on data in refs. 1, 12, 13, 14.
**Some of the firms operate more than one production facility.
*** Includes only those firms involved in production of Dacthal, mirex, simazine, atrazine, propazine and pentachloronitrobenzene (PCNB).
‡ No exact estimates available due to fluctuations in munitions needs which involve activation and deactivation of many munitions production sites.

the 16 companies manufacturing chlorinated solvents, 5 representing 7 production sites and accounting for an estimated 37 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. HCB waste quantities generated at three other production sites were estimated based on data provided by an off-site disposal contractor which had previously handled HCB waste from one of the sites and the data collected for similar production

* All data on number of plants in various industries and their production capacities are based on the information in ref. 1, 12, 13 and 14.

TABLE 4

Major sources and quantities of HCB wastes

| Industry/product | Waste quantities (tons/year) | |
|---|---|---|
| | HCB | HCB-containing |
| Chlorinated solvents (perchloroethylene, trichloroethylene, carbon tetrachloride) | 2,650 | 23,665 |
| Pesticides | | |
| Dacthal | 250 | 333 |
| Simazine, propazine, atrazine | (55)* | not available |
| Pentachloronitrobenzene (PCNB) | 1,400 | 1,750 |
| Mirex | 5.5 | 550 |
| | 1,655 | 2,633 |
| Electrolytic chlorine manufacture | (6)* | 156 |
| TOTAL | 4,305 | 26,454 |

* Indicates lb/yr.

operations at other plant sites. These 3 plant sites account for an estimated 21 percent of the total U.S. chlorinated solvents production capacity.

Five additional chlorinated solvents production plants representing an estimated 41 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 included in this study, 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 recover HCB from chlorinated solvents wastes. Each year approximately 210 tons of HCB are recovered for sale. This quantity, however, accounts for only 8 percent of the total HCB generated by the chlorinated solvents industry; the other 92 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. The estimated total quantity of HCB waste generated in the pesticide industry is 1,655 tons per year. The HCB is present mainly in tars and still bottoms from the manufacturing operations.

Very limited data are available on HCB waste generation by the electrolytic chlorine industry. When graphite anodes are used, the electrolytic process for the production of chlorine may result in the formation of HCB [1]. HCB production is believed to result from attack of chlorine on the graphite and/or hydrocarbon oils (e.g., linseed oil) which are used as anode coatings [1]. Of the 67 domestic electrolytic chlorine production sites, 32 were identified as using graphite anodes. Eight of these sites were contacted during this study. Four of the sites had conducted analyses on their streams, but only two had ever detected HCB in their waste streams. At one plant site, HCB was determined to be close to the 20 ppm level in still bottoms from the chlorine distillation operation. Because of the low concentration level, however, the quantity of HCB generated is very small (approximately 6 lb/year). At the other plant site, HCB was detected in the product chlorine which is not purified but sold directly. No quantitative data are available on HCB waste for this site.

Based on the data available, it can be concluded that the quantity of HCB produced in the electrolytic chlorine industry is probably very small relative to the waste generated in the chlorinated solvents and pesticide industries. In addition, some of the sites which currently use graphite anodes have indicated that they plan to convert to the use of non-graphite electrodes in the future.

*Storage and transportation practices*

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 release into the environment. Sublimation, wind and water erosion, possible accidental spills, and use of inadequate environmental safeguards can contribute to the transport of HCB wastes away from their point of origin. Accordingly, as part of the present study, data were collected on methods of HCB waste storage and transportation. These data are summarized in Tables 5 and 6, respectively. Waste storage under plastic cover and in water-covered lagoons account for the largest percentages of the total HCB waste for which data on storage and handling methods were obtained from industry (Table 5). The data collected on waste transportation methods (Table 6) indicate that the largest quantities of wastes are transported by fork-lift and trucks. In some cases the HCB handled in trucks is in drums which may or may not be lined.

As indicated in Table 6, the largest quantity of HCB is handled at one pesticide production site which uses the forklift method of transportation; this same site stores HCB under plastic cover. At this site, HCB is generated as a waste product in the production of pentachloronitrobenzene. Heavy still bottom tars containing 80 percent HCB from the distillation operation are discharged into 1-cubic yard molds and allowed to cool to 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. To date,

TABLE 5

HCB waste storage and handling practices

| Practice | % of total HCB waste* | Industry type | No. of sites |
|---|---|---|---|
| Storage of solid cubes under plastic cover | 44.2 | Pesticide industry | 1 |
| Water-covered open storage lagoons | 33.1 | Chlorinated solvents | 2 |
| Drums which may or may not be lined | 14.4 | Chlorinated solvents | 1 |
| Insulated and heated storage tanks | 8.2 | Chlorinated solvents | 2 |
| Nitrogen-blanketed steel tank | <0.1 | Chlorinated solvents | 1 |

* For 3,168 tons/year of HCB (74% of the estimated total) for which data were obtained from industry.

