# THE LEGACY OF LINDANE AND TECHNICAL HCH PRODUCTION

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**Introduction**

1, 2, 3, 4, 5, 6-Hexachlorocyclohexane (HCH)[A] has been one of the most extensively used pesticide and has been industrially produced mainly after the Second World War. HCH is available in two formulations: technical HCH and lindane[B]. A total of eight HCH isomers have been identified in technical HCH; however, only the α-, β-, γ-, δ- and ε-isomers are stable and these are the ones commonly identified in technical formulations. Generally, technical HCH contains the isomers in the following percentages: α: 55-80%, β: 5-14%, γ: 8-15%, δ: 2-16%, and ε: 3-5%. Of these isomers only the gamma isomer has specific insecticidal properties. Lindane contains more than 90% of γ-HCH, but lindane used in many countries is almost pure γ-HCH.

The application of lindane and technical HCH during the last 5 decades has resulted in environmental contamination with global dimension[1, 2a, 2b, and 2c].

In the late 1940s and 50s the Technical HCH mixture as a whole was sprayed in Europe (and other countries). However it was soon discovered that the application of the technical HCH resulted in inedible crops, vegetables and fruits due to the bad smell and taste of some of the HCH isomers. Therefore, some companies started already in the 1950s with the isolation of the active, and in the applied concentration tasteless, gamma isomer and sold it under the trade name lindane.

The other HCH isomers resulting from production remained as by-products and became finally hazardous waste. It has been largely unknown to the public that the production of lindane has created one of the globe's largest hazardous organic waste problem: the production of lindane is inefficient as for each ton of lindane 8 - 12 tons of other HCH isomers are produced[3, 4, 5]. These isomers have ended mostly as hazardous waste, which were dumped uncontrolled at many sites around the world. Furthermore, the attempt of recycling the waste isomers to trichlorobenzene resulted in highly PCDD/PCDF contaminated residues[6]. These sites and the fate of the waste as well as the consequences for humans and the environment have virtually been ignored but need to be addressed.

This paper summarizes the results of the report "The Legacy of Lindane HCH Isomer Production, A Global Overview of Residue Management, Formulation and Disposal", by the International HCH & Pesticides Association (www.ihpa.info), that has been published in January 2006[1] and has been submitted to the secretariat (Persistent Organic Pollutants Review Committee) of the Stockholm Convention in order to stimulate that lindane and technical HCH will be nominated as new POP. The report and this short paper make a first effort to quantify the extent of the waste and show the related problems.

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[A] The Hexachlorocyclohexane compound is called "HCH" by the WHO. Another common name of Hexachlorocyclohexane is "benzene hexachloride", or "BHC" by UN FAO and ISO, which is, however, incorrect according to the IUPAC rules.

[B] The term "lindane" should be differentiated from γ–HCH in order to avoid some confusion. γ–HCH is one of several isomers of HCH, and is contained in both technical HCH and lindane. Lindane is one of two grades of HCH, and contains almost pure γ–HCH.

**Materials and Methods**

A global review has been undertaken, in order to estimate the global amount of HCH production and HCH waste (dumped and stockpiled HCH) (Figure 1). Two approaches have been used for the estimates:

The first approach is based on the collection of information over the last 20 years from production sites, production capacities and produced amounts, as well as information on waste amounts occurring. The outcomes using this approach can be viewed as an underestimate since a number of sites are still unknown. It is worthwhile to point out that the production of technical HCH was common worldwide from the 1950s and 1960s, detailed information is, however very limited in this respect.

For the second approach, the historical usage of lindane worldwide has been investigated from different sources. The total quantity of HCH waste can be estimated by the factor of waste isomers produced per ton of used lindane, which, according to Bodenstein[3], was around 8 tons of HCH isomer waste. Other experts mention higher amounts of waste, such as 10 tons [4] and 10 to 12 tons [5] per ton of lindane produced. For the second approach used in this paper, the estimate of Bodenstein[2] was used as it reflects the experiences of the most important lindane producers at that time organised in the CIEL (Centre International d'Etudes du lindane).

**Results and Discussion**

**Data Collection**

Information available from papers submitted to the seven International HCH and Pesticides Forums[7] held since 1992 has provided a valuable basis for answering the questions related to production of lindane and wastes from the lindane production. This information was used in compiling a comprehensive list of countries, which are affected by lindane production (Figure 1).

