The Swedish National Chemicals Inspectorate
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Phase-out of PBDEs and PBBs

Report on a Governmental Commission

PREFACE

In its appropriation directions for 1998, the Government commissioned the National Chemicals Inspectorate to submit, not later than 15 March 1999, proposals for the phasing out of PBDEs and PBBs.

As part of the commission, an account was also to be given of international activities. Work within the EU with reference to existing substances is of importance in this connection, and new data emerging from that work are presented here. An account is also given of work by other international organisations, such as the OECD and OSPARCOM.

Work on this commission has proceeded within the Risk Reduction Plans process. An external reference group, comprising representatives of national authorities and business organisations, has been associated with the commission. This reference group held three meetings and communicated viewpoints concerning the working approach, proposals and consequences.

Input data for an assessment of policy measures and the consequences of a possible prohibition were collected partly by means of a questionnaire circulated to upwards of 200 businesses selected in consultation with the business organisations.

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Eva Ljung

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SUMMARY

In 1990 the Government decided that the most harmful brominated flame retardants were to be abolished. The National Chemicals Inspectorate has previously (in its report KemI Report 5/96) pointed to the urgent necessity of phasing out the PBDE and PBB groups of substances. Its present commission requires the Inspectorate to propose a strategy for the phasing out of PBDE and PBB flame retardants.

PBDEs, polybrominated diphenyl ethers, are not manufactured in Sweden but are imported and used as flame retardants, e.g. for rubber cables. PBDEs can be included in electronic components and other imported goods. They can be present in motor vehicles and electrical devices. Before the 1990s, PBDEs were also used in Swedish textiles. Today PBDEs can occur in imported textiles and upholstered furniture.

PBBs, polybrominated biphenyls, are an additive used in plastic and rubber manufacturing. There are no registered imports of PBBs in Sweden. PBBs can also be included in electrical equipment of all kinds.

A survey of 200 businesses by the National Chemicals Inspectorate indicates a poor level of knowledge as to where these flame retardants are used, one explanation being that it is difficult and time-consuming for the Swedish importer to obtain information from the manufacturers. Electronic products and components, above all, are manufactured in Southeast Asia, and go through many different stages before reaching the Swedish market.

In the Flame Retardants project (KemI Report 5/96), the National Chemicals Inspectorate estimated the amount of PBDEs in Swedish commodity imports at approximately 400 tonnes annually. About 100 tonnes of PBDEs were imported as a chemical product in 1997, mainly for cable use. The quantity of PBBs imported as goods has been estimated at about 10 tonnes annually.

The lower-brominated technical PBDE compounds, containing mostly pentaBDE, are persistent, bio-accumulative and toxic in the aquatic environment. They show effects above all on the liver but also on thyroid hormone and affect the behaviour of mice. They occur widely in the environment, in human blood and in mother´s milk. The highly brominated compounds included in technical octaBDE and decaBDE are persistent, have effects on reproduction and can cause tumour formation in the liver. There are data which support the suspicion that these compounds can be transformed into lower-brominated compounds.

Lower-brominated PBB compounds are highly toxic and produce effects resembling those of chlorinated dioxins and PCB. Just as with PBDEs, there are suspicions that decaBB, the technically used PBB compound, can be transformed into lower-brominated biphenyls.

The above are strong reasons for hastening the phase-out of PBDEs and PBBs as groups.

PBDEs and PBBs have attracted international attention. Within the OECD, business organisations have made voluntary agreements concerning PBDEs and PBBs. The EU has rules forbidding the use of PBBs in textiles coming into contact with the skin. PBDE risks to health and the environment are currently being evaluated as part of the EU programme for existing substances. In Germany, PBDEs and PBBs are restricted through the Dioxin Ordinance and by voluntary agreements with industry. In Germany and Denmark, projects are in progress to investigate the flow of brominated flame retardants and substitution possibilities. In the Netherlands, PBDEs and PBBs have been voluntarily phased out by industry.

As regards the programme for existing substances within the EU, it is unclear at present when the risk assessments will be ready and what the conclusions will be. Sweden has contributed to the risk assessments, partly by supplying newly acquired knowledge concerning occurrence in mother´s milk and concerning behavioural effects on experimental animals following exposure at a very early age. Even if the risk assessment leads to the conclusion that risk containment measures are needed in the form of a ban on the use of PBDEs, it may take a long time, perhaps up to ten years, for any such prohibition to be introduced and implemented in the Member States.

