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International HCH & Pesticides Association

The Legacy of Lindane HCH Isomer Production

Annexes

A Global Overview of Residue Management, Formulation and Disposal

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Front Page:
Photo: *HCH residuals (white hills) deposited next to a railway.*
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Annex I: Variations in the production of HCH

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1. Manufacture of Technical HCH

For the manufacturing of technical HCH, the irradiation by intensive light sources having a high ultraviolet content was mostly done with high-pressure mercury lamps, which provided with protection pipes, were brought into benzene. This has been established as one of the standard procedures (Amadori, 1993). The production process should be directed to the formation of pure HCH, and the formation of undesirable by-products such as chlorobenzene should be avoided. Attempts are made to keep the portion of gamma-HCH as high as possible (Amadori, 1993). Specially at the beginning after the second world-war, many companies started to produce HCH. For example in Germany 26 companies started in the early days, but most of them faded due to the fact that they have been burnt down or exploded or have been literally "suffocated" by the enormous amounts of alpha-HCH being created and lying around at the production sites. The use of the UV lamp being held in the benzene is a direct source for possible incineration and when breaking leading to a catastrophe. Only a limited of companies remained afterwards.

1.1 Manufacture of Technical HCH by means of a catalyser

Instead of UV light a catalyst has been applied. Here ice and benzene are added in a relation 1:3 as well as calcium oxide. The calcium oxide serves as catalyst one producer indicated to have used calcium hydroxide). Ice has to be added in order to avoid too high temperatures during the exothermal reaction of Chlorine and benzene. Fluid chlorine is brought in (Relation chlorine to benzene is 3:4). Temperatures rise to about 25 º C and after the reaction of chlorine follows a short after-reaction and the temperature rises to ca. 35 º C. Thereafter 45% NaOH is added to neutralize the mixture. During the following water vapor distillation a mix of benzene and chlorobenzene is collected. If the concentration of chlorobenzene is lower than 6%, the mix is returned as re-distillate in the next batch and if it is greater, follows a fractionated distillation and benzene is separated from chlorobenzene. The HCH is washed and stored in a drying room. The concentration of gamma-isomers is 14%.

Another producer has indicated to have worked with another variation using calcium hydroxide as catalyser. In the process also carbon tetrachloride has been used as a solvent for chlorine. Ratio carbon tetrachloride: benzene = 20:1 at a temperature of 15 ºC. As the dosing of chlorine at low temperature is difficult, is the chlorine brought in solution with carbon tetrachloride which makes the reaction much easier.

2. Manufacture of Enriched HCH

2.1 Butylacetate-method

In this method Butylacetate is used for extraction and for the manufacture without residuals, disulfide has been applied. With this method one obtains an 85% final product.

2.2 Method for the manufacturing of 85% HCH

Technical HCH (14%) is mixed at 60 º C with TCE. Gamma –HCH, oily by-products and a part of the other Hexa-components are dissolved. After cooling down follows centrifugation where a residual cake is collected that contains mainly Alpha- and beta HCH. By distillation of the residual TCE is recovered and re-used.

In the process used benzene, which is a socalled “Boilingpointbenzine”, which has a boiling range from 100 to 140 º C. During the extraction the inactive isomers and oily contaminations dissolve and gamma-HCH is separated as final product with 85%-Gamma concentration. The distilled benzine-dioxane mix is brought back into circulation again.

2.3 Benzine-Dioxane Method

In earlier methods, the oils (ca 8%) in the technical HCH were eliminated during the treatment process, but in this method the greases are removed directly at the start of the process by means of a “benzene-pre-treatment”. In the following TCE-extraction, the pre-cleaned HCH is mixed with TCE, heated to dissolve all the gamma-HCH, thereafter cooled off and vacuum-filtered. The filtercake, which contains mainly alpha-HCH is deposited. Via vacuum distillation TCE is recovered. Now one has obtained a socalled Tri-sludge consisting of 62.7 % gamma-HCH, 15.6% alpha-HCH and 21.7 % other isomers and contaminants. In the following benzine-dioxane-extraction, benzene is added to the hot tri-sludge. After centrifugation Lindane is then drained and due the vacuum-distillation the benzene-dioxane-mix can be re-used. In order to achieve the Lindane quality, the dioxane-complex has to be destroyed thermally in the drying process.

2.4 Modified Benzine-Dioxane Method

In this method several optimizing steps have been incorporated:

- By means of a hydraulic press, apart from water also the main volume of oily and greasy are removed, which were separated in the benzene-dioxane method by the application of large volumes of benzene.
- During the benzene-dioxane-extraction, only 95%-age HCH is produced in order to save dioxane. Alpha-isomers are separated at 40 º C and after cooling off till 25 º C, during the following vacuum-filtration 95%-ageHCH occurs as filtercake. The filtercake consists of 52-age HCH and can be applied again for the next TCE-extraction in order to save technical HCH. After vacuum-distillation the benzene-dioxane is able to take up HCH-isomers, thus only the lost volume of benzene and dioxane has to be supplemented.
- For the manufacture of Lindane, 95%-age HCH is, after centrifugation lead into benzene and during vacuum-filtration Lindane occurs as filtercake, which is 60%-age HCH and can be re-used. Due to the application of benzene, the dioxane-complex is opened, thus is the under 2.2.1 described thermal destruction not needed anymore and after re-distillation can benzene-dioxane be re-used.

2.5 Benzine Method

After TCE-extraction and benzine-extraction, as described before, 96%-age HCH is obtained. In order to obtain a Hexa-post-precipation, the benzinefiltrate is cooled and vacuum-filtered. After centrifugation and drying 40%-age HCH occurs – socalled Hexa-post-precipate, which is used for the production of crop protection products specifically for cotton-dust.

For the manufacture of Lindane the humid 96%-age HCH is added under increase of temperature and after cooling off precipitated. The filtercake is dried.

Due to the lack of technical HCH and TCE, several years later, one has initiated the utilization of the 40%-age Hexa-post-precipation.

2.6 Methanol-circulation-method

This method is the same as the Benzine method, with the only difference that instead of Benzine methanol has been used as extract.

2.7 Production of Export-Lindane

In order to achieve the required quality of export, the Lindane, produced during the methanol circulation method, was crystallized an extra time with TCE.

Annex II: Attempted Destruction of HCH Isomers

Annex II: Attempted Destruction of HCH Isomers

1. Germany

In Germany 2 manufacturers have been able to eliminate HCH-residuals. In one case a total amount of 40 000 tons of HCH residuals has been completely used within a couple of years for the production of 1,24-trichlorobenzene (TCB) which was then in a thermal destruction converted to 1,2,4,5-tetrachlorobenzene and was chlorinated via trichlorophenol to 2,4,5-trichlorophenoxyacetic acid (2,4,5-T).

In the other case more than 30 000 tons have been converted to trichlorobenzene. The method was relative simple, but very cost-intensive due to the high corrosion of the equipments used. Continuous processes were possible. For the production of 1,2,4,4 tetrachlorobenzene, a trichlorobenzene with 75% 1,2,4 TCB brought an economical advantage. This was possible by means of the application of certain kind of active carbons. The HCl-separation took place on the granulated carbon at high temperature (sublimation). Problems occurred with the sales of the formed HCl, which only could achieve a marketable quality by means of costly adiabetical adsorption and application of active carbon as final polishing step. Therefore HCl was used in most of the manufacturers internally for neutralization purposes. The chlorination to 1,2,4,5-tetrachlorobenzene as pre-product for the 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) brings again a high percentage of undesirable tetrachlorobenzene isomers and high chlorinated side-products (up to penta-and hexachlorobenzene) and these products only seldom could be used!

2. France

In the beginning of the ninetees, France was one of the last countries of Lindane producers. The French production of technical HCH (25 000-30 000 t/year) was completely used to make Lindane (estimate 3 200 t/y). In France the manufacturing of HCH and Lindane were separated. HCH was made in one of the factories and the manufacturing company of the Lindane was situated at an other location. The following capacities were mentioned at the beginning of the 90s: 36 000 t/y of HCH, 4 000 t/y of Lindane, 16 400 t/y TCB and 12 000 t/y of HCl. During 1994, the last producer stopped the Lindane production and the production of 1,24-TCB by its cracking. The pure 1,24-TCB was then produced by distillation by another company and sent back to be used as intermediate in the synthesis of a pesticide by the manufacturer in a continuous process in a closed system.

3. Russia

The situation in Russia is described by Treger, (October 2004), at the chemical plant "Khimudobrenij" at the town of Chapaevsk, in 1968 – 1971: "following the isolation of gamma-HCH (for 1 ton of gamma-isomer up to 10-12 tons of "intoxic" isomers were formed), processing of all other isomers was introduced at the industrial scale. The production stopped approximately in 1986-87.

The technological scheme was as follows:

1. Thermal (at 240-250°C), initiated with chlorine, dehydrochlorination of HCH isomers resulting in 1,2,4-trichlorobenzene (TCB) in the liquid phase and isolation of relatively small amount (up to 1 000 t per annum) of purified TCB.

2. High temperature (up to 600°C) chlorination of TCB on the charcoal resulting in the commercial hexachlorobenzene (HCB) – about 1 000 t per annum.
3. Water-alkali hydrolysis of HCB resulting in sodium pentachlorophenolate – annual capacity was 2 400 t."

This technological scheme was used during more than 15 years, up to end-80s, when all these production facilities, including the ones for HCH, were closed down.

Jones (2005) mentions that China and Russia still manufacture PCP from HCB by caustic soda hydrolysis, which utilises the waste alpha-HCH from Lindane manufacture. This is believed to be the only current direct use of HCB as a chemical intermediate (Bailey, 2001)

4. Czech Republic

Holoubek et al, (Holoubek, 2004, Matousak, 1994) report that a somewhat different approach, which was applied at the Spolana Factory (presently in the process of remediation). In the year 1965, a complex processing of HCH isomers was introduced according to technology developed by the research department of agrochemical technology in Bratislava. In the first phase, the isomers underwent dechlorination by caustic soda to trichlorobenzene (specifically a mixture of trichlorobenzene isomers), which was isolated from the reaction mixture by steam distillation. Trichlorobenzene was then processed by direct catalytic chlorination to a tetrachloro- and hexachlorobenzene (HCB) compound. Tetrachlorobenzene (hereafter TeCBz) due to the action of caustic soda was converted to sodium trichlorophenolate, which either by acidification was converted to trichlorophenol, or due to the action of chloroacetic acid to the sodium salt of 2,4,5-trichlorophenoxyacetic acid (hereafter just 2,4,5-T). The reaction of sodium salt of 2,4,5-T with butylalcohol produced the butylester of 2,4,5-T acid, which was the main active ingredient of arboricidal preparations ARBORICID E 50 and ARBORICID EC 50.

Sodium pentachlorophenolate was sold dried and in 7-11% water diluted solution forms. Pentachlorophenol was sold dried and as a xylene solution with a minimum 23% PeCP content. PeCP was equally used as one of the active ingredients in the combined insecticidal and fungicidal preparation PENTALIDOL for all types of wood treatment, constructions, bannisters, furniture, flooring and roofing against wood-damaging pests, wood-damaging fungi and various types of moulds.

Due to the action of caustic soda, Tetrachlorobenzene (TCB) was converted to sodium trichlorophenolate, which either by acidification was converted to trichlorophenol, or due to the action of chloroacetic acid to the sodium salt of 2,4,5-trichlorophenoxyacetic acid (hereafter just 2,4,5-T). The reaction of sodium salt of 2,4,5-T with butylalcohol produced the butylester of 2,4,5-T acid, which was the main active ingredient of arboricidal preparations ARBORICID E 50 and ARBORICID EC 50.

Non-reacted parent lyes were brought back to previous stages, which on one hand made this technology almost without waste, however on the other hand led to the concentrating of pollutants and reaction side products.

At the time when the technology of processing ballast HCH isomers was being implemented, it wasn't known that side reactions occur during the above-mentioned syntheses with trace amounts of substances harmful to human health, causing liver necrosis and manifested externally by the presence of chloracne.

Attention was called to the cause of this problem by the workers of the Chemical-Technical University in Pardubice, who from literature and then during in-person discussion abroad, were able to find out information about similar problems in Germany. There it was discovered, that during dehydrochlorination of HCH and during further processing of chlorinated derivatives of benzene, trace amounts of polychlorodibenzodioxins are created, among them even 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD), which has the highest toxicity.

5. China

Jones (2005) quotes: "China and Russia still manufacture PCP from HCB by caustic soda hydrolysis, which utilises the waste alpha-HCH from Lindane manufacture. This is believed to be the only current direct use of HCB as a chemical intermediate (Bailey, 2001). China has been listed as an exemption from the Stockholm Convention for production and use of HCB as an intermediate, and HCB is still being produced in a large chemical factory near Ya-Er Lake, in Hubei province, NE China (Kunisue *et al*, 2004).

6. Others

According to Jones (2005), HCB may also be synthesized by by refluxing hexanchlorocyclohexane (HCH) isomers with sulphuryl chloride or chlorosulphonic acid in the presence of a ferric chloride or aluminium catalyst.