A questionnaire to obtain an idea on production amount, export, waste quantities and deposition was developed and sent to stakeholders in the Forum network. At first more than 50 organizations, mainly governmental, industry and individual persons were contacted. The result of the questionnaire was highly disappointing, as from over 50 recipients only Albania, Australia, Austria, Belgium, Brazil, Hungary, Japan, Pakistan, Poland answered officially. Intensive efforts in France, being one of the major producers, comprising repeated requests and phone-calls to various ministries and regional authorities, were never answered.

Efforts to interview persons and organizations gave similar limited results as those from questionnaires, and it revealed that the HCH and lindane issues are still very sensitive to public, authorities and industry, interpreted as fear of raising unmanageable concerns and reactions.

Extensive support for this investigation was provided by US EPA and the work was facilitated by their extensive overview of data available from the reports from Superfund projects and other projects managed by the EPA's or other environmental authorities of the individual States.[8]

A second round addressing 30 governments was made again in October and November 2004 in a last attempt to improve the quality of the information. This effort provided some supplementary information. Repeated requests to the governments of China and India to obtain information on the ongoing lindane production have never been answered, and therefore similar to France, Poland and the former Soviet Union only a rough estimate can be made for these two countries.

**Estimation of global lindane use**

Global historical lindane use for agricultural purpose between 1950[C] and 2000 is estimated to ca. 450 000 t (Table 1). The largest share of this is within Europe with approximately 63% of the total global consumption, although the use of lindane has been stopped in some European countries already in the 70s. In general, peak production of lindane occurred in the 1960s and the beginning of 1970s.

Additional use of lindane on livestock, forestry, human health and other purposes has also to be considered and is estimated to 150 000 t. Therefore the total global lindane usage for all purposes may be estimated at approximately 600 000 t.

[C] Production in the 40s have been reported but no information could be obtained for that period.

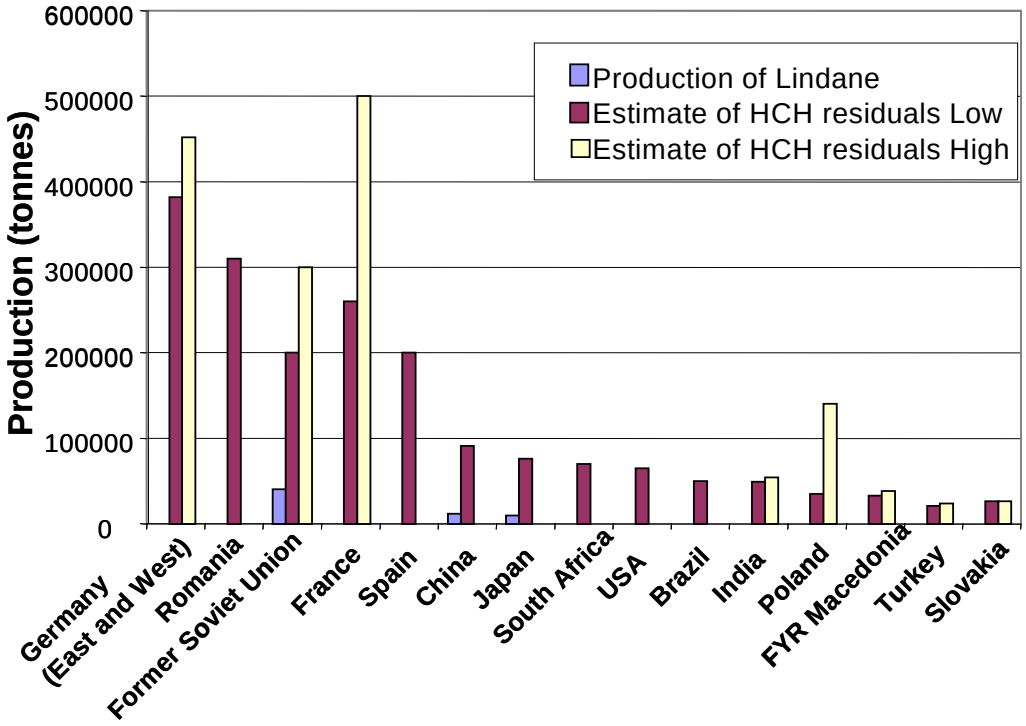


**Figure 1**: Preliminary estimate on key quantities of HCH-residual waste present in various countries.

**Table 1:** Estimated HCH consumption for agriculture on the continents

| Continent | Amount (1000 t) | Percentage |
|---|---|---|
| Europe | 287.16 | 63.32 |
| Asia | 73.20 | 16.14 |
| America | 63.57 | 14.02 |
| Africa | 28.54 | 6.29 |
| Oceania | 1.03 | 0.23 |
| Total | 435.50 | 100 |

**Estimated stored and deposited amount of HCH waste**

The estimation on deposited and stockpiled HCH using the first approach (i.e. collection of historical information) has resulted in a preliminary approximate of a total of 1,600,000 – 1,900,000 Million tons[D] of HCH-waste being the "minimum" estimate (Figure 1).