Several years' experience has taught the National Chemicals Inspectorate that the voluntary path is a slow one and prodigal of resources, due to the very great number of players in the market. Swedish industry has made a great deal of headway in phasing out PBDEs and PBBs, but imports through commodities, not least from markets outside the EU, remain a problem. In addition to the Swedish activities, both international bodies and individual European countries have for some ten years been pursuing questions related to brominated flame retardants. Even so, exposure to PBDEs and PBBs remains widespread, resulting among other things in growing concentrations in mother´s milk. Even with voluntary national work supplemented by active participation in various international fora, above all within the EU, the National Chemicals Inspectorate anticipates that the phase-out of PBDEs and PBBs will not proceed fast enough.

A new strategy is called for by the aggregate risks to health and the environment which have been presented and by the difficulty of influencing commodity imports of PBDEs and PBBs by means of voluntary phase-out. Most of the products containing PBDEs or PBBs are imported, and a broad-based policy package is therefore needed, not only aiming at national limitations on use but also ensuring that the foreign suppliers can offer alternatives. In addition to co-operation at EU level, contacts are needed with national authorities and with organisations representing manufacturers above all in the USA and Asia.

Notification to the EU of a Swedish prohibition entering into force in a few years' time gives business enterprises a very distinct cue for stepping up the pressure on their foreign suppliers.

A transparent regulation with clearly prohibited uses and few exemptions should be opted for, because an arrangement of this kind has more chance of gaining acceptance in a European perspective.

A prohibition will reduce exposure to PBDEs and PBBs, even though, due to the existing accumulation in products, it may be some time before the effects are quantifiable. It has not been possible to estimate the economic consequences other than in certain particular respects. A prohibition introduced in Sweden only can create difficulties, above all for smaller enterprises.

Proposals

- A ban, referring to specified areas of use, on the sale, supply or use of PBDEs or PBBs should be introduced in Sweden. The professional sale or supply of products containing or treated with these substances should not be permitted. A suitable juncture for entry into force is within a five-year period from the notification date.
- Through contacts with other Member States and through its participation in the work of the EU, Sweden should continue its active efforts to bring about a ban on use at EU level as soon as possible.
- Sweden should also actively endeavour to bring about a far-reaching phase-out also in other markets which are important suppliers of PBDEs and PBBs. This can be done through direct contacts with strategically important countries, through regional bodies and through the work of international organisations.

1. INTRODUCTION

In the appropriation directions for 1998, the Swedish Government commissioned the National Chemicals Inspectorate to elaborate the proposals put forward in its report 6/97 concerning the phase-out of PBDE and PBB brominated flame retardants.

The Inspectorate's assignment includes putting forward "proposals for a phase-out, including a possible prohibition, proposals for legislation and the consequences of a prohibition, as well as drawing up a timetable for phase-out and international activities". The commission also includes consideration of the risks associated with the recycling of products containing these flame retardants.

Brominated flame retardants have previously been dealt with in Government commissions, Government Bills and other official inquiries. The following standpoints have been adopted.

The Risk Reduction Commission

In the so-called Risk Reduction Commission, reported in June 1990, the Inspectorate called upon manufacturers and importers of brominated flame retardants to give an account of the damage which their products were capable of causing to health and the environment. That account was to form the basis of a closer assessment of the need for risk reduction measures.

Government Bill 1990/91:90 "A living environment"

In Government Bill 1990/91:90 "A living environment" the Government adopted the standpoint that the use of brominated flame retardants is to be limited. The aim is for the most harmful substances in this group to be rapidly phased out.

The Flame Retardants Project

The Flame Retardants Project was started to facilitate achievement of the objectives stated in Government Bill 1990/91:90. The purpose of the project was to analyse risks for health and the environment associated with flame retardants and to propose risk reducing measures if necessary. Lack of information caused the risk assessments to be limited to seven substances/groups of substances, PBDEs and PBBs being two of them.

The conclusions drawn in the Flame Retardants Project (KemI Report 5/96) included the following:

- That the information available in open databases concerning the environmental and health-related properties of these substances and exposure to them had been inadequate.
- That, in the light of existing knowledge concerning concentrations in the environment, bio-accumulation and persistence, the use of PBDEs and PBBs must cease.
- That imports of products treated with flame retardant accounted for the heaviest influx of flame retardants into Sweden.