Annex III: Table Global Overview of HCH/Lindane Production and Residuals

Country/ Producers	**Production period**	**Production**	**HCH residuals (in tons)**
Albania			
Former Lindane plant (Kolaci, 2001)	1982 till 1990 (Quest Tafaj, UNEP 2002)	Chemical plant of HCH still stored there. (UNEP 2002)	700 t
Argentina			
(Alvarez, 1998, UNEP, 2002) HCH in the beginning only produced by 1 manufacturer. Later by at least 3 other manufacturers Lindane production only by 1 manufacturer	1947 first time HCH was synthesised. 1949 : In 1949 one used HCH powders by at least 3 other manufacturers At least four companies produced HCB** although their production capacity are unknown. (Torres, 1999) It is not clear if HCB** is connected to HCH and Lindane production	1949 HCH: 15 000 tons of 10 and 20 % for "tucura" (??) and 20 000 tons of 20 % for locusts To exterminate the" tucura" and the locusts the use of HCH decreased substantially to values of 1967 for example of 4000 ton. of powders of 20 %. (Alvarez, N. 1998) Lindane production in 1956 was 20 t (conc. 100%) and decreased to 5 t (conc. 5%) and 30 t (conc. 2.4%) in 1967 (Alvarez, 1998)	??
Austria			
5 companies in total. 1 producer which became later formulator 4 formulators (Questionnaire, UBA, 2004)	Start of HCH production is unknown Producer 1: Lindane till 1965. After 1965 only formulator till 1990/ After 1965 5 formulators and no production Formulator 1: of PPPs until 1994, probably no export of formulated materials Formulator 2: of PPPs starting app. 1950 until 1980. Formulator 3: no info available Formulator 4**:** for three veterinary products on the Austrian market till present	For Austria summarized data: Lindane 1992-97: 61.9 t for Austrian market Lindane export 1991: 0.443 t Lindane export 1993: 8.087 t Estimate in 60s 300-500 t/y (anonymous 2005)	There are no registered Lindane con-taminated sites in Austria

Country/ Producers	**Production period**	**Production**	**HCH residuals (in tons)**
Australia			
(Chemlink Website)	Chemicals plant established in 1936. This plant was progressively expanded to produce chemicals derived from caustic soda and chlorine, including pesticide chlorohydrocarbons such as DDT and BHC, herbicide chemicals. At other site 2,4-D and 2,4,5-T These two herbicide chemicals, produced by chlorinating phenol, were produced through the 1970's Only **HCB**** at same site, from 60s till 1991 as by-product of chemical solvents and plastics (Botany website). Here HCB no relation with HCH!!!	Use Technical HCH: 3 700 t/y (Li 1999) "The information on actual volumes of BHC and Lindane produced in Australia is restricted and therefore not available".(Questionnaire, Dept of the Environment and Heritage, 2004) 10 500 t (**HCB**)**	
Azerbaijan			
See also Former Soviet Union 1 producer (Li et al, Okan, 2004)	HCH 1960 – 1985: In 1986 (?) replaced with Lindane production (Okan, 2004).	100-300 t/y Estimate 200 t/y	**Several thousands of tons of HCH were produced** (Okan, 2004)
Belgium			
(Stoffbericht, 1993, Questionnaire Leefmilieu, 2004)	Many small formulators Export Lindane 1977: prior 2003/yearly : prior 2000/yearly:	74 t to European Community Export to Nigeria : 100 000L of 200 g/l EC formulation on cocoa Export to USA/Canada: 60 000L of 500 g/l SC formulation Export to France: 15 000L of 200 g/l EC formulation	

Country/ Producers	**Production period**	**Production**	**HCH residuals (in tons)**
Brazil			
(UNEP, 2002)	1962-1985	98 583 t of total HCH Production/use 2 080 t/y (Li, 1999) in the 90s	Total estimate Brazil: with HCH contaminated soils **100 000 to 200 000 tons. A waste amount of at least 50 000 tons is estimated**
	Lindane is currently used for louse control and as a wood preservative in some countries (UNEP, 2002).	Imported ca 4200 t of the mixture in the same period (MDIC, 2002). 490 t of Lindane from 1996 to 2002 (MDIC, 2002) available stock estimated between 21 to 40 t (UNEP, 2002)	
Rio de Janeiro State: at a former production site (Lopez, 1999, Bastos, 1999, Österreicher in print)	1950-1955 Production and Deposition HCH-isomers 1960	12 tons	**33 000 t soil contaminated with HCH and 300 t HCH waste**
Sao Paulo State: 5 areas in total. 1. Production site M	1. production 1946-1986 (Cunha)	1. BHC 16% 400 t/month (Cunha) BHC 40% unknown	1. At M: 15 000 m2, max 8 m depth**.(est 30 000 m3) + ca 5 000 t HCH Waste**
2. Former HCH-formulation			2. plant **15 000 m2**
3. 3 smaller sites (Lopez, 1999)			3. 3 smaller sites: on one of the sites 122.49 tons pure HCH and soil removed
4. River/Stream	4. 1962 to 1985 (Rosetti, 1994)		4. During canalization works of Stream/river **18 000 m3 BHC waste have been excavated (**See also Annex IV)

Country/ Producers	Production period	Production	HCH residuals (in tons)
HCB Prod site (Torres, 1999) Brazil HCB Residuals (UNEP, 2002, Lopez, 1999) (deals with same site as above) Rio Grande do Sul State, former pesticides formulation site (Lopez, 1999)	**HCB**** is a good biomarker for exposure to the residues of this site. HCB is not usually found in Brazil. (Torres, 1999) Main environmental input of HCB occurs as a by-product in the industrial manufacturing of chlorinated solvents and some pesticides such as PCP. There are well known highly contaminated sites and stockpiles of **HCB**** in Brazil, that may be a significant environmental source (CETESB, 2001). At this site HCB probably generated from PCE production and burning of other chlorinated residues. In 1965, Brazil imported 834 tons of **HCB**** (MDIC, 2002).	*11 000 m3 waste disposed*	According to CSD-Geoklock studies, there are still 238,6 tons of residues impregnated to the soil in a region; a water-contaminated plume has around 9,4 hectares, and a volume of 142 000 m^3 and a total of 104,2 Kg of organochlorine. [31] (Torres, 1999) **20 000 m3 (30 000 t)** from sources
Bulgaria			
(Hauzenberger, 2004)	19xx to 1966		
Canada			
(CEC, 2000) NRTEE, 2000	manufacturer voluntarily discontinued the production of this compound in 1984??. 1972 Manufacturer voluntarily discontinues production of technical HCH in Canada and the United States.	Information could not be traced by Canadian authorities	

Country/ Producers	Production period	Production	HCH residuals (in tons)
Chili			
1 plant could be possible but no concrete information	The presence of alpha-HCH could either be due to releases from the manufacturing of technical HCH or Lindane, or to the use of technical HCH as an insecticide. (Greenpeace 2000)		
China			
(Li, 2001) 1 producer in China (pers Communication Li, 2004) (UNEP, 2002)	1952-1984 technical HCH 1991-2000: Lindane 1 producer: 1995-2000: 1000 t /y(Li, 2004)	Technical HCH: 4.500.000 t only used in China, no export Lindane: 11400 t Export Lindane: 8 200 t (Li, 2001) Technical HCH: 4.900.000 t	No information Based on Lindane production **91 200 t of HCH** residuals expected
Czech Republic			
1 manufacturer in present Czech Republic and 1 in present Slovakia (Former Czecho-slovakia), see also under Slovakia	1954-April 1977 1958-1977	HCH: more than 60 000 tons technical HCH (Hauzenberger 2004) Lindane production: 3 330 t (Holoubek et al, 2004)	Although at 1 factory HCH has been used for the production of TCB, still large amounts of HCH residuals ex-pected to be around. 55 000 t HCB** deposited in a large chemical landfill (anonymous) Eventually there is a link between Lindane and HCB production
Croatia			
4 manufacturers. It is not certain if all 4 have been producing		Approx. 7 t Lindane produced/year (UNECE, 2000).	

Country/ Producers	Production period	Production	HCH residuals (in tons)
Denmark			
(De Bruin, 1997)	Lindane export 9 t in 1997 HCH never been produced in DK 6 companies hold registrations for Lindane containing products, but it is not known how many formulate these products (Miljøstyrelsen, 1990)		
Egypt			
(Li, 1999)			
FYR Macedonia			
(Hadzi-Panzov, 2001)	1964-1977		3 000 t Delta-HCH 30-35 000 t Alpha/Beta-HCH total: **33-38 000 t HCH-isomers** also outside factory wild dumps of HCH-isomers found (anonymous)
France			
	For year 1977 (Heinisch, 1994)	Technical HCH: 28 000 t Lindane: 3 000 t	The amounts of HCH residuals **expected are hugh**, in spite of the enormous gap of information. On the basis of only a part of the sites around **260 000** tons have been located. It is **estimated that around 500 000 tons are present**
	For year 1979 (De Bruin, 1979)	Technical HCH: 27 000 t Lindane: 3 000 t	
	No total overview available but collection of scattered waste issues:		**Tens of thousands** HCH-residuals deposited. Except 1 factory in Northern France HCH brought to incineration plant.(anonym) Reported dumps with HCH from 2 factories have been brought there (Anonym)

Country/ Producers	Production period	Production	HCH residuals (in tons)
France (continued)			
Fr-1	Early fifties 1972 restrictions on HCH use from 1972 only Lindane (Goubier, 1992) In 1979: technical HCH with tank cars transported ca 150 km to next plant where HCH is processed into Lindane, TCB and HCl (De Bruin, 1979)	1972-1984: 1 800 t/a Lindane Plant cap 1990: 36 000 t/y HCH Lindane: 4 000 t/y TCB: 16 400 t/y HCl: 12 000 t/y	
Fr-2	between 1950 and 1970		HCH deposits in 7 sites and 4 are currently groundwater monitored (anonym-1) 800 t over area of 300m2 (Depêche, 16/02/2004) and groundwater contamination **Fr-2: 700 t** HCH production residues (powder) surface area 3 000 m2
Fr-3			**Fr-3:** 95 400 t HCH production residues (powder) mixed with other wastes and contaminated soils surface area 10 600 m2 +38 420 t HCH production residues (powder and concrete) surface area 4500 m2→ **total 128 820 t**
Fr-4			**Fr-4: 112 000 t** HCH production residues (powder + contaminated soils) surface area 17 000 m2
Fr-5	Former industry where Lindane was produced.		Residues have been burned in 1986
Fr-6	HCH production	HCH residuals stored in concrete and soils around polluted	
Fr-7	1943 till 1960		
Fr-8 (Stoffbericht,1993)	1980 produced Lindane		**500 t** moved to Northern France for destruction in 80s) (anonym)
Fr-9 (Anonym)	No data		

Country/ Producers	**Production period**	**Production**	**HCH residuals (in tons)**
Germany (former East +West Germany)			
Eastern Germany			
(Heinisch, 1994)	1967-1982: Until 1967 unknown	Lindane: 12000 t	***Estimated total HCH-isomers:*** ***236 000-246 000 t***
(Heinisch, 1992, Heinisch 1994, Johne, 2001) (Heinisch 1994)	1977 1982	Technical HCH: 5 225 t/y Lindane: 733,5 t/y Technical HCH: 2 110 t/y Lindane: 150,7 t/y	Riverbasin 2000 ha, from which 500 dangerously contaminated
EG-1 (Heinisch, 1994) Anonymous, 1990)	1951-1972 1957-1989 Data are incomplete!!	Technical HCH: 25 759 t Enriched HCH 1 227 t Lindane 4 618 t	From calculation of production numbers **ca 36 000 t** and 17 000 t solvents were estimated. Part of HCH brought to TCB plant till market prices fell then stopped and HCH deposited. All waste deposited at landfillsite **82 000 m2** contaminated by HCH-isomers. Production areas 37 000m2 and 45 000m2 infiltration ponds Also additional deposition at a Landfill site
Eastern Germany continued			
EG-2 (Heinisch, 1994), (STUA, 2004)	1950- end of 1977: mostly HCH only 1959-1976: 1977: Until 1959: After 1959 technical HCH was produced and brought to a neighboring factory for the production of Lindane	HCH 31 000 t (Heinisch, 1994) 2 500-3 500 t/y 657 t Lindane only in trials produced ca 100 kg/y? Calculation of STUA numbers would lead to ca 55 000 t HCH produced!	No pure residuals, but only soil and groundwater contamination see Annex IV
EG-3 (Wallbaum, 1993, Heinisch, 1994)		Total HCH for EG-3: 93 000 t	
EG-3	1955-1967:	HCH estimate 1959-1967: 20 000 t (no exact data)	
EG-3	1967-1982	HCH: 73 000 t	
EG-3	1951 start up	Lindane: 50 t (anonymous, 2005)	**100 000 t residuals still on site**

Country/ Producers	Production period	Production	HCH residuals (in tons)
	1955-1967 1967-1982 1982 stop	Lindane: no data Lindane: : 5400 t Lindane: 450 t/y	(anonymous)
Landfill site (Wallbaum, 1993, Heinisch, 1994) EG- 4 (Wallbaum, 1993, Heinisch, 1994)	1955-1976 HCH: 34 552 1955-1981 Lindane: 8 110 bought ca 35 000 t Tech grade HCH from mainly EG-3, but also USSR +Romania		**70 000 - 80 000 t from EG-3** 76 000 (Johne, 2001) (only 40 000 acc to anonymous, 2005) 1995-1981: **60 000 t dumped** in quarries
West Germany			
	For year 1977 (Heinisch, 1994)	Technical HCH: 15 000 t Lindane: 1 500 t	**Estimate total HCH-isomers: 127 400 – 137 400 t**
	For year 1979 (De Bruin, 1979)	Technical HCH: 15 300 t Lindane: 1700 t	100 000
	For year 1983 (Stoffbericht, 1993)	Technical HCH: 12 000 t Lindane: 1 500 t	
WG-1	Discontinued operations many years ago (De Bruin, 1979)		In large waste disposal ca **5 000 t** HCH waste
WG-2			Estimate **30-40 000 t**
WG-3	1955-1971 Discontinued 1972 (De Bruin, 1979)	Total Lindane production: 16 000 t (ca 1 000 t/y) Total Residuals 125 000 t: -86 400 t on site deposit -8 000 t parking area -30 400 t used for production of TCB + HCl -10 000 t to waste landfill sites Deposition was performed acc to official permits of the local government	**92 400 ton**
WG-4	1951-1968:	Before final closure 1968 Lindane production: 60-80 t/month (720-960 t/y). In peak years 1 200 t/y A total of 40 000 t HCH isomers were used for the production of TCB and Trichlorphe-	(De Bruin, 1979) All residuals eliminated

Country/ Producers	Production period	Production	HCH residuals (in tons)
		nol (anonymous). With a production of 6-8 t/d all residuals were eliminated from 1967-1972	
WG-5	1949 – 1954		400 t of HCH-residuals
WG-6		Area used by production used as waste disposal site	Large-scale contamination of a small stream and several areas. 1588 tons of contaminated soils
Ghana			
	Ghana established a plant to formulate Lindane in the 1950s The plant formulates Lindane into the product Gammalin (PAN-UK).	Estimated annual production 9 m3 (UNEP, 2002)	
Hungary			
1 manufacturer (Bárczi, 1994)	1953-1964 only technical HCH no waste product (Bárczi, 1994) Although Lindane has been produced, it seems that this production has now been stopped (De Bruin, 1979)	1950-70: tech HCH: 6 955 t 1969-2000: Lindane: 14 285 t (active ingredients imported from former GDR, Fr, Japan), (Central Service for Plant Protection and Soil Conservation (CSPPSC, 2004) Total produced HCH (1953-1964) active ingredient 10 000 t. Rest of amount was sold until end of 1966.(Barczi, 1994)	No residuals (Bárczi, 1994, CSPPSC, 2004) This conflicts with the reference of De Bruin, referring to Lindane!
India			
(International Atomic Energy Agency, 1988) Producers: BHC was produced by 4 manufacturers (Benzene Hexa chloride, no date)	Total consumption of technical-grade HCH in India in 1986-87 I-1. has decommissioned it's BHC plant some years ago. I-3 was the other important producer of BHC which after the ban been planning to diversify into the production of other pesticides. The company produces BHC in water dispersable form for the National Malaria Eradication Programme(NMEP) under the aegis of the Ministry of Health.	Ca. 27 000 tons in 1986	It is **expected that large** amounts of HCH-residuals are present in India. Roughly calculated that about 6 200 tons of Lindane have been produced, which would bring around **49 000 tons of HCH residuals.** Taking into account that one of the manufacturers has encapsulated around 3 000 tons, that would leave about 46 000 tons for the remaining residuals, if not being treated as described in Annex I.