The second approach, using the global lindane use outlined above, has lead to an upper estimate of 600 000 tons. Using a factor 8 assumed for each ton of lindane produced[3], a total amount of HCH residuals of approximately 4.8 Million tons[B] may be present worldwide.

[D] For comparison: The global production of PCB is estimated to 1,600,000 tons in total.

**Storage practice and deposition**

During the 1960s HCH residues where often stockpiled in open piles known as white mountains, often called muck or scum (Figures 2 and 3).

The uncovered HCH powder contaminated neighbouring areas due to distribution by wind. For example, it has been found that cow and human milk have been highly contaminated by HCH in the vicinity of the Ugine-Kuhlmann company (Hunigue, France bordering Switzerland) producing lindane from 1947 to 1974[9].

Most of the residuals from the production processes have been dumped without special care over the last 50 years, which have created an extensive environmental hazard. In this context it should be noted that originally the residuals were considered harmless and insoluble in water. No objections have therefore been raised in particular in the 1950s and 1960s to the practice of using residuals for construction purposes, e.g. filling unwanted holes or pits wherever they were encountered[9,10,11] (Figure 4, 5).

Also, the storage practice from the past in open piles, resulting in contamination of neighbouring areas can still be observed in some locations (e.g. East Europe Fig. 2) today. Even today most of other storage places do not have safe standards and some securing and remediation actions need to be undertaken (Figures 2 - 5).

Figure 2: Extensive HCH-piles in Eastern Europe (ca. 250 000 tons)

Figure 3: waste HCH isomers being collected inside a former lindane production facility in Basque Country Region of Spain. (Source: IHOBE, Basque Country)

Figure 4: HCH waste dump in Northern Spain

Figure 5: Open HCH dumpsite in India.

**Attempts to recycle HCH stockpiles**

The problems encountered with the "white mountains" and the problem of waste isomer management led to recycling efforts of the HCH waste. The HCH waste isomers are a relative pure waste product of one molecule containing 70% of chlorine by mass. Several recycling attempts have been made to use these residuals for the production of trichlorobenzene, HCl and other derivates. However, most of the efforts have been unsuccessful and some of these attempts leaded to highly PCDD/PCDF contaminated waste streams[6]. In one case, these PCDD/PCDF contaminated residues led to the close down of a large chemical factory in Germany by state authorities.

**Current Production**

During the past years the production of lindane has rapidly decreased, now leaving only a small number of producing countries (India and Romania). In India, a ban was imposed on the use of technical HCH in 1997, but restricted use of lindane was permitted. Thus in India industry is still manufacturing lindane. In China, the production of lindane was stopped in 2003[12]. Exact information on existing production capacities were not available, but it is estimated that between 1300 and maximum 2 000 tons lindane are produced per year at present.

**Conclusions**

Based on the results obtained it can be concluded that the international society is confronted with a vast legacy of toxic materials in the form of by-products from lindane production. Although the exact amounts of HCH-residuals are not known, a first estimate indicates a range between 1.6 to 4.8 million tons. The extent of the HCH problem is therefore exceeding present estimates on other obsolete pesticides such as the pesticide stockpiles in Africa (55 000 tons)[13] and in the Eastern European region (varying from 150 000 to 500 000 tons)[14,15]. With the exception of some locations in industrialised countries, which are somehow "contained and controlled" in the framework of national soil remediation programmes, it can be expected that at most locations in other parts of the world, environmental impacts have and are still taking place (Figures 2-5) and that appropriate measures have to be taken as soon as possible. The international society should therefore take action within the framework of the Stockholm Convention to nominate lindane and HCH as a new POP and establish an environmentally sound strategy for the development of destruction strategies of HCH waste in a sustainable and economical way.

IHPA wants to stress that the objective of this work is NOT to accuse former producers, but merely to draw attention to this problem of global dimensions and thereby call for a concerted action of all international stakeholders to work jointly towards sustainable solutions on the legacy of lindane and technical HCH production.

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