The Phase-out Project

A follow-up of the Risk Reduction Commission was presented in the Phase-out Project (KemI 1997). The proposals put forward by the Inspectorate concerning PBDEs and PBBs were as follows:

- The Inspectorate adheres to its standpoint that PBDEs and PBBs should be phased out.
- Swedish industry shall continue to work for a substitution of PBDEs. An account of their occurrence shall be given not later than 31st December 2002.

- Importers of electrical and electronic products and components should give an account of the occurrence of PBBs to the Inspectorate not later than 31st December 2002.

Government Bill 1997/98:145 ”Swedish environmental targets”

In Government Bill 1997/98:145 ”Swedish environmental targets” the Government reiterates its view that the use of brominated flame retardants should be limited. In particular, a phase-out of PBDEs and PBBs is urgently needed.

2. DESCRIPTION OF THE PRESENT SITUATION

2.1 National activities

The Inspectorate has pressed for the phasing out of PBDEs and PBBs, partly by calling upon business enterprises to write declarations of intent, indicating how they are endeavouring to phase out the use of PBDEs and PBBs, and by distributing information to improve the state of knowledge on the part of those concerned. By the end of 1995 two firms had sent in declarations of intent. No declarations of intent have been written by the business organisations on their members' behalf.

Eco-labelling systems, ecological product declarations, rules on public procurement and producer liability have also been accelerating influences on the phase-out process. Personal computers and screens can be eco-labelled to TCO '95, since reconstituted as TCO '99, and Nordic Eco-labelling (Nordisk Miljömärkning), all of which stipulate that PBDEs and PBBs may not be present in plastic parts weighing more than 25 g or included in covers and casings. About 1,100 display screens and ten computers have been labelled to both these systems. TCO (the Swedish Confederation of Professional Employees) estimates that one out of every three display screens sold on the Swedish market in 1998 was labelled in accordance with TCO '95 or TCO '99. The requirements applying to chemicals etc. are the same as in TCO '95.

Environmental product declarations have been devised by the Swedish IT Companies Organisation for personal computers, fax transceivers, copying machines and printers. The declaration contains various kinds of environmentally related data. PBDE and PBB use, for example, is stated for components exceeding a certain weight (25/50 g). Today more than 700 IT products have been eco-audited in this way. Where personal computers are concerned, roughly 80 per cent of suppliers in the market are affiliated to the system. As a result, covers and casings for eco-declared personal computers no longer contain PBDEs or PBBs. The Norwegian and Danish trades are also introducing corresponding systems for their countries. A newly established Nordic environmental council for the trade is to co-ordinate and develop the system.

The Public Procurement Act applies to virtually all public procurement of goods, services and construction. In the procurement process, the purchaser can stipulate that PBDEs and PBBs are not to be included in the product. The County of Västernorrland, for example, has issued a guide dealing among other things with brominated flame retardants in office machinery, furniture and textiles. This guide is being used and observed by many local authorities. Display screens now have to be labelled in accordance with TCO '95 or corresponding requirements.

A proposed Ordinance concerning producer liability for electrical and electronic products has been notified to the EU and is intended to take effect on 1st January 2000. Under this Ordinance, whoever professional manufacture, import or sale of electrical or electronic products will be obliged to accept the same quantity and type of equipment as the customer buys. The Ordinance will apply to products used in the home, in offices, in medical technology and in laboratories. On the other hand it will not apply to industrial equipment or motor vehicles.

Useful information is expected to result from the research programme on brominated flame retardants which is now in progress within MISTRA.

2.2 Activities in other countries

At the end of the 1980s **Germany** proposed a ban on PBDEs and PBBs. The proposal was withdrawn because it was not felt to be feasible within the EU. Subsequently Germany imposed regulations on PBDEs and PBBs by means of the Dioxin Ordinance. Since dioxins can be formed in the production of flame-retarded plastic, the requirements of the Ordinance lead indirectly to a restriction of PBDE and PBB use. In a declaration of intent in 1989, the chemicals industry and plastic manufacturers in Germany declared that they would neither produce nor use PBDEs. PBDE production has ceased in Germany, but PBDEs continue to be used, both as a chemical product and in imported products.

A research project on flame retardants was inaugurated in Germany in the autumn of 1998. Alternatives and designs are to be identified and evaluated for selected groups of products.

The Blue Angel is a German eco-labelling system. Personal computers, keyboards and screens can qualify for labelling. Parts for covers and casings may not contain flame retardants in the form of halogenated organic substances. An exception is made for plastic parts exposed to high temperatures: these may contain PBBs or PBDEs. A hundred or so IT products have been labelled with the Blue Angel.