Country/ Producers	Production period	Production	HCH residuals (in tons)
(UNEP 2002) 1 manufacturer	1995-2000: manufacturing Info on HCB**: 1995-1997: 1970-1992 imported by Pakistan used by Pakistan (Jones, 2005)	Technical grade Lindane: ca 4 462 MT 42 612 MT (tech grade HCB**) ca 15 390 MT (tech grade HCB**) 12 162 MT	
Fact Sheet, 2005 (Source: Dept. of Chemicals and Petrochemicals, Ministry of Chemicals)		Lindane production: 1995-1996: 700 t 1996-1997: 800 t 1997-1998: 800 t 1998-1999: 900 t 1999-2000: 1107 t 2000-2001: 484 t (Jensen : 619 t for 1 manufacturer) 2001-2002: 266 t (Jensen: 520 t for 1 manufacturer) 2002-2003: 331 t 2003-2004: NA 2004-2005: NA (Apr-Sept.) Total 1995-2002: 5387 t	
I-2 (Jensen, 2004)	Was the largest producer of BHC in India and production level was reported to be around 16,000 tonnes per annum. Made BHC from 1971 -1996 (officially banned) they still use the BHC plant as a precursor to make Lindane. Lindane production started 1990-1991 till 2003. No prod Lindane for first 9 months of 2004. Lindane production cap of 3 t /day. However, only produce 300 kg/day for 6 months/year, because production is demand driven. Plant runs now at 5% of its capacity	2000: Lindane production 619 t 2001; Lindane production 520 t (Chemical Purchase, 2001)	ca. 3 000 MT
Fact Sheet, 2005			In 2003 under CPB's guidance 33 256 MT of muck out of 44929 MT was "encapsulated" by the company

Country/ Producers	Production period	Production	HCH residuals (in tons)
			Estimated amount of HCH: 43096 tons
I-3 I-4 I-5(Greenpeace, 2002) I-6 (Jensen,2004), Rup Lal* et al, 2005) Fact Sheet 2005	In 1971, a plant was put up for the manufacture of BHC with a capacity of 3 000 MT/a to meet the requirement of agriculture and public health. The Govt. has imposed a ban on the production of BHC in the country. Hence, the company has stopped the operation of BHC Plant from 01.04.1997 (Department of Chemicals & Petrochemicals, India no date) Started BHC production 1955/56 Indian Officials were not sure if at this facility Lindane still would be produced Later it was confirmed that Lindane has been produced Established in 1992 with a production capacity of 300 MT/y. Uses at present its full production capacity	Lindane production India: 1998-1999: 900 t/y Storage of MIC and BHC at "BHC store" (BHC not produced here but imported) and BHC soil contamination Total ca 100 t. Probably also former BHC production???	First estimate **10 000 – 15 000 t**
Israel			
(Lindane, 2001)			
Italy			
At the beginning of the 50s 1 producer was producing HCH and later started also a Lindane production (Anonymous, 2004) Several producers Anonym) (North American Commission for Environmental Cooperation, 2000)	Lindane production. Italian Export in 1977: 10t /y. Italy has been one the largest European users of Lindane (see under 6.5)	No data	At one of the plants large amounts of HCH-residuals have been witnessed. Several thousand tons expected

Country/ Producers	**Production period**	**Production**	**HCH residuals (in tons)**
Japan			
(UNEP, 2002) (Questionnaire Ministry of Agriculture, Oct 2004)	1948-1987: 1958- 1972 Rest 1948-1957 1958-70:	HCH: 389 000 t HCH: 313 200 t HCH: 75 800 t Lindane: 9 532 t	No information **If no re-use of HCH-residuals has taken place one should reckon with at least 76 000 t or more**
Korea			
India imported 11 t of lindane from Korea in 1996-97 (Fact Sheet, 2005)	No further information obtained		
Mexico			
(Stoffbericht, 1993) 1 manufacturer BHC Mexico produces and manufactures Lindane, and imports Technical HCH [obtained from Dr. Victor Hugo Borja, Director, *Centro Nacional de Salud Ambiental*, January 2000], CEC, 2000)		Production/use: 1 740 t/y (Li, 1999) in 90s	
Nigeria			
(UNEP, 2002) 1 formulation plant Lindane		Lindane production: data gap	
Pakistan			
(UNEP/FAO/WHO,2001) 1 manufacturer of BHC. Lindane was never produced (Quest Jan 2005, Qadir) (UNEP, 2002)	In 1985, 65 mt of active ingredient of BHC was produced and the manufacturing capacity 1 320 mt 1970-1992: HCB** was imported by Pakistan HCB** was used by Pakistan (see also India)	HCB** 15 390 MT HCB** 12 162 MT	Stocks BHC(Punjab): 42.8 t Stocks BHC(Sindh): 240 t
Philippines			
Possibly 2 or 3 Pesticides formulators			

Country/ Producers	Production period	Production	HCH residuals (in tons)
Poland			
1 manufacturer (Questionnaire Sept 2004, Heinisch 1994) Persistent Organic Pollutants in Poland, Krakow, 2001	1956-1968 Lindane 3 900 t Official comp: 1965-82: 4 450 t Lindane (Questionnaire)		Estimate 35 000 t (info from questionnaire) (But at 6th Forum in 2001 100-140 000 t. It may be that the large amount relates to mix of soil and waste and not to pure HCH)
Romania			
2 manufacturers	Although no data were submitted from Romania and the Russian Federation, there is evidence that Romania still produces Lindane. (Nafta, 2003, Hauzenberger, April, 2004)		
Ro-1 (anonymous)	It is not certain if Romania has still a very small production or has stopped the Lindane production, but certain is that the producer still sells either from its present left-over stock or from still ongo-ing small production		**250 000 t (anonymous, 2004)**
Ro-2 (Draft NIP, Romania, 2004)	Factory has been closed		**60 000 t (draft NIP, 2004)**
(Former) Soviet Union			
(Li et al., 2005)	1950 – 1990	Total use technical HCH: 1 960 000 t in FSU (Li et al., 2005)	For every 100 t of γ-HCH used in the FSU, there were 723 t of technical HCH containing isomers (Li et al., 2005)
	1950-90	Use Lindane: 40 000 t (Li, 2005)	
	In 1980	Usage of technical HCH: approx 53 580 t	
	In 1985	40 800 t (estimate)	
	1984 (Heinisch, 1994)	Technical HCH: 20 000 t Lindane: 2 000 t	
	In 1980	HCH isomers used totalled 14 229 t/y	
	During the 1990s	Increased up to 21 284 t. (Zhulidov, 2000)	

Country/ Producers	**Production period**	**Production**	**HCH residuals (in tons)**
(Pokarzherski, 1994) 3 basic plants at: (Li et al., 2005)	1965-1985 Approximately between 1978 and 1988, from 500 to 1 000 t of Lindane were imported for the plants annually. Lindane itself was never produced in the former SU (Treger, 12 Oct 2004)	5 000-3 000 t/y over the years decreasing (Pokarzherski, 1994) produced HCH grades that contained 12%, 25% and 90% γ-HCH.	
(Former) Soviet Union continued			
-FSU-1 (Treger, 12 Oct 2004)	1960 – 1987 1968-1971	Capacity: 1 000 t/y (gamma-isomer) Lindane production and industrial process-ing of isomers took place: -ca 1 000 t/y of purified TCB was produced -ca 1 000 t/y HCB -ca 2 400 t/y pentachlorophenolate This production was used for more than 15 years till end of 80s. Then all facilities were closed down (Treger, 12 Oct 2004)	
-FSU-2	Produced HCH grades containing 12% and 25% γ-HCH. Preparations of various commercial pesticides were produced on the basis of HCH transported from elsewhere (Treger, 12 Oct 2004).		
FSU-3, now **Ukraine**	This plant produced HCH containing 16% γ-HCH.		
HCH also made in significant quantities at: FSU-4 (Treger, 12 Oct 2004)	1948 – 1980	Capacity: about 10 000 t/y (technical grade product) under commercial product “DUST” (about 12% powder).	
FSU-5, now in **Azerbaijan** (Treger, 12 Oct 2004)	1960 – 1985	Capacity: about 30 000 t/y (technical grade product) under commercial product “DUST” (about 12% powder).	
HCH stocks in Russia			800 -1 000 t obsolete stocks HCH acc to

Country/ Producers	**Production period**	**Production**	**HCH residuals (in tons)**
(Treger, 14 Oct 2004)			experts
Chemicals plant in Ukraine	At chemicals plant of Kalush 11 000 t of **HCB**** as by-product of PVC production (SBC, 2004)		
Slovakia			
S-1 (Holoubek et al, 2004). See also under Czech Republic	1956-1966: total Lindane production of 3 330 tonnes (correspondence with Holoubek, January 2005)		No information **If no re-use of HCH-residuals has taken place one should reckon with at least 26 000 t or more**
Serbia & Montenegro			
	Several factories, but HCH and Lindane not confirmed		
South Africa			
SA-1 (UNEP, 2002)		Lindane: 55 tons/year	**70 000 t (UNEP, 2002)**
Spain			
2 Lindane factories (De Bruin, 1979). This information is incorrect. There were at least 4 factories	For year 1975(Ministerio de Industria y Energia) For year 1979 (De Bruin, 1979) 1984 (Heinisch, 1994):	HCH: 1 638 t Lindane: 219 t Lindane: 1 000 t/y Technical HCH: 10 000 t Lindane: 1 000 t	**Ca. 200 000**
SP-1 + SP-2 (Azkona, 1993;Barquín, 2001; Quintana 1997)	1947-1987 (Barquín, 1999)		**82 000 t of pure HCH but only 3 500 tons pure left rest spread and mixed with soil**
SP-1	1944-1953 Technical HCH, 1953-1987 Lindane	82 000 t HCH residuals generated. 5 000 t brought by Bilbao Chemicals from another factory ii Aragon were dumped illegally	3 500 tons pure HCH Other **77 000 t HCH residuals spread** and mixed with soil, which has lead to 500 000-1Mio t of contaminated soils.
SP-2	30 years- what years?? 1966-1986??		14 000 t from which 7 000 t to Catalonia for HCB production 7000 dumped around factory 1966-1986
SP-3 (Aragon, 2004)	6 200 t/y HCH 800 t/y Lindane (anonymous, 1990)		At one location ca 25 000 t and at the other location 90 000 t have been dumped. In total ca**. 115 000 t**
SP-4 (Crespo González, 2001)	50's-60s. Closure mid 60s		**1 000 t** mixed and dispersed, polluted area 90 000 m2

Country/ Producers	Production period	Production	HCH residuals (in tons)
Switzerland			
SW-1 (Bentz, 2004)	From 1935 to 1965 agrochemical products, like Arsenic-, Copper- and Lead-compounds and also 2,4-Dinitro-o-cresol (DNOC) and Lindane (HCH) were produced.		Around 10 000 m3 contaminated soils, from which 100 t pure HCH
Taiwan			
The Netherlands			
	Use of Lindane: 1985: 29 t 1988: 24.3 t 1991: 21 t 1994: 19 t 1998: 21.164 t		**350 000 t of contaminated soil**
N-1 around former production site (Grinwis et al., 1993)	1948-1952 tech HCH, 1950-Lindane	150 000 m3 soil cont with HCH	
Till now, a list of around 290 suspected sites has been compiled (VROM Press Release, 20.02.04)	At present court case pending since many years of National Lawyer against buyer of former production plant.	In 1954, former producer sold its plant to its 'neighbour' N-1. At that time, at least 5.500 tonnes of HCH were being stored on the company's premises. In 1956, N-1 sold 1 500 tonnes of HCH to N-4 for reprocessing. The remainder 4 000 t of the mountain of HCH waste was transported in some 22 500 drums to Germany in 1975.(VROM Press Release, 20.02.04) Remaining problem of 200 000 t lower contaminated soils in the region	
N-1 at former production site	Soil and groundwater contaminations		
N-2 (Grinwis, 1993)			**25 200 t of with HCH contaminated soil**
N-3 Former plant	1947-1949		**11 600 tons of soils heavily to light contaminated and also large surrounding groundwater contamination**
N-4	Technical HCH from 1947 onwards and discontinued before 1980. Lindane production never took	Inactive isomers were dumped on the site, located along the North Sea Canal. Later	1 500 t HCH from N-1 was stored on the site for many years