TABLE 6

Methods for transportation of HCB wastes

| Method | % of total HCB waste* | Industry type | No. of sites |
|---|---|---|---|
| Forklift | 35.7 | Pesticide industry | 1 |
| Truck | 38.4 | Chlorinated solvents | 3 |
| | | Pesticide industry | 2 |
| Pipeline | 19.1 | Chlorinated solvents | 2 |
| Heated tank trucks | 6.6 | Chlorinated solvents | 1 |
| Rail | 0.1 | Pesticide industry | 1 |

* For 3,924 tons/year of HCB (91% of the estimated total) for which data were obtained from industry.

approximately 3,500 tons of the HCB-containing waste blocks (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, dust formation and volatilization through sublimation).

Ten-foot deep rectangular concrete lagoons are used for temporary storage of HCB-containing wastes at 2 sites engaged in the manufacture of chlorinated solvents. At these sites waste discharges from process operations enter the lagoons through steam-jacketed fiber-cast pipes. The waste is distributed along the length of the lagoon by a submerged mobile discharge pipe. Ordinarily, a water cover of 1 to 2 ft. 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 and a clam-type shell bucket) and transported by a dump truck to an on-site landfill location. Since some water is also scooped out with the waste, this water may act as a seal in the dump truck during transportation.

The operation of lagoons at the two sites provides some potential for environmental contamination. Although compared to soil and polyethylene film, a water cover has been shown to be more effective to reduce HCB volatilization and loss to atmosphere (see Table 1), 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 $\mu$g/l for distilled water at 23.5° C, see Table 1) and can be lost to the atmosphere through evaporation and wind action.

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 photographs of the drums containing HCB wastes as delivered to a sanitary landfill are shown in Fig. 1.

*Ultimate disposal*

Based on the industry-furnished data, methods currently used for the ultimate disposal of HCB-containing wastes include land disposal (industrial landfill*, sanitary landfill and deep well injection), incineration, 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 is shown in Table 7 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 7 indicate that based on the total quantity of waste handled, land disposal is currently the most prevalent method for ultimate disposal of HCB waste. Eight of the sites use land disposal; approximately 1,533 tons of HCB waste which are contained in a waste mixture of 19,164 tons are disposed of by this method each year. Among land disposal methods, the use of industrial landfills is the most prevalent method, accounting for the disposal of 56.8 percent of all HCB wastes. Ranked next to land disposal is incineration which is used at eight of the sites for the destruction of a minimum of 1,163 tons per year of HCB contained in a waste mixture in

* As used here, industrial landfills are those on-site or off-site landfills which accept only industrial wastes. Sanitary landfills are off-site landfills which accept both municipal refuse and industrial wastes.

Fig. 1. Photographs of drummed HCB waste at a disposal site. Note dust formation and spillage due to ineffectiveness of the plastic bag enclosure for waste containment.

excess of 5,257 tons per year. Compared to land disposal and incineration, the quantities of waste discharged to sewage treatment plants and to the atmosphere are very small. No data were available on the quantity of HCB waste which is used at one site as a chemical feedstock for the production of low-molecular weight aliphatic halogenated hydrocarbons. Of the 19 sites listed in Table 7, six use the services of off-site disposal contractors, which handle 723 tons per year of HCB wastes.

Table 8 presents a breakdown of the various land disposal methods and their use at on-site and off-site facilities. As indicated in this table, the largest quantity of waste is handled at on-site industrial landfills at two plant sites associated with chlorinated solvents manufacture. The HCB wastes are scooped from the settling lagoons and brought to the landfills in dump trucks. The disposal sites at the two facilities are essentially identical. HCB wastes are deposited in excavated pits 10 to 12 ft. deep and roughly 20 × 30 ft. in

(*continued on p. 356*)

TABLE 7

Prevalence of methods used for ultimate disposal of HCB wastes

| Disposal method | Industry type | Plant sites | | HCB waste | | HCB-containing waste | |
|---|---|---|---|---|---|---|---|
| | | No. | % of total | Quantity (tons/year) | % of total | Quantity (tons/year) | % of total |
| Land disposal | | | | | | | |
| Sanitary landfill | Chlorinated solvents | 1 | 5.3 | 208 | 7.7 | 281 | 1.1 |
| Industrial landfill | Chlorinated solvents | 3 | 15.7 | 1,050 | 38.9 | 7,000 | 28.7 |
| | Pesticide industry | 1 | 5.3 | 50 | 1.9 | 67 | 0.3 |
| | Electrolytic chlorine | 1 | 5.3 | — | — | 156 | 0.6 |
| Deep well disposal | Chlorinated solvents | 2 | 10.5 | 225 | 8.3 | 11,660 | 47.7 |
| (Subtotal) | | 8 | 42.1 | 1,533 | 56.8 | 19,164 | 78.4 |
| Incineration | | | | | | | |
| Without by-product recovery | Chlorinated solvents | 4 | 21.0 | 213* | 7.9 | 3,991* | 16.4 |
| | Pesticide industry | 2 | 10.5 | 200 | 7.4 | 266 | 10.0 |
| | Electrolytic chlorine | 1 | 5.3 | not available | — | not available | — |
| With by-product recovery | Chlorinated solvents | 1 | 5.3 | 750** | 27.8 | 1,000** | 4.1 |
| (Subtotal) | | 8 | 42.1 | 1,163 | 43.1 | 5,257 | 21.5 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Resource recovery (excluding incineration) | Chlorinated solvents | 1 | 5.3 | not available | — | not available | — |
| Discharge to waste treatment plants | Pesticide formulation/ distribution | 1 | 5.3 | small; data on exact quantity not available | — | not available | — |
| Emission to atmosphere | Pesticide industry | 1 | 5.3 | not available | — | not available | — |
| Total | | 19 | 100% | 2,696*** | 100% | 24,421*** | 100% |