In **Denmark** a project is under way to investigate the flow of brominated flame retardants in the community, PBDEs and PBBs among them. Substitution possibilities are also to be described. Denmark is also discussing restrictions on the use of brominated flame retardants.

In **the Netherlands**, the Environment Minister proposed at the beginning of the 1990s that PBDEs and PBBs should not be allowed to be placed on the market. The sale of goods containing these substances should also be prohibited. The proposal has since been withdrawn, partly because the risks were considered to be smaller than had previously been supposed and also because industry has given a voluntary undertaking to phase out PBDEs and PBBs. Industry is to carry out annual checks of the use of brominated flame retardants. An evaluation is to be performed in 1999.

Industrial use of PBDEs and PBBs in the Netherlands has been halved since 1990. Only about 3 per cent of the quantity used stays in the Netherlands. The remainder is exported in finished or semi-manufactured goods.

Voluntary efforts, generally speaking, mainly influence the use of pure PBDE and PBB substances. The occurrence of these substances in imported products is not affected to the same extent.

2.3 International organisations

The OECD

Industry has given a voluntary commitment which was accepted by the OECD Joint Meeting in Paris in June 1995. The main points of that commitment were as follows.

Industry promises:

- not to manufacture, process, import or use PBBs with the exception of decaBB,
- to manufacture, process, import and use deca-, octa- and pentaBDE which are the PBDEs in commercial use today,

- to use the best available technology in the manufacture of deca- and octaBDE so as to minimise pollution,
- to use the best available technology in the manufacture, processing and handling of pentaBDE, so as to minimise emissions.

DecaBB is the only PBB manufactured today. The entire world output of PBB takes place at a plant in France. All other enterprises within the organisations of producers of brominated flame retardants (EBFRIP and BFRIP) promise not to produce PBBs. The manufacturer of decaBB is to review the need for continuing production in the year 2000 and has undertaken to carry out a risk assessment.

The OECD has received an initial report from the manufacturers of brominated flame retardants concerning measures taken in compliance with the agreement. A new, improved report is to be compiled by the industry and presented in November 2000.

The Esbjerg Declaration, the Fourth North Sea Conference

At the North Sea Conference in 1995, the Environment Ministers agreed on common action to be taken within the international organisations to replace brominated flame retardants with less hazardous substances where alternatives were available.

OSPAR, Oslo and Paris Conventions for the Prevention of Marine Pollution

Sweden has pursued questions concerning brominated flame retardants, starting in PARCOM, the Paris Convention for the Prevention of Marine Pollution, 1990. Background material, describing available knowledge on individual substances and alternatives to PBDEs and PBBs, has been presented to the working group for diffuse emissions, DIFF, on several occasions. To minimise unnecessary duplication, Sweden awaited the results of the OECD risk reduction work before presenting a draft recommendation.

In the autumn of 1994 Sweden felt that there was enough supportive documentation for a recommendation to be put forward concerning the phase-out of PBDEs and PBBs. The proposal did not receive enough support from the other Member States to be adopted. A new proposal was put forward in 1995. This had been modified in the light of the work started under the EU programme for existing substances; see below. The proposal was now solely concerned with a phase-out of PBBs. This proposal was not supported by enough Member States to be adopted, but there was an expressed desire for work concerning brominated flame retardants to continue.

At DIFF 1996, Sweden undertook to compile a questionnaire in order to codify existing knowledge as to where PBBs are used. The response rate was very poor. At Sweden's suggestion, the Member States resolved that work within DIFF should remain dormant. Discussions of the question are to be re-opened not later than 2001.

The European Union

Brominated flame retardants have been regulated by the EU in Council Directive 76/769/EEC on the approximation of the laws, regulations and administrative provisions of the Member States relating to restrictions on the marketing and use of certain dangerous substances and preparations. Use of PBBs in textiles coming into contact with the skin is prohibited in amending directives 83/264/EEC and 79/663/EEC.

Penta-, octa- and decaBDE are being investigated under the EU programme for existing substances. The UK has drawn up risk assessment proposals for pentaBDE and, together with France, for octa-

and decaBDE. The British and French proposals for these commercial mixtures are currently being discussed at Community level. The risk assessments which the Member States finally agree on will then form the basis of a risk management strategy. The timetable for risk assessment and risk management strategy is uncertain. Both can take several years to materialise.
Within the European Commission, work is in progress on drafting a directive concerning waste from electronics and electrical products. In the course of this work, stipulations are being discussed which can lead to a phase-out of PBDEs and PBBs.