Country/ Producers	Production period	Production	HCH residuals (in tons)
	off.	when this canal was widened, the soil was removed in its entirety and dumped into an ocean trough (anonymous, 1990)	
N-5			Duirng the 80s with HCH contaminated soils have been partially remediated (Anon)
Turkey			
5 manufacturers (Türkman et al., 1993) Only 1 producer and the other 4 have been formulators only Due to legislation introduced in Turkey banning the use of these products various units of the plants were eventually closed down. (Greenpeace, 5 April 2000)	Most production of Lindane till 1982: After 1985-ban, most stopped. (Türkman et al., 1993) In 1997, France imported 500 t of HCH from Turkey (De Bruin, 1997) 1977: HCH production 2000 t/y (Rippen, 2004) In 1963 was started to produce chlorine, caustic soda, DDT, BHC (Lindane), hydrochloric acid, sulphuric acid and sodium hypochloride.	Total Lindane consumption: 1982: 200 t/y 1983: 199 t/y 1984: 1053 t/y 1985: 1458 t/y 1986: 40t/y (Türkman et al., 1993) 1977 : Lindane production : 100 t/y	It is known that some 3 000 tonnes of HCH residues (by products of Lindane production) are stored in a warehouse in a plot. It is not clear who is currently responsible for the wastes since the company has since gone bankrupt. (Greenpeace) Since June 1985, **3 000 tons** of 2-3 gamma BHC waste was stored next to the plant. It is estimated that the Turkish problem is much bigger. Only the lindane use in the last 5 years before stop of own production 2950 tons of lindane can be traced corresponding with around **23 500 tons of HCH,** from which only 3000 are known till now.
United Kingdom			
UK, like France on of the "parent countries" of BHC has also made considerable use of this material, but abandoned technical BHC …..sooner than France and changed to other materials including Lindane (Ulmann, 1976/77) About 36 t of Lindane were released into the air in the UK in 1998, of which some 29 t came from timber treatment of evaporation	1974 (Stoffbericht 1993)	Lindane: 1 200 t	??

Country/ Producers	Production period	Production	HCH residuals (in tons)
from treated wood. A further 6 t came from agricultural uses and the remaining 1 t from, domestic use (WWF Detox Campaign)			
(Swannell, 1993) at least 1 manufacturer (IPCS, INCHEM home)		Production stopped in 1983	
USA			
In the US and Canada BHC and Lindane have never had the same prominence as in some of the European countries and Japan (Ulmann, 1976/77). (Stoffbericht, 1993) (IPCS, INCHEM, FAO/PL: 1967) (Stoffbericht, 1993) (Fitz, 1999) 4 manufacturers (SRI 1987, 1988); Superfund sites: have been investigated. See below US-1 (Weston, 1993)	1963 1963 For year 1976 Produced 1950s-1970s In 1978 the US EPA set an end to the production of technical HCH 1946 – 1958: Lindane production	Technical HCH: 3 100 t 3 060 tons (including 720 tons of Lindane). Technical HCH: 500-2 000 t Manufacturing of 28 million pounds of Lin-dane. Approx. 100 million pounds of alpha BHC and 9 million pounds of beta BHC were likely produced as waste. The BHC cake at the time of the disposal was a solid that was not containerised. Stockpiling at 3 locations. Later between 1974 and 76 cake was move to one site only. Between 1978 and 79 the remaining BHC cake pile was closed by filling to grade with sludges removed from waste Water	**50 000 tons (200 000 cubic yards)**

Country/ Producers	**Production period**	**Production**	**HCH residuals (in tons)**
		Pond 1 during construction of CAPD 7 and capping with a clay cover. This capped area is approx. 250 ft by 450 ft.	
US-2 (The Miami Herald, January 7, 2004)	In 1952 the BHC production was started Lindane production was halted in 1966. A $100 million settlement has been reached in a lawsuit over massive contamination from a nearby pesticide manufacturing plant. The pesticides DDT and Lindane were formerly manufactured. Lindane was produced ……..for approximately 20 years prior to 1966 (Havlicek et al, 1998)		**Massive contamination** the settlement calls for extensive remediation that alone will cost a projected $45 million. The cleanup is expected to begin this year and take five to seven years to complete About **500 000 cubic yards of sediment** will have to be removed as part of the remediation. Sediment also will be removed from the county ditch.
USA continued			
US-3 US-4	Start production during 50s 1954-1957 BHC research and production 1957-1963 high production plant for gamma/BHC (Lindane) Experiments to make alpha residuals marketable (anonymous) US-4 manufactured the technical grade of the pesticide DDT (dichloro-diphenyl-trichloroethane) from 1947 until 1982 at a plant	Production data not known Production data not known	
US-5 (EPA Superfund, 1992)	At the US-5 plant, technical BHC was produced between 1947 and 1955. Also, for a one-year period during this time interval, DDT was produced at the plant (production ceased in the early 1950s). BHC filter cake residuals containing lindane and waste sulfuric acid containing DDT were disposed on the Site. (1947-1959 production of various organic and inorganic products).	Production data missing	Summary: For a 30-year period ending in the 1950's, US-5 dumped approximately **400 tons of powdered Lindane** in the area (Review 1980).

Country/ Producers	**Production period**	**Production**	**HCH residuals (in tons)**
USA continued			
US-6 (Love Canal, 1981)	1942-1953	Production data missing	"In all, US-6 dumped 22 000 tons of industrial wastes which included pesticides such as Lindane and DDT, multiple solvents, PCB's, dioxin, and heavy metals. Once the metal drums that housed the wastes filled the canal, a layer of loose soil was used to cover the site (Case Studies). **6 900 tons (solid) Lindane/BHC were disposed of solid in drum and nonmetallic containers** The larger portion of the landfill was operated from 1943 until 1971, when about 23 500 tons of mixed organic solvents, organic and inorganic phosphates, and related chemicals were deposited at the landfill. Brine sludge, fly ash, electrochemical cell parts and related equipment, **and 300 tons of HCH process cake, including Lindane, were deposited at the site.** The smaller portion of the site operated as a landfill from 1948 to about 1970, during which time 66 000 tons of mixed organic and inorganic chemicals were deposited.
USA continued			
US-7 (EPA Superfund ROD, 030/091991)	Early 1950s. Disposal areas are primarily contaminated with DDT and its metabolites DDD and DDE; BHC and its isomers alpha, beta, delta and gamma BHC, and chlorobenzenes	No Production data missing	<u>Area 9 (BHC burial area):</u> Chemical material burial covered with clay fill. The area contains bulk pesticide by-products, predominantly isomers of BHC, and residues. Estimated volume of contamination in area 9 is

Country/ Producers	Production period	Production	HCH residuals (in tons)
			32 100 cubic yards (ca. 8 000 tons). Further several area with disposal the waste comprising of pesticide residues, by-products, and intermediates from pesticides manufacturing.
US-8 US-9:(Hoff, R., L. Harris, 1990)	1951-1986 pesticides manufacturing incl. chlordane, alpha-, beta- and gamma BHC and toxaphene From 1958 to 1970, US-9 produced insecticides, fungicides, rodenticides, and herbicides, including 2,4,5-trichlorophenoxy-acetic acid (2,4,5-T), noted for being contaminated with dioxins and related compounds.	Production data missing	So far only minor parts on BHC, main contaminants DDT and Toxaphene. Pesticides were measured at high concentrations in sediment on site particularly for a-BHC (BHC 590 mg/kg), dieldrin, and DDT, but sediment cores were lower off-site. Pesticide concentrations were also high in soil on the site (alpha BHC 45 000 mg/kg and gamma BHC 23 000 mg/kg, alpha but lower in off-site soil.
USA continued			
US-10 (US EPA, Five Year Review, 2003)	The Site operated as a pesticide blending and formulation facility by various operators from approximately 1947 to 1967, and by retail distributors of agricultural chemicals from 1967 until 1989. The pesticides DDT, toxaphene, and BHC were received in bulk at the Site, blended with clay and other inert materials, repackaged, and sold. (US EPA, Five Year Review, 2003)	Pesticides were not manufactured at the Site but were formulated by dry mixing into a product suitable for local consumer use	**10 235 tons of contaminated soils and debris** with main contaminants aldrin, BHC isomers, dieldrin, endrin, toxaphene, DDD, DDE, DDT and chlordane isomers The previous owners took action to removed approximately 3 300 tons of contaminated soil and debris, and EPA removed approximately 6 935 tons of soil and debris. The contaminants of concern are; aldrin, BHC isomers, dieldrin, endrin, toxaphene, DDD, DDE, DDT

Country/ Producers	Production period	Production	HCH residuals (in tons)
			and chlordane isomers
Venezuela			
Zimbabwe			
1 Formulation plant (UNEP, 2002)		Lindane production: 2.5 tons/year	Datagap

Estimates for world		
Global use **(Li, 1999)** **(Li, 2001)**	Technical HCH: 1952 to 1984 Lindane between 1991 and 2000	Global total production technical HCH: ca 4 million t 11 400 t per year
World production (anonymous 1990*)	1990: World-wide	Total Lindane prod: 4 500 t/y Total Technical HCH prod: 20-30 000 t/y for direct use only produced for use by India
World production (anonymous 1990*)	1990: only 3 main producers left. France: (anonymous 1990*)	 Technical HCH: 25-30 000 t/y solely for production of Lindane Lindane: 3 200 t/y
World production (anonymous 1990*)	1990, China:	Technical HCH: 7 700 t/y solely for Lindane production. Lindane: 1 000 t /y
World production (anonymous 1990*)	1990, India	Technical HCH 32 000 t/y. Here only 300 t/y for Lindane production. Rest for other purposes.
Production world-wide Lindane (OSPAR, 2002)	for 1986	Approx. 38 000 t
World Production Lindane (OSPAR, 2002)	1988-1993	4 400 t/y
World Production Lindane (OSPAR, 2002) (OSPAR, 2002)	1990-1995	3 222 t/y
Production Lindane in Western Europe (OSPAR, 2002)	in the 90s	Approx. 2 055 t/y
Production Lindane in the EEC (Rippen, 1990, 2000)	1991	1 000 – 5 000 t/y
IPCS, INCHEM, FAO/PL: 1967	1963: World wide use estimated by industry (Cela, private communication).	Technical HCH: 60 000-70 000 t Lindane: 5 000-6 000 t

NOTES:
*Acc. to Anonymous 1990, is the large portion of technical HCH in India in sofar relevant for the situation in EC that Lindane and the other isomers of HCH can evaporate and enter the atmosphere – in particular Alpha isomer. Air masses are constantly circling the earth and in this way some of the alpha-HCH brought into the environment by its extensive application in India (between 20 000 and 30 000 tons/y may find its way into the EC, where some of it may be deposited.

**HCB information has been included in several cases, as in various cases HCB has been related to the HCH-production

Annex IV: Global Lindane usage

Annex IV: Global Lindane usage

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Abstract

Historical usage of lindane worldwide has been investigated from different sources. Global lindane use for agricultural purpose between 1950 and 2000 is estimated to be 450 kt, among which 280 kt was used in Europe, 73 kt in Asian, 64 kt in America, 29 kt in Africa, and 1 kt in Oceania countries. Although lindane use in most Europe countries are stopped, the historical lindane use from 1950 to 2000 in Europe reached approximately 63% of the total global use. Global lindane usage was highest in the 1960s and the beginning of 1970.

Keywords: Organochlorine pesticides; HCH; Lindane, Global, Inventory

1. Introduction

Technical hexachlorocyclohexane (HCH) and lindane are two formulations of HCH, an organochlorine insecticide. While lindane consists almost entirely of γ-HCH, the insecticidal form, technical HCH contains a total of eight HCH isomers, among which only the α, β, γ, δ and ε isomers are stable and commonly identified. Generally, technical HCH contains the isomers in the following percentages: α, 60-70%; β, 5-12%; γ, 10-12%; δ, 6-10%; and ε, 3-4% (Kutz et al., 1991; Iwata et al., 1993).

Several international agreements have been reached to reduce future environmental burdens of those persistent organochlorine pollutants (POPs) and heavy metals. One such agreement is the 1998 Aarhus Protocol on POPs under the 1979 Geneva Convention on Long-range Transboundary Air Pollution (LRTAP Convention) (UNECE, 1998). The overall and long-term goal of the Aarhus Protocol on POPs is to eliminate any discharges, emissions and losses of POPs to the environment. The Aarhus Protocol listed 16 POPs substances, 11 of which are organochlorine pesticides (OCPs), one of which is lindane.

Another recent international agreement is the Stockholm Convention on POPs which is aimed at eliminating or at least controlling 12 POPs (aldrin, chlordane, dieldrin, DDT, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, PCBs, dioxins and furans) (UNEP, 2002, 2003). Although lindane is not included in the list of 12 POPs in the Stockholm Convention on POPs, there has been a strong effort to include lindane in the POP's list in the future. In support of the Stockholm Convention on POPs, the United Nations Environment Program (UNEP) funded the development of regionally-based assessment reports for persistent toxic substances. Lindane and other HCH isomers were identified as priority persistent toxic substances for the Central and North East Asia region.

The objective of this work is to make a best estimate for the use of lindane globally. This task, however, is not easy to reach. First, many countries do not keep records or have no reporting mechanism for information of production, sales, and usage for some pesticides, including lindane, while in others information is proprietorial. The lack of disclosure has made our work very difficult. Secondly, the term of lindane has been used in the same way as γ-HCH, making some information of lindane very uncertain. We strongly suggest that 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. If technical HCH is used, all isomers, including α-, β-, and γ-HCH, should be considered. If lindane is used, however, only γ-HCH is taken into account (Li 1999).

2. Registration Status

Lindane, containing almost pure γ-HCH (the only insecticidally active isomer), replaced technical HCH in Canada, the United States and western Europe during the late 1970s - early 1980s and in China in 1991. Although lindane is still important on a global scale, many countries have restricted or eliminated its usage. Table 1 gives the registration status and usage for lindane in some countries.