* Includes a very small quantity of HCB wastes (400 lb. per year) from three plant sites engaged in chlorinated solvents manufacture. These wastes are extremely dilute (10 to 40 ppm HCB) and were not included in the total waste quantities in order to avoid gross distortion of "HCB-Containing Waste Quantities" handled by incineration.

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

*** Does not include 1,400 tons per year of HCB waste (1,750 tons of HCB-containing waste) temporarily stored under cover at one pesticide production site. Also does not include 210 tons of HCB which is recovered for sale from 284 tons of HCB-containing wastes at one chlorinated solvents plant.

TABLE 8

Methods and sites for land disposal of HCB wastes

| Method of land disposal | Disposal site type | Quantity of HCB waste (tons/year) | Industry source of waste |
|---|---|---|---|
| Sanitary landfill | off-site | 208 | Chlorinated solvents |
| Industrial landfill | off-site | 50 | Pesticide industry |
| | on-site | 810 | Chlorinated solvents |
| | on-site | 240 | Chlorinated solvents |
| | on-site | not available | Chlorinated solvents |
| | on-site | 6 lb | Electrolytic chlorine |
| Deep well disposal | off-site | 52 | Chlorinated solvents |
| | on-site | 173 | Chlorinated solvents |

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 4 to 6 ft. of soil and a 10-mil thick polyethylene film is placed approximately in the mid-depth of the soil cover. The subsurface structure at the site includes impermeable strata which are considered adequate to prevent groundwater contamination.

Prior to the use of on-site land disposal, HCB wastes from one plant site producing chlorinated solvents were handled by a private off-site contractor and deposited in a nearby sanitary landfill. The landfill received 14 to 17 $ft.^3$ 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 repellant. This operation was later identified as the major source of environmental contamination in the Louisiana HCB contamination episode of 1972. The site has since been closed and the wastes buried under polyethylene sheeting in an isolated section of the landfill.

Table 9 lists the sites for the incineration of HCB wastes and the quantity of waste handled at each site. The largest quantity of waste is handled at a chlorinated solvents plant, 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 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. An incineration system at one plant site handles HCB-containing wastes from chlorinated solvents production at this site and at two other production sites. The incinerator is equipped with scrubbers and handles chlorinated solvents wastes containing 10 to 40 ppm of HCB. Based on the stack monitoring data 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 lb/lb of tar input, respectively.

TABLE 9

Sites for the incineration of HCB wastes

| Disposal site type | Quantity of waste (tons/year) | Industry source of waste |
|---|---|---|
| On-site | 750 | Chlorinated solvents |
| Off-site | 208 | Chlorinated solvents |
| | 200 | Pesticide industry |
| On-site* | min. 0.2 | Chlorinated solvents |
| Off-site** | 5.5 | Pesticide industry |
| On-site | not available | Electrolytic chlorine |

* This facility handles HCB-containing wastes from its own production operations as well as wastes from two other chlorinated solvents plants.
** No HCB waste has been hauled to the site since mid-1974.

*Waste treatment/disposal costs*

Very limited actual disposal cost data are available on existing facilities handling HCB wastes. 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. The cost charged to waste generators by four off-site waste disposal contractors employing landfill, incineration and deep-well injection range from \$ 20 to \$ 32 per ton of HCB-containing wastes. At one plant site engaged in chlorinated solvents production, the cost for the operation of pretreatment lagoon, removal and transport of waste from the lagoon to an industrial landfill, and equipment maintenance is estimated at \$ 9 per ton.

## Conclusions

Based on the results collected in this study, the following conclusions can be drawn:

Chlorinated solvents production and pesticide manufacturing are the two major sources of HCB wastes accounting for nearly all of the reported HCB waste generation from the industrial categories studied. The electrolytic chlorine industry is a minor source of waste. Eleven other industry categories which were reported to generate HCB wastes are basic HCB production/distribution, pesticide formulation/distribution, ordnance and pyrotechnics production, sodium chlorate production, aluminum manufacture, the seed treatment industry, pentachlorophenol production, the wood preservatives industry, electrode manufacture, vinyl chloride monomer production and synthetic rubber production. However, very limited data are available to assess the magnitude of the HCB waste generation problem for these industries.

The largest current use of HCB is as a peptizing agent in the manufacture of nitroso and styrene rubber for tires. This quantity of HCB, however, accounts for only five percent of the total HCB generated.

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 environmental contamination.

While landfill disposal of HCB does not eliminate movement into air, it can be environmentally acceptable if an adequate soil cover which includes an intermediate layer of plastic is provided to reduce the sublimation rate, and if 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.

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

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