The UN

HexaBB are included on the so-called POPs protocol, in the UN Convention on Long-range Transboundary Air Pollution (CLRTAP). The POPs protocol contains a list of substances concerning which the parties have agreed on commitments to reduce and eliminate emissions and losses. Under the Convention, global dissemination of persistent organic pollutants (POPs) is to be eliminated by the parties taking steps to discontinue their production and use.

3. DISPERSAL OF PBDEs AND PBBs IN THE SOCIETY

3.1 Use

Flame retardants are used to impede the ignition or reduce the spread of a fire. The addition of flame retardant does not make the product unignitable, merely less flammable. It is mainly polymer materials, such as plastic and rubber, that are protected in this way, but textiles, wood and paper can also be treated with flame retardant. The increasing use of electricity entails a growing risk of overheating or flashover in electrical equipment. In many cases there are official stipulations describing the fire safety codes which different products have to comply with. In other instances it is the manufactures or consumers themselves who want the product to meet certain requirements of fire safety. Those requirements focus mainly on ignitability characteristics. Reference is often made to international flame retardant codes, e.g. UL 94, which is an ignitability method. The codes indicate functional requirements for the material, without indicating the flame retardant which has to be used. In addition to passing an ignitability test, the flame retardant also has to meet other technical requirements. The flame retardant selected for a plastic, for example, must be miscible with the plastic and must not be affected by the temperature at which the plastic is processed.

There are many different chemical substances which can be used as flame retardants. Compounds with chlorine or bromine atoms often have good fire prevention properties. Polybrominated biphenyls, PBBs, and polybrominated diphenyl ethers, PBDEs, are two groups of flame retardants which can be used for achieving fire prevention.

Plastics and rubber can be mixed with the flame retardant without reacting with it chemically. If so, the flame retardant is additive. If the substance bonds chemically with the material it is called reactive. The chemical bonding decides the mobility of the flame retardant in the material and affects the spread of the substance in the environment.

PBDEs are used exclusively as flame retardants. PBDEs are sold as three commercial mixtures with different degrees of bromination. DecaBDE consist of 97 per cent decaBDE and 3 per cent nona- and octaBDE. OctaBDE consist mainly of hepta- and octaBDE, but hexa- and nona- also occur in minor concentrations. PentaBDE is mainly a mixture of penta- and tetraBDEs. These ethers are used in many different plastics and resins because they have a high bromine content, are stable at high temperatures and are inexpensive. They are mixed into the plastic material without reacting chemically with it. Concentrations vary between 5 and 30 per cent. Antimony trioxide is often used in combination with PBDEs for the enhancement of flame-retarding properties.

There is no Swedish production of PBDEs, but the deca-form of PBDE is imported, mainly for use as flame retardant with rubber cable.

The large quantities of octa- and decaBDE probably come to Sweden in products, the biggest influx being through the medium of electrical and electronic goods. OctaBDE are used mainly in covers and casings, in a concentration of 12-18 per cent in the end product, while the deca-form is more widely used in different plastics. The end products are parts for electrical or electronic equipment.

First-time use of PBDEs has been reduced in covers and casings for electrical and electronic equipment. Random tests performed in November 1998 by the Swedish Consumer Agency on new coffee makers, tea kettles, toasters etc. have shown that their casings do not contain brominated flame retardants.

PBDEs can be included in the plastic capsule surrounding electronic components. Components are for the most part assembled and encapsulated by a small number of firms in Southeast Asia which cater for most of the international electronics market. Compared with casings and covers, an electronic component contains an insignificant amount of flame retardant. On the other hand, the number of components in products of various kinds exceeds the number of casings and covers. Added to this, electronics is an expanding sector.

PentaBDE can occur in printed circuit boards, which consist of paper saturated with phenolic resin. Circuit boards of this kind can occur in electronic products made in Asia.

National activities have led to a discontinuation of the use of PBDEs in Sweden's textile industry during the 1990s, but decaBDE can still occur in imported textiles. PentaBDE can occur in the upholstery of imported furniture.

PBBs are used exclusively as a flame-retardant additive. They are sold exclusively as technical decaBB, which consists of at least 94 per cent decaBB and up to 6 per cent nonaBB, with traces of octaBB. The advantages from a flame retardant point of view are high bromine content and a wide range of applications, mainly in different types of plastic.