Table 1: Lindane use regulation for some countries.

Country	**Action**	**Year**	**Restrictions / Remaining uses**
Argentina	severely restricted	1995	
Austria	Banned	1992	N. A
Bangladesh	Banned	1991	
Belgium	severely restricted	1989	Veterinary use and wood protection
Belize	severely restricted	1991	
Brazil	Banned	1992	
Bulgaria	Banned	1993	
Canada	Restricted		
China	severely restricted	1991	Use started in 1991
Cyprus	severely restricted	1987	Paints & wood protection; agricultural use banned
Czecho-slovakia	severely restricted	NA	NA
Denmark	Banned	1995	
E.C.	severely restricted	1978/1988	EEC Directive 79/117 on HCH containing less than 99% of the γ-HCH
Finland	Banned	1987	
France	Banned	1998	
Germany	Severely restricted Banned for pesticides applications	1988 2004	

Country	Action	Year	Restrictions / Remaining uses
Hungary	severely restricted	1968	Registered as grain treatment for winter wheat and nurseries
Iceland	Restricted use		Never registered as a pesticide
Italy	severely restricted	NA	NA
Netherlands	severely restricted	1991	Use for agricultural applications prohibited
Norway	Banned	1991	Lode et al. 1995
Poland	Phase-out	NA	
Portugal	Banned	1974	Ban on products using mixed isomers
Sweden	Banned	1989	
Switzerland	severely restricted	1986	Prohibition of sale of mixed isomers. Sale of γ-HCH for some applications
U.K.	Banned	1979	Sale of γ-HCH allowed
United States, Alaska	Banned	1983	Cancelled for most uses 1983
United States	Restricted		
Form. U.S.S.R	severely restricted	1988	Prohibited for use as pesticide
Russia			Tech. HCH probably still in use. Lindane still in use.

NA = No information Available

3. Global Lindane Usage

Around 10 Mt of technical HCH has been released to the environment between 1948 and 1997 (Li, 1999). The amount of global lindane usage has also been estimated by a few scientists. Voldner and Li (1995) gave worldwide lindane usage between 1948 and 1993 as 720 kt , and Sang et al. (1999) suggested the global consumption of lindane should be 6,000 kt, more than 8 times as that given by Voldner and Li (1995).

3.1 Lindane use in Europe

Breivik et al. (1999) give the total lindane application in Europe as 81 kt between 1970 and 1996, and 2.2 kt in 1996, which includes 6.5 t for the former Czechoslovakia and 115 t for the European part of the former Soviet Union (FSU), including Belarus, Estonia, Latvia, Lithuania, Moldova, Russia, and Ukraine. Figure 1 shows the annual use of lindane in Europe from 1970 to 1996 given by Breivik et al. (1999).

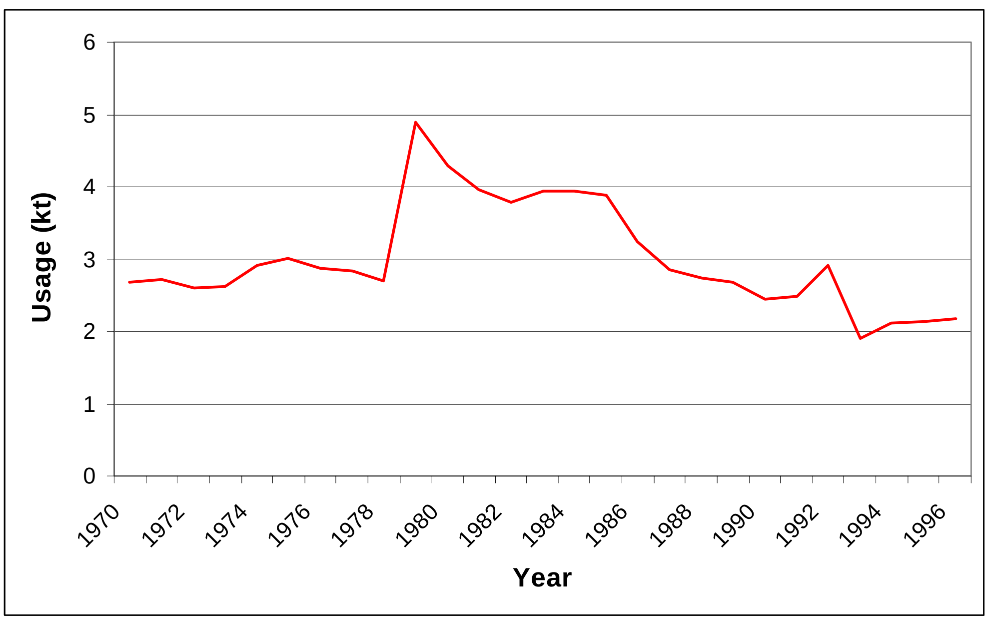


Figure 1. Annual use of lindane in Europe from 1970 to 1996 (estimated by Breivik et al. (1999)).

Recently, Li et al. (2005a) gave a new estimation of lindane use in FSU for agricultural from 1950 to 1990 as **40 kt**, and annual usage is shown in **Figure 2.** The usage (**25 kt**) in the European part of the FSU is also shown in the figure.

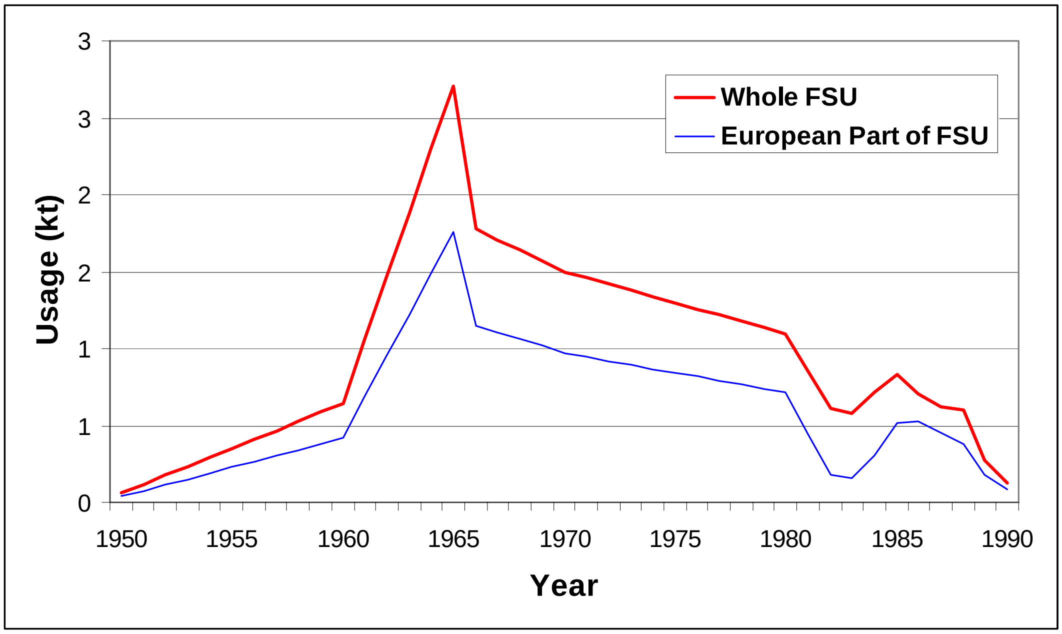


Figure 2. Annual lindane use in the whole FSU (the red line) and in the European part of FSU (the blue line) for agricultural purpose from 1950 to 1990. The total usage was 40 kt for whole FSU, and 25 kt for the European part of FSU (Li et al. 2005a).

In the former Czechoslovakia, **61.7** kt of lindane was used from 1963 to 1979 (see **Figure 3**, Holoubek et al., 2004).

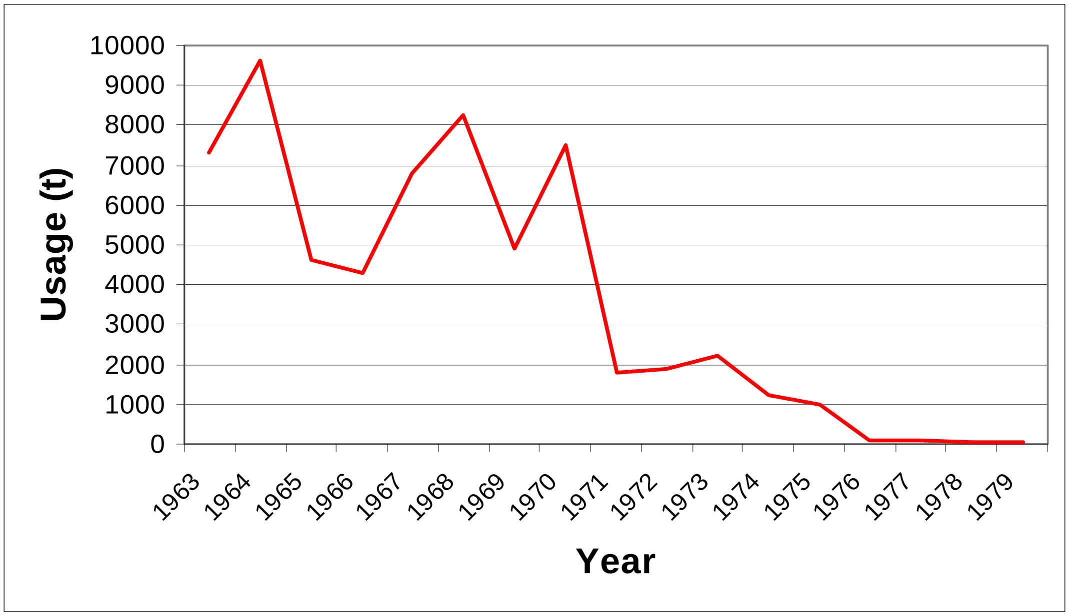


Figure 3. Annual lindane use in the Former Czechoslovakia from 1963 to 1979. The total usage was 61.7 kt (Holoubek et al., 2004).

The annual usage in Europe from 1950 to 2000 is shown in **Figure 4**. The total usage of lindane in Europe during 1950 to 2000 was **287 kt**, and the highest usage happened in the 1960s.

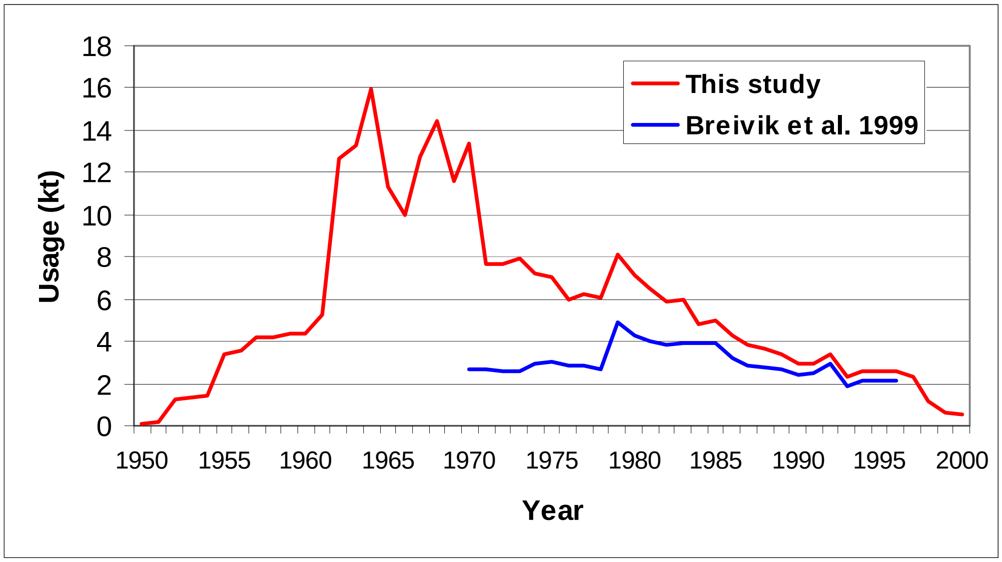


Figure 4. Annual lindane use in Europe from 1950 to 2000. The total usage was 287 kt. Data by Breivik et al. (1999) are also included here for comparison.

Figure 5 gives top 10 countries with highest lindane usage in Europe between 1950 and 2000. The total usage of these 10 countries was 210 kt, 96% of the total usage in Europe.

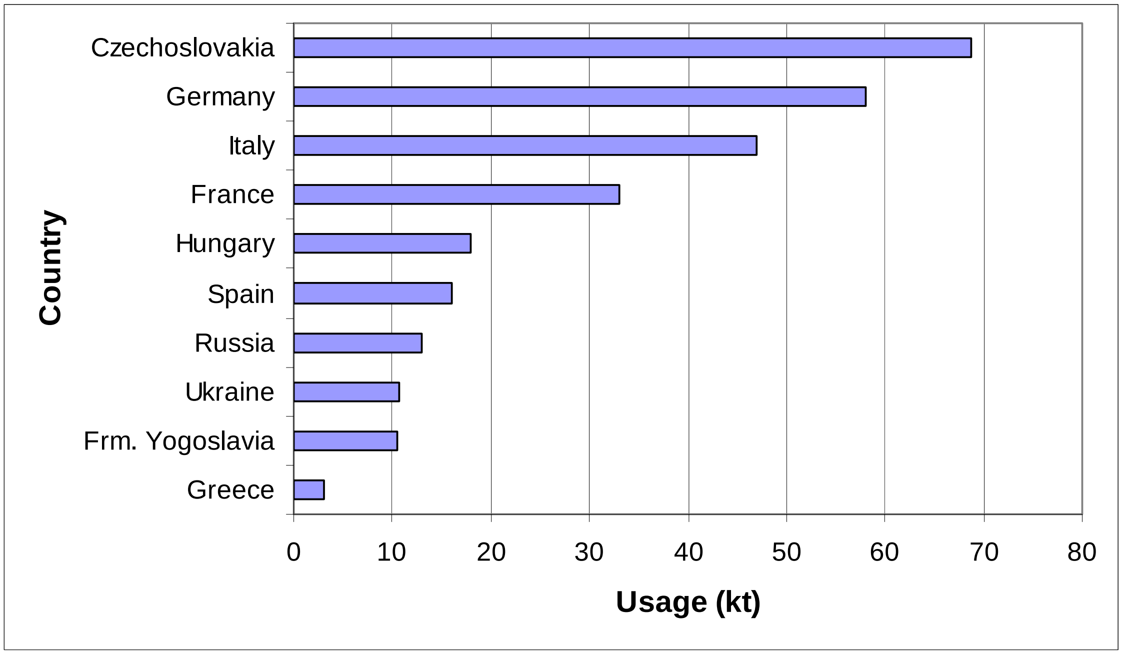


Figure 5. Top 10 countries with highest lindane usage in Europe between 1950 and 2000.

3.2 Lindane usage in North America

The major use of lindane in **Canada** has been on canola and corn. Li et al. (2004) estimated the total lindane usage as **9 kt** between 1970 and 2000, with highest value (558 t) in 1994. **Figure 6** gives annual usage in Canada on canola and corn between 1950 and 2004. The total usage in this period of time has been estimated to be **11.7 kt**.

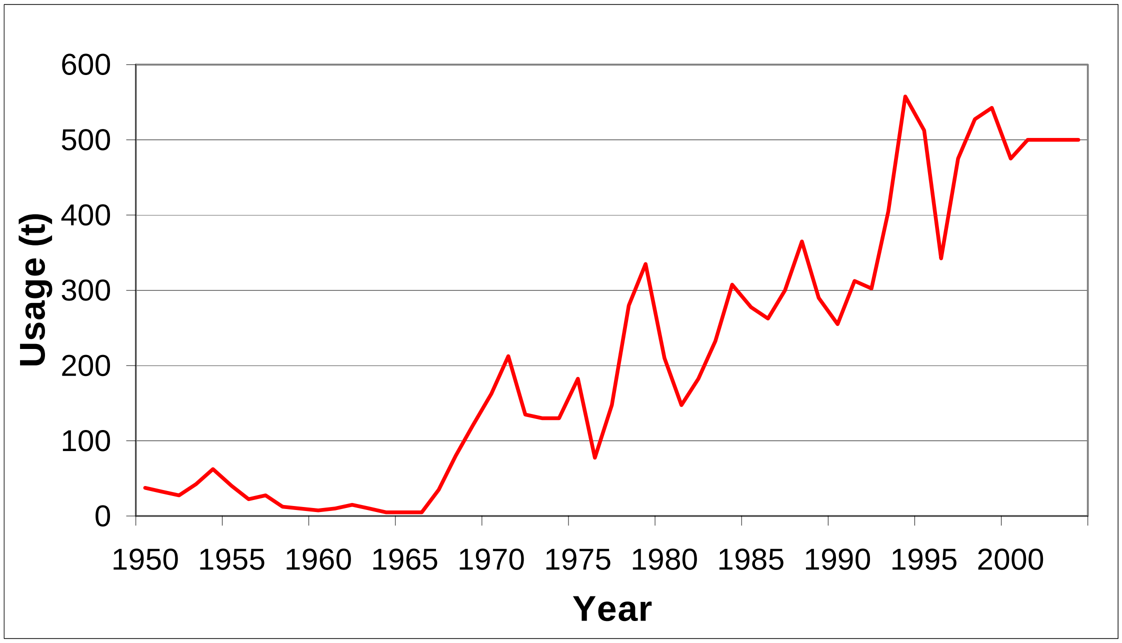


Figure 6. Annual lindane use in Canada from 1950 to 2004. The total usage was 11.7 kt.

In the United States, total lindane usage between 1950 and 2004 is **18.8 kt**, and the current annual lindane usage in the United States is around 150 t (see **Figure 7**, Li et al. 2005b).

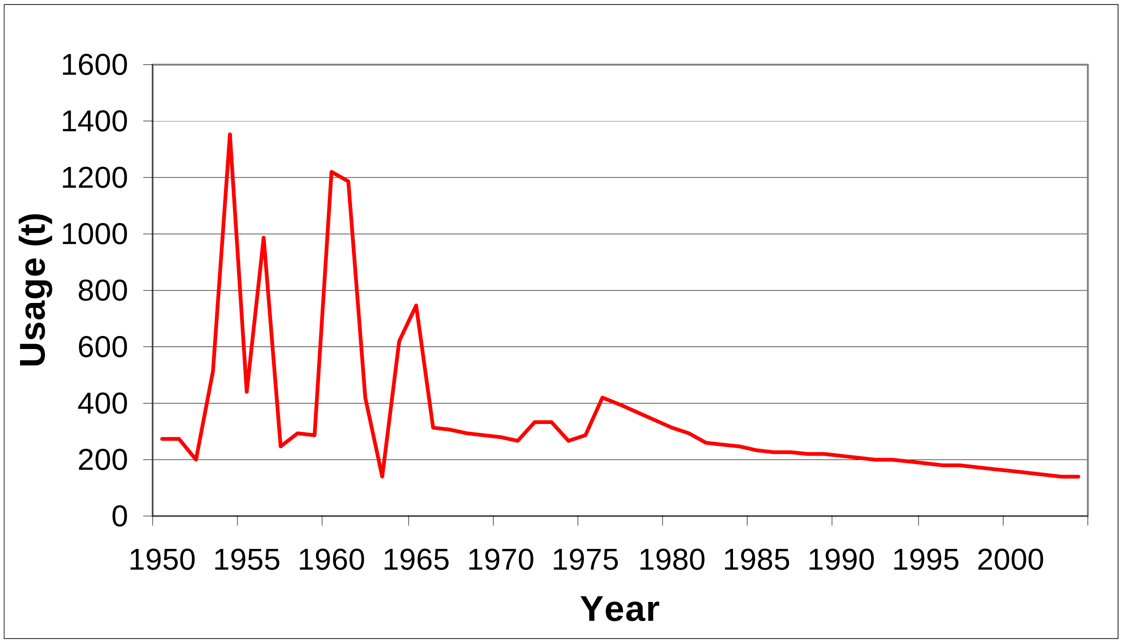


Figure 7. Annual lindane use in the United States from 1950 to 2004. The total usage was 18.8 kt (Li et al, 2005b).

It was reported that HCH was not produced in Mexico. Both lindane and technical HCH have been imported from other countries (CEC 2004). Mexico imported **190 t** lindane between 1994 and 2004. **Figure 8** shows the annual lindane usage in Mexico between 1950 and 2004 with total usage as **3.2** kt. Mexico planned to phase out all use of lindane in 2005.

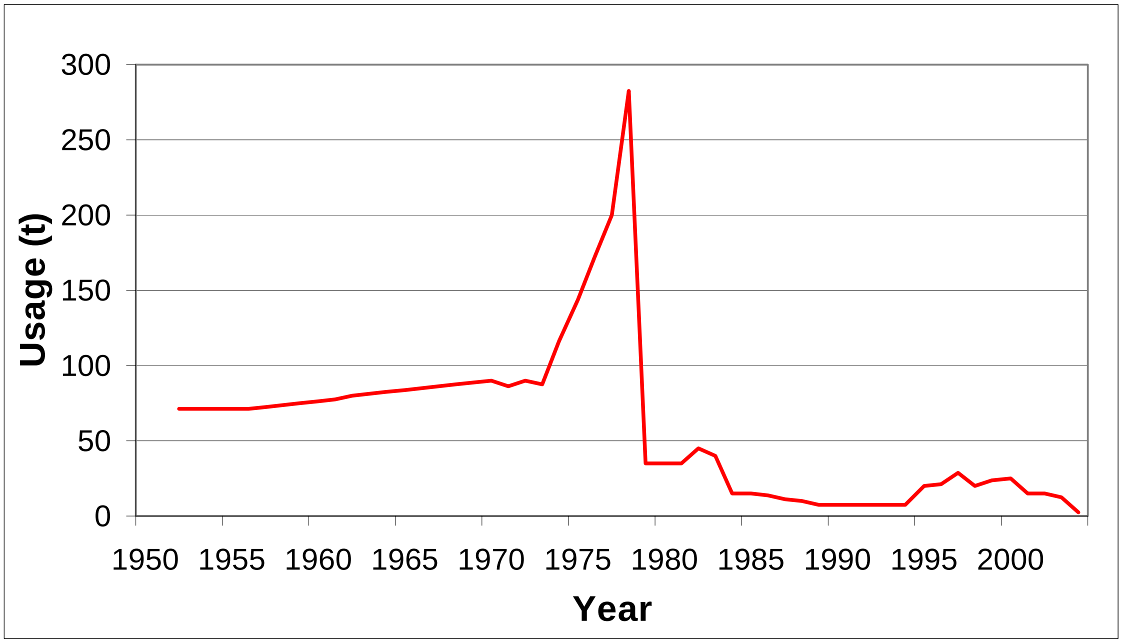


Figure 8. Annual lindane usage in Mexico between 1950 and 2004 with total usage as 3.2 kt.

Total lindane usage in the North America between 1950 and 2004 is 34 kt, (see Figure 9, Li et al. 2005b).

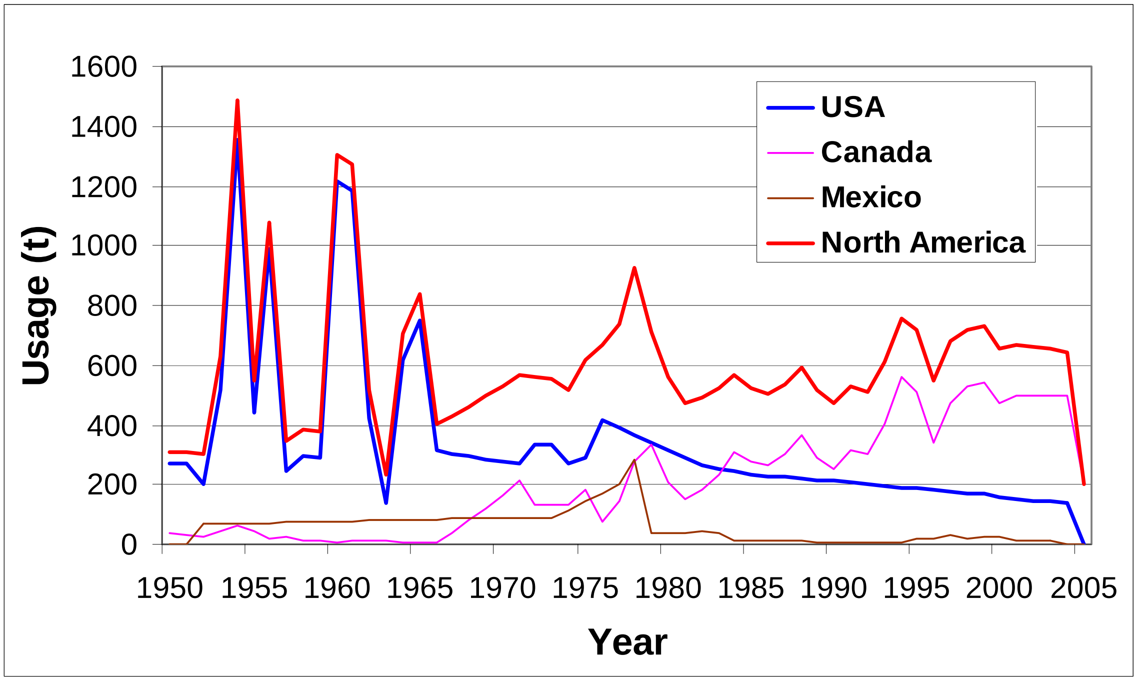


Figure 9. Annual lindane use in the North America from 1950 to 2004. The total usage was **34 kt** (Li et al, 2005b).

3.3 Lindane usage in South America

Figure 10 depicts annual lindane usage in South America from 1950 to 2000. The total usage was **19** kt.

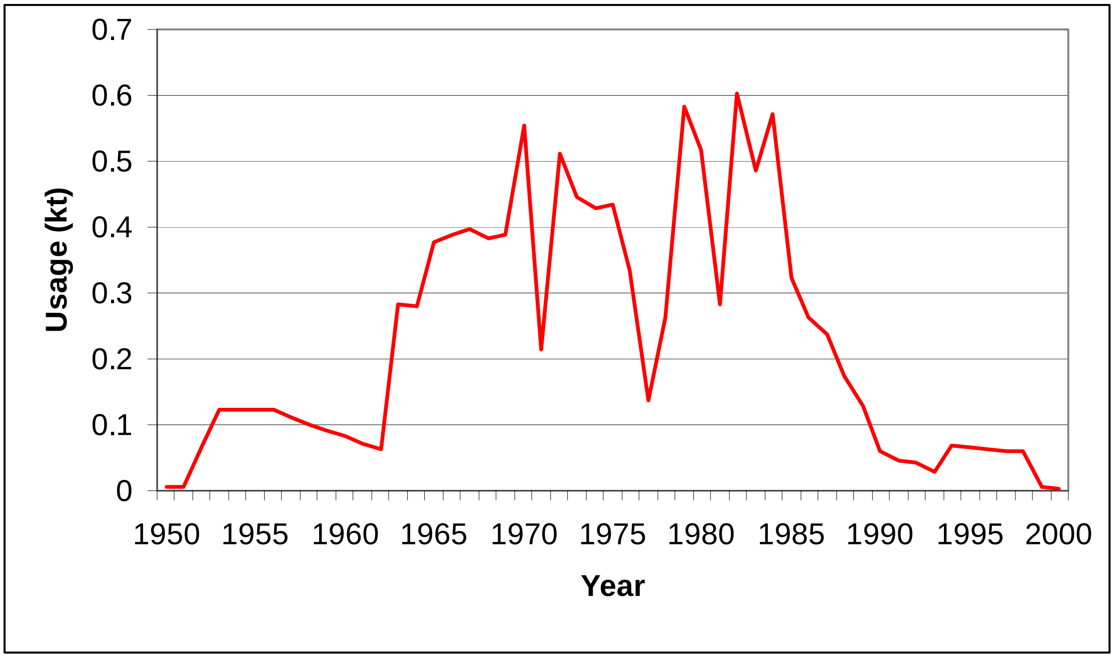


Figure 10. Annual lindane usage in South America from 1950 to 2000. The total usage was 19 kt.