PBBs are neither manufactured nor used in Sweden. The use of PBBs as a flame retardant in other parts of Europe indicates that they can be imported to Sweden in products. The Inspectorate has had isolated reports of PBB occurrence. PBBs are used mainly for electrical and electronic equipment.

3.2 Flows in society

There is no Swedish production of PBDEs or PBBs. These substances enter Sweden through imports of pure substance (PBDEs), as part of a material or in a product. Diffuse transport may also occur with the winds, as with the long-range airborne transport of PCB.

Imports of chemical products, in the form of pure substances or mixtures of substances, are entered in the Inspectorate's product register. Flame retardants which have already been added to parts of goods or finished products, on the other hand, are not recorded, and so the total quantities imported are hard to estimate.

Registered imports of PBDEs in 1997 totalled 120 tonnes. It is above all the deca form of PBDE that is imported, mostly as flame retardant for rubber cable. The large cable manufacturers, however, have replaced PBDEs or set themselves the environmental target of discontinuing PBDE use by the year 2000.

No imports of PBBs have been reported to the product register.

In the Flame Retardants Project (KemI Report 5/96), the Inspectorate estimated the amount of PBDEs entering Sweden in products at some 400 tonnes per annum. Of this amount, decaBDE account for about 300 tonnes and the remainder consists of octaBDE (about 60 tonnes) and pentaBDE (about 40 tonnes). This estimate is based on Sweden's GDP being one per cent of the combined GDP of the OECD countries. Our share of the globally used quantity of PBDEs, therefore, should be one per cent. Similarly, the Inspectorate has estimated the amount of PBBs entering Sweden in products at about 10 tonnes per annum. These quantity estimates are based on the assumptions made in 1995. This quantity may have changed by now. Brominated flame retardants have been reduced in covers and casings, but meanwhile the influx of electronic goods to Sweden has increased.

In its work on this commission, the National Chemicals Inspectorate has endeavoured, by means of a questionnaire survey, to chart the occurrence of PBDEs and PBBs more reliably. For this survey, companies were selected which were typical of the business sectors dealing in goods which can contain electrical or electronic components, furniture and textiles. The questionnaire was drawn up in consultation with the relevant business organisations and was distributed to upwards of 200 member enterprises. The response rate was low, only about 35 per cent. In spite of repeated requests through the business organisations, more information has not been obtainable, and so it is impossible to draw any general conclusions about the different business sectors. In some cases firms have replied that they have products which are flame-retarded with PBDEs or PBBs. Products of this kind are electronics components, cable and various fittings for motor vehicles. The survey also revealed that in many cases it is not known whether a firm’s products contain the flame retardants in question. To clarify this matter, the Swedish importers will have to ask their foreign suppliers.

The step from the individual Swedish importer to the foreign supplier consists of a long chain of contacts before the “right” person is reached who is in a position to influence the process. The chain extends from the Swedish sales management through links with the European contact to subcontractors, ending with the individual component fabricator, who is often located in Southeast Asia. This makes the procurement of information a difficult, time-consuming process. Replies from the foreign suppliers vary. Sometimes the importer is told which products or components contain the substances in question, but very often it has not been possible to obtain any information at all.

Representatives of the motor trade stated in the questionnaire that PBDEs were present in imported cars from the Asian countries and the USA. They are used for upholstery, seats and doors, floor mats and wiring, with upholstery accounting for the biggest share. The average amount per vehicle was given as <250 g. According to vehicle trade statistics for 1997, Sweden imported 72,000 cars from Asia and the USA. On the basis of these figures, and assuming that PBDEs can also occur in British and French cars, a rough estimate indicates that up to 18 tonnes of PBDEs annually can enter Sweden with imported cars. The number of new cars registered in 1997 was 225,000.

3.3 Waste and recycling

The waste stage is a source of PBDE and PBB emissions both into the working environment and into the natural environment. There are no data from which to assess the magnitude of this source or the diffusion paths. Better data are needed. The goods containing either of these substances have a service life time of great variability. Waste containing these substances will need to be disposed of for a long time to come. One great difficulty lies in identifying the goods in which these substances occur at the waste stage.

Once a product has been used up, it can be recycled, incinerated or landfilled. In an ecocyclic perspective, stress is laid on the importance of re-using parts of products and recycling materials to the greatest possible extent, but this should not apply to products containing substances with properties so dangerous for health and the environment as PBDEs and PBBs. Once these products have been discarded and become waste, their PBDE or PBB content should be removed from the ecocycle. Disposal of plastics and other waste containing these substances must therefore be conducted in a manner acceptable from the viewpoint of health and environment protection. The difficulties involved in identifying and separating parts containing brominated flame retardants imply a risk of the diffuse distribution of BPDEs and PBBs.

The largest quantities of PBDEs and PBBs occur in plastic parts in and surrounding electrical and electronic equipment. There are various possible modes of disposal. In the case of goods handled by electronics disposal firms, covers are most often collected and burned in refuse incineration plants.

There are no survey reports to show what happens to the brominated flame retardants during combustion in refuse incineration plants. There may be a risk of halogenated dioxins forming. Printed circuit boards containing brominated flame retardants can either be sent to metal smelting plants or be treated in connection with fragmentation. It is not known today what quantities of brominated flame retardant enter the complex scrap delivered to fragmentation plants or how they are emitted into the atmosphere and water during fragmentation and in the resultant material flows and waste products.

Demands for better disposal of these substances are an important part of the provisions which the Swedish Environmental Protection Agency is now drafting on pre-treatment of waste comprising or containing electrical and electronic products.

4. RISKS OF PBDEs AND PBBs

4.1 PBDEs

The commercially available PBDEs are technical mixtures of diphenyl ethers with degrees of bromination ranging from four to ten (tetra to deca) bromine atoms; see 3.1. In the section which now follows, the three technical products - deca-, octa- and pentaBDE - are dealt with separately since they have different properties, for example, with regard to distribution, persistence, bio-accumulation and toxicity.

Environmental exposure to PBDEs

PentaBDE occur widely in environmental samples from sediment and biota in concentrations which increased during the 1970s and 1980s. In Swedish surveys of pike and of guillemot eggs, this trend appears to have been inflected during the 1990s. PentaBDE are persistent, both microbially and abiotically in water and air. PentaBDE have a potential for long-range airborne transport and have been identified in air samples from Swedish background sites on the island of Gotland and in the Scandinavian mountain range (de Wit, 1998).

Tetra- and pentaPBDEs in particular have a high potential for bio-accumulation, with a bio concentration factor (BCF) of between 5,000 and 35,000. Monitoring data from the Baltic and elsewhere suggest higher concentrations of lower-brominated PBDEs (tetra/penta) higher up in the food chains (EU, 1998a).

Where octaBDE and decaBDE are concerned, no significant bio-accumulation has been demonstrated in fish and BCF varies between about 5 and less than 50. This is due to low uptake. OctaBDE and decaBDE are larger molecules and, consequently, are less readily absorbed than pentaBDE. A recent Swedish study has shown that decaBDE are absorbed from food by fish and possibly metabolised to lower-brominated PBDEs. The uptake, however, is small, only about 0.02-0.13 per cent of the dose having been found in muscle tissue (EU, 1998b, c). Studies where decaBDE have been administered to rats also indicate low uptake from food.

OctaBDE and decaBDE are judged to have a potential for airborne distribution (EU, 1998b, c). Octa- and decaBDE are persistent, both microbially and abiotically in water and air. Successive debromination in UV light and sunlight has, however, been demonstrated for decaBDE. Microbial degradation to lower-brominated PBDEs in an anaerobic environment is also expected to be possible (EU, 1998a). Photolytic and anaerobic debromination of PBDEs is being investigated more closely under the EU programme for existing substances.

Human exposure to PBDEs

Tetra- and pentabrominated diphenyl ethers have been identified in the indoor air of offices and in edible fish from Northern Europe. The concentration in edible fish varies a great deal, but high concentrations have above all been observed in freshwater fish such as pike, perch and eel (EU, 1998a). Other foodstuffs have not been analysed. In Swedish mother´s milk the concentration has been rising exponentially since the 1970s (Norén, 1998), but by way of comparison it should be added that concentrations in mother´s milk are still far below the total concentration of PCB.

OctaBDE have been measured in indoor air on premises containing flame-retarded electronic apparatus such as computers and television receivers (Bergman, 1997). Elevated blood concentrations of octaBDE have recently also been shown in occupational categories handling computers, for example (Bergman, 1998). Workers employed on the dismantling of computers have a blood concentration of heptaBDEs, the commonest compound in technical octaBDE, which is 65 times greater than in a reference group consisting of cleaners employed in hospitals. Thus there is a very low basic exposure to octaBDE which increases in connection with work involving products treated with octaBDE flame retardant.

Of the three technical PBDE products, decaBDE has the lowest volatility, but this too can be slowly emitted from flame-retarded devices. The occurrence of decaBDE in blood samples from personnel dismantling electrical apparatus shows that decaBDE can also be absorbed by inhalation (Bergman, 1998). Insofar as food contains decaBDE, uptake is probably small. In the USA, decaBDE have been found in human fatty tissue from a normal population (EU, 1998c). Thus there are data pointing to human exposure, but quantitative data concerning the magnitude of exposure are lacking.

Health risks of PBDEs

In conventional sub-chronic animal experiments, the liver is the organ most sensitive to pentaBDE. Effects have been seen on both morphology and function when pentaBDE exposure through food exceeds 1 mg/kg and day (EU, 1998a). Skin injuries and effects on thyroxin hormone levels can also be suspected at high exposures. No animal studies have been made of lifetime exposure to pentaBDE (EU, 1998a).

In recent Swedish studies, young mice were given a very low single dose of tetraBDE or pentaBDE (0.7-12 mg/kg). Effects on their behaviour were then studied after they had reached adulthood. The results showed that exposure during the critical period when the brain is growing and maturing fastest leads to effects on the behaviour of the adult animals. Effects were seen on motor activity, and for pentaBDE on memory and learning (Eriksson, 1998). PCB has also been studied in the same experimental model. In the case of PCB, the behavioural changes are accompanied by chemical changes in the brain. There is also evidence to show that the behavioural effects which PCB can produce in experimental animals can also occur in human beings. Given the simultaneous occurrence of PCB and growing concentrations of pentaBDE in mother´s milk and the ability of both compounds to influence the behaviour of experimental animals, these new research findings are disquieting.

The injuries caused by octaBDE to experimental animals are primarily concerning the reproduction (EU, 1997a). In the EU’s work with existing substances, there is discussion of classifying octaBDE as toxic to reproduction, since increased embryo mortality and delayed skeleton formation were seen without the parent animal being affected. These effects occur when exposure exceeds 2 mg/kg body weight and day. In addition, octaBDE can affect the functioning of the liver at low levels of exposure (EU 1997a).

The animal studies performed to investigate the teratogenic effects of decaBDE suggest that, like octaBDE (see above), they affect skeleton formation in embryos (EU, 1997b). DecaBDE, however, are less potent than octaBDE, and the effects on reproduction do not occur until exposure exceeds 100 mg/kg body weight and day. In long-term animal experiments, decaBDE have caused liver tumours (EU, 1997b). With oral exposure, however, high exposure is required in order for tumours to occur.

In the risk assessment methodology which is now in general use, human exposure is compared with the highest exposure in animal experiments which has not given rise to harmful effects (NOAEL). Good risk assessments have generally proved difficult to achieve where persistent organic substances are concerned, the reason being that human beings are exposed to such substances throughout their lifetime. Effect studies on animals with lifetime exposure and exposure for several generations (one, two or three-generation reproduction studies) are often lacking. In addition, exposure assessment is very difficult, owing to the diffuse migration paths of these persistent substances. Lastly, it has been found that several different persistent organic substances can produce similar effects, and additive effects of such substances should therefore be taken into consideration.

In the case of pentaBDE and octaBDE, NOAEL for rats and rabbits is 1-2 mg/kg and day. It has to be realised, however, that these experimental animal data are not based on lifetime exposure, which would be a more realistic point of departure for comparison with human exposure.

Human beings are exposed to PBDEs through food, inhalation and dermal uptake. Quantitative estimates of total exposure and of the relative importance of the different exposure pathsways, however, are difficult to make. In the case of octa- and decaBDE, analytical difficulties provide a further deterrent to analysis, thus reducing the possibilities of assessing exposure correctly. In the risk assessment work of the EU, the risks in the occupational environment have been observed with regard to both penta and octaBDE, and further information and testing are likely to be requested.

Environmental risks of PBDEs

Up till now, PBDE toxicity has above all been studied for pentaBDE. For octa and decaBDE there exist a few studies of aquatic organisms. Generally speaking, toxicity in short-term tests appears to be higher at lower levels of bromination.

PentaBDE consist of components which are persistent, bio-accumulative and highly toxic to aquatic organisms even in short-term tests. According to preliminary assessments under the EU's existing substances programme, pentaBDE can constitute a risk to aquatic and terestrial organisms and, locally at least, lead to secondary poisoning, e.g. of fish