3.4 Lindane usage in Central America

Figure 11 depicts annual lindane usage in the Central America from 1950 to 2000. The total usage was **13 kt**.

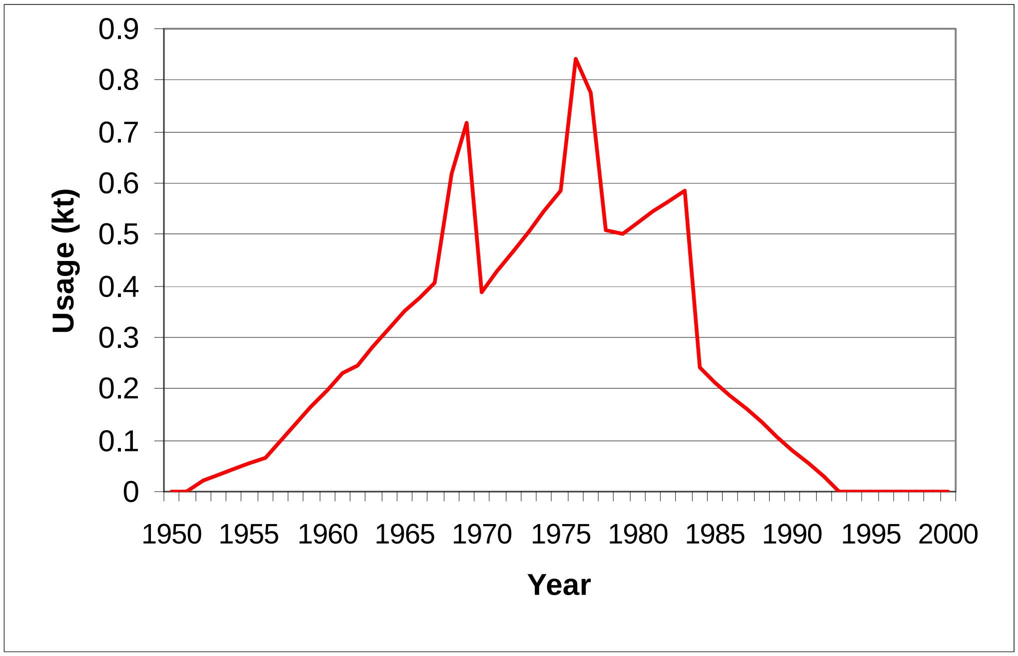


Figure 11. Annual lindane usage in the Central America from 1950 to 2000. The total usage was 13 kt.

3.5 Lindane usage in Asia

After China banned the use of technical HCH in 1983, lindane has been used in this country since 1991. The total lindane production was **11.4** kt and lindane usage was **3.2** kt between 1991 and 2000 (Li et al. 2001).

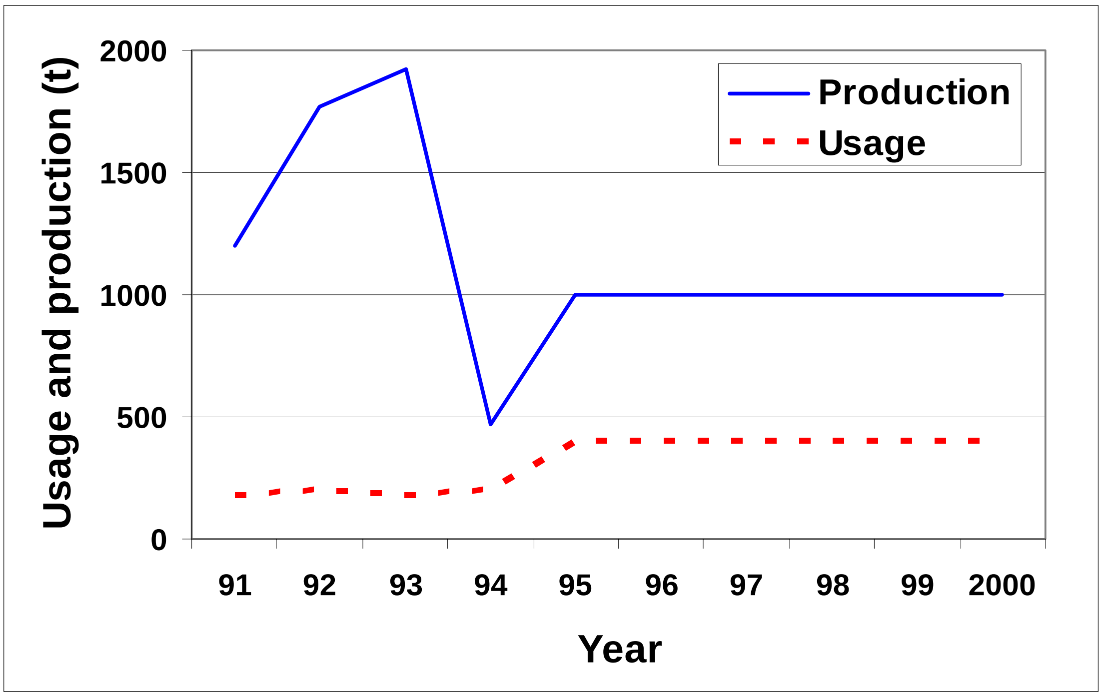


Figure 11. Annual lindane usage in China between 1991 and 2000 (Li et al. 2001).

Lindane production in India started in 1990 and stopped in 2003. In 1996, the main Indian manufacturer exported 90% of lindane output to US and Europe. But according to UN FAO, India stated to use lindane at the beginning of 1950s. Annual usage of lindane in India is shown in **Figure 12** from 1990 to 2004. The total lindane usage is **6840 t** between 1990 and 2004.

Jensen (2004) reported in 2004 that the lindane production of the main Indian producer has been greatly reduced and at the moment only produces 5 % of its capacity.

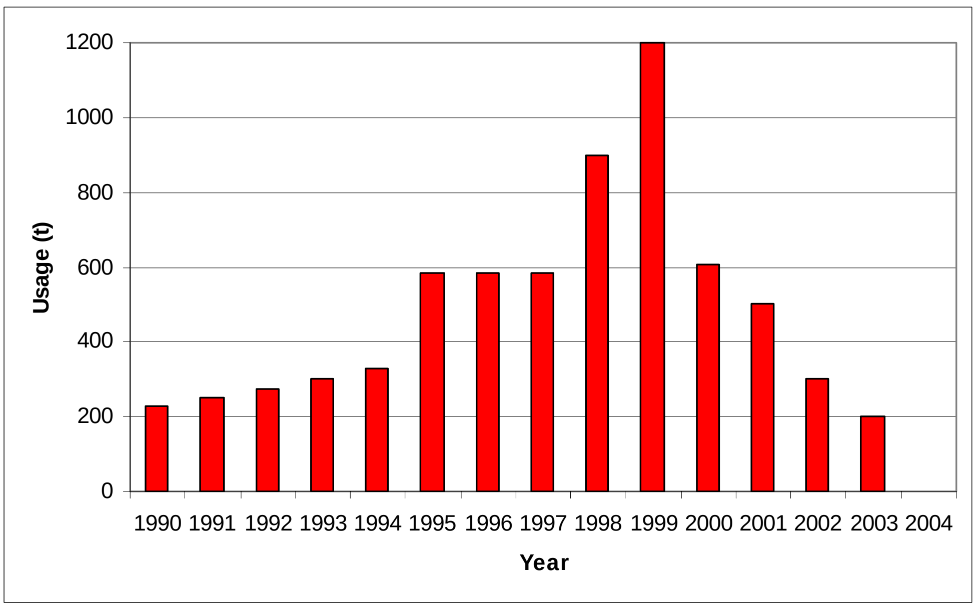


Figure 12. Annual lindane usage in India between 1990 and 2004 (Dept. of Chemicals, 2002; UNEP/WHO 2004; UNEP, 2002b, some interpolation was made.).

Figure 13 gives annual lindane usage in Asia from 1950 to 2000. Total usage was **73 kt** during this period of time.

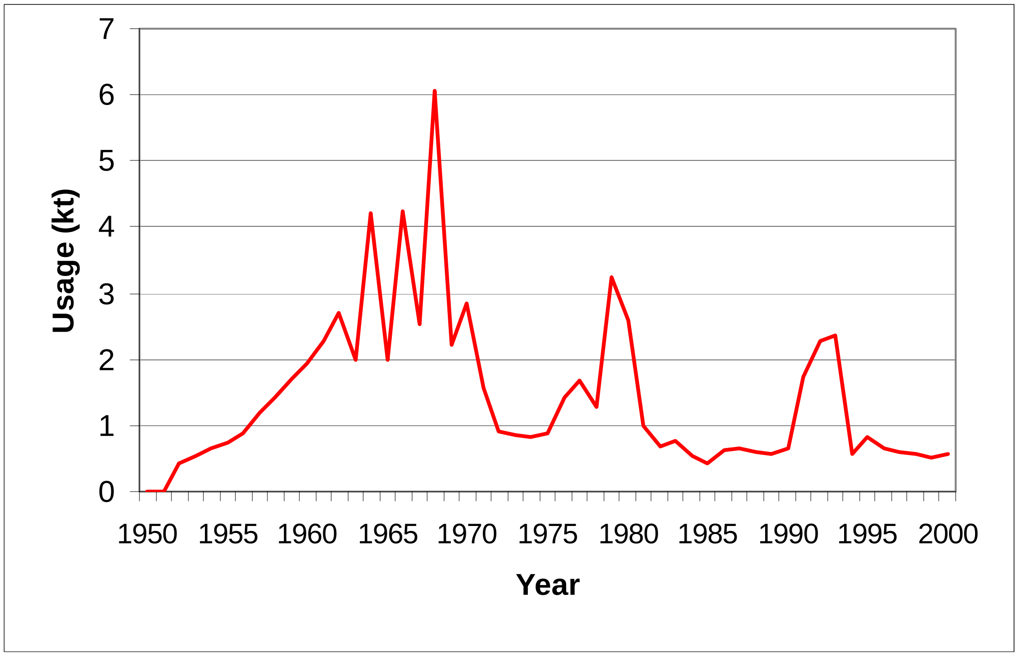


Figure 13. Annual lindane usage in Asia from 1950 to 2000. Total usage was 73 kt.

3.6 Lindane usage in Africa

Annual lindane usage in Africa from 1950 to 2000 is shown in **Figure 14**. Total usage during this period of time was **28.5** kt.

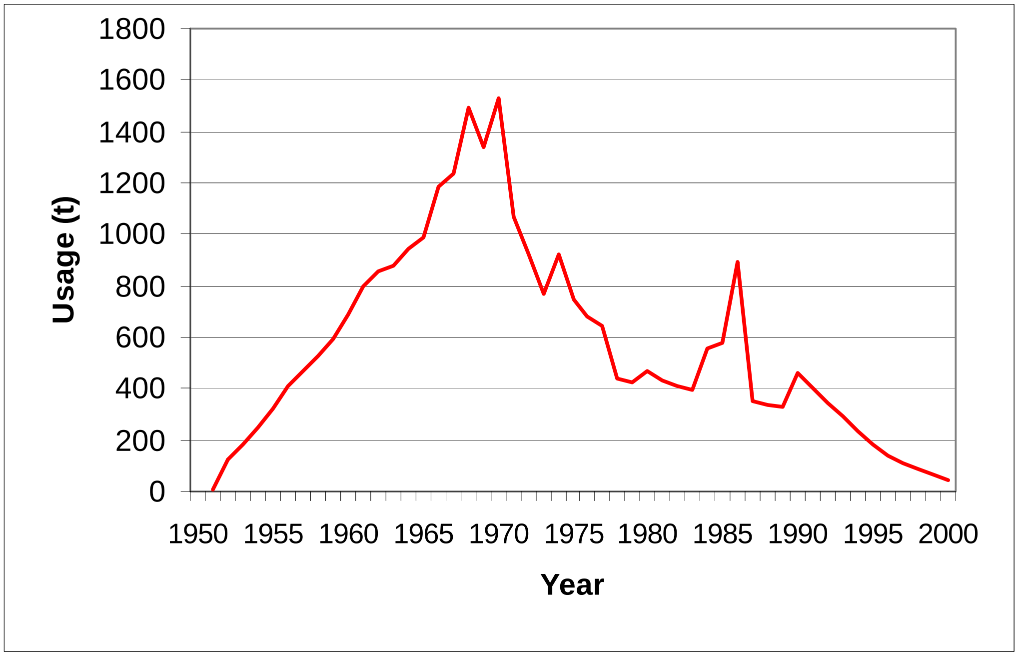


Figure 14. Annual lindane usage in Africa from 1950 to 2000. Total usage was **28.5** kt.

3.7 Lindane usage in Oceania

Figure 15 gives annual lindane usage in Oceania from 1950 to 2000.

Total usage was **1** kt.

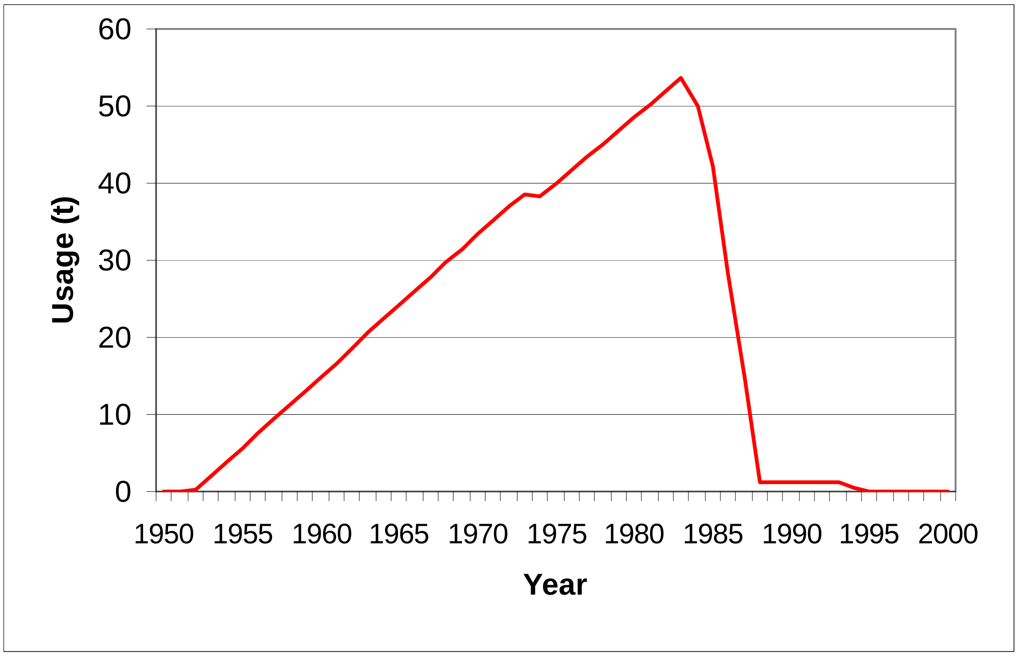


Figure 15. Annual lindane usage in Oceania from 1950 to 2000. Total usage was 1 kt.

3.8 Global lindane usage

Global annual lindane use is given in **Figure 16** showing lindane usage world-wide was highest in the 1960s and the beginning of 1970. The total lindane use for agricultural purpose between 1950 and 2000 is **450** kt. The new estimate of global lindane use is less than those given by both Voldner and Li (1995) and Song et al. (1999).

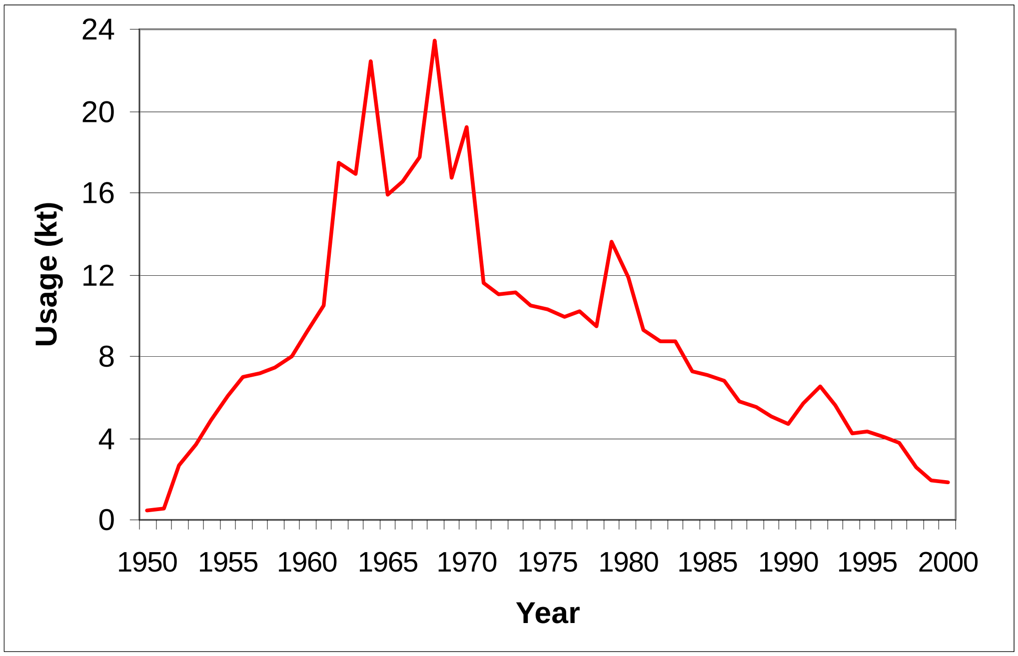
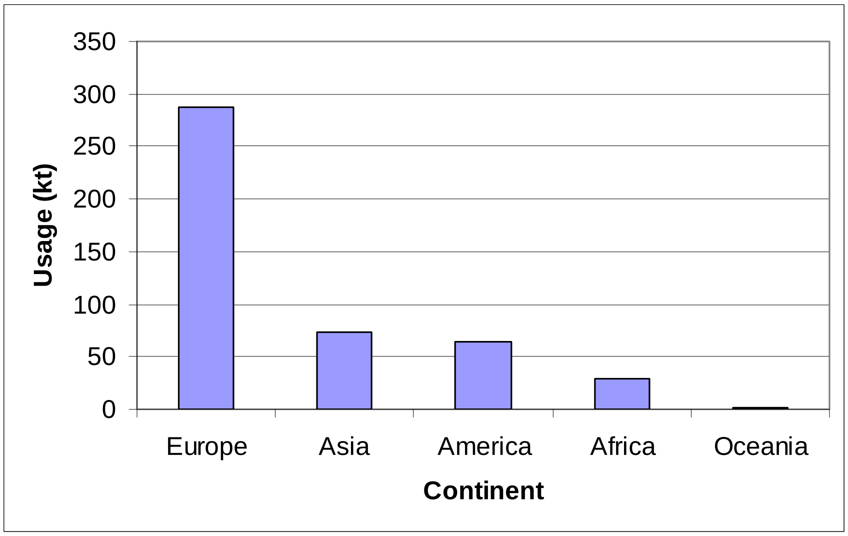
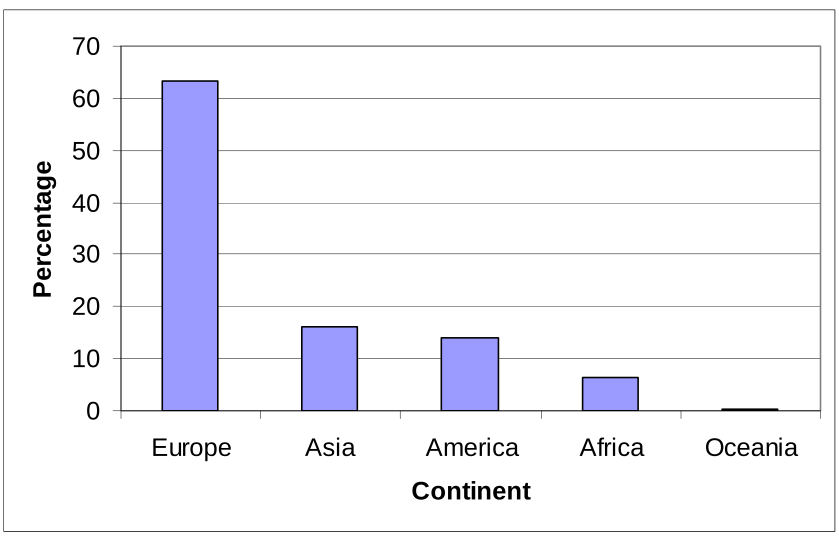


Figure 16. Global annual lindane usage from 1950 to 2000. Total usage was **450** kt.

Figure 16 gives lindane usage in different continent from 1950 to 2000. Although lindane use in most Europe countries are stopped, the historical lindane use from 1950 to 2000 in Europe reached almost 290 kt, approximately 63% of the total global use.



(a)



(b)

Figure 16. Lindane usage in different continent from 1950 to 2000. (a) The tonnage (kt) and (b) the percent of usage to the total global use.

4. Conclusions

Historical usage of lindane worldwide has been investigated from different sources. Global lindane use for agricultural purpose between 1950 and 2000 is estimated to be 450 kt, among which 280 kt was used in Europe, 73 kt in Asian, 64 kt in America, 29 kt in Africa, and 1 kt in Oceania countries. Although lindane use in most Europe countries are stopped, the historical lindane use from 1950 to 2000 in Europe reached approximately 63% of the total global use. Global lindane usage was highest in the 1960s and the beginning of 1970.

The estimation on the global lindane usage made in this Report has been the best estimation so far, although some effort is still needed to make the estimate better. It should be pointed out that lindane has also been used on livestock, forestry, human health, and for other purposes. The total global lindane usage for all purposes could be approximately **600 kt**.

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Annex V: Tables used for figures in the report

Annex V: Tables used for figures in the report

Table 1: Indian production

Year	Technical HCH (BHC) (t)	Lindane (t)	Source
1986	27 000		Jaffery F.N., 1997)
1989	47 000		
1990	32 000	300	Anonymous, 1990
1990	19 466	226	(UNEP/WHO 2004)
1994	9 154	328	(UNEP/WHO 2004)
1995-2000		4462	UNEP, 2002
1996	16 000		(Benzene Hexa chloride)
1998		900	Dept. of Chemicals, India
1999		1200 (estimate)	Dept. of Chemicals, India
2000	0	607	(UNEP/WHO 2004)
2000		500	Dept of Chemicals, India, 2002
2001		500(estimate)	Dept of Chemicals, India, 2002
2002		300	Dept of Chemicals, India, 2004
2003		200 (estimate)	Dept of Chemicals, India, 2004
2004		none	Jensen, 2004

Table 2: First estimate on important amounts of HCH-residuals in countries

Country	Production lindane tonnes	Estimated HCH residuals in tonnes (for the calculation of residuals it is assumed that for 1 t of lindane 8 t of HCH residuals are produced with the exception of FSU (Treger, 2004))
Germany (East + West)		363 400 - 383 400
Romania		310 000 (only in the last years eventual re-use for TCB and HCl has taken place at 1 manufacturer)
Former Soviet Union	40 000 t	200 000 – 300 000
France		Min. 260 000 but probably ca 500 000. However at the main producer re-use to TCB and HCl has been taken place
Spain		Ca 200 000
China	1991-2000: 11 400 t	91 200*
Japan	1958-1970: 9.532 t	76 000 (No numbers reported but expected residuals in case no-re-use for TCB, HCl production)
South Africa		70 000
USA		At least 65 000
Brazil		At least 50 000
India		56 000
Poland		At least 35 000 (but also 100-140.000 indicated but the last amount most probably is then not pure waste but eventually mixed with soil)
FYR Macedonia		33 000- 38 000
Slovakia		26 000
Turkey		3 000 are known. Last 5 years 23500 but from former periods much more expected
Others		
Total Minimum		**1 665 100**
Total Maximum		**1 925 100**

*The information on China is sparse and it is unknown if residuals have been utilised in other ways or not

Annex VI: Permits from 1961 for the Deposition of HCH-residuals (translated and anonymised)

Annex VI: Permits from 1961 for the Deposition of HCH-residuals (translated and anonymised)

………………..
of the County of the…….
1961
County Construction Office

Compared with the original certificate:

Building certificate Nr.

On behalf of … (Company name)…………………………………………………………………

……
………
is according Paragraph …….. irrespective of the right of third parties for the in the appended construction measure, provided with the approval on the detailed documents for the construction.

Establishment of a pit for the storage of residuals
(type and objective of the measure)

……
……………
(estate)

……
……………..
under consideration of exceptions Paragraph ….

……
…………….
the planning and building permission given

The planning and building permission is given under the following restrictions (conditions, time-limits, obligations, restrictions for cancelling):

A. Obligations:

I. For the planning and building permit (Paragraph……………………):

1.) Along the railway side of the ………………………… railways a dam with a height of 2, 00 m has to be established provided with the necessary vegetation

2.) The foot of the dam must have a distance of minimum 3,00 m from the edge of the railways.

3.) It has to be avoided that persons can fall into the pit. Therefore sufficient precautions have to taken by the installation of illumination and safeguarding measures

District President of
Lower Water authorities

1961

Company name

Re: Water right;
Here: Storage of solid wastes of ....
on the company-owned production area in............

Herewith you receive, after assessment of the submitted information as part of the application, the permit to extend the already available waste pit on the company-owned production area, ..., for the storage of solid waste stemming from the lindane production.

It is referred fully to the contents of the following individual planning documents, which are part of this permit.

1. Description of the construction measure
2. Site plan 1:10000
3. Plan M= 1: 500

Additionally is this permit connected with the fulfilment of the following conditions:

1. <u>Supervision of the works:</u>

The representatives of the supervising authorities must be assured of unhindered access to the facility on the company owned area at any time.

2. The waste products that are brought to the storage site have to be examined from time to time by a recognised office agency (chemical technical investigation authority). A copy of the results of the investigation has to be sent to the water authorities

3. <u>Taking over of costs:</u>

Costs, occurring for the supervision of the facility by the concerned authorities respectively their representatives, have to be borne by the applicant. These costs have to be in accordance to, by the official regulations, fixed travel costs and investigation duties.

4. Liability:

The applicant respectively his successor in interest, are liable to the permit- issuing authorities for damages occurring within the legal directions for damages, that arise from construction, presence, operation, modification or elimination of the concerned facility. The applicant is obliged to release the permit-issuing authorities in the same extent from claims by third parties against this authority, because of extension of the permit or because of the presence and operation of the facility.

5. Reservations:

With the issue the right for further obligations remains.

Legal remedy instruction:

Against this permit it is possible to complain within a period of one month after announcement. The complaint has to be forwarded at my authorities in writing or has to be recorded in writing with them.

Annexes:

Description of works
Site plan
Sections

Signed

District
President

District President

..

1960

To the ……..Company

Ref: Facility of a pit 80x50 m for the reception of production residuals

Ref: Our meeting from ……………….1960

Dear Mr. ……………………….,

In relation to abovementioned meeting, we issue herewith the permit for the construction of the waste pit, under the condition that the bottom of the waste pit will be at a level ……. above N.N.. This restriction was necessary, as according to Paragraph ….., section … of the new Law on Water Management, materials can only be disposed in such a manner that a harmful contamination of the groundwater or other disadvantageous change of its properties not has to be feared.

The establishment of this level will be undertaken on Wednesday, the …. 1960, by my Underground Engineering Department.

Yours sincerely

Signed

District President

Annex VII: References

Annex VII: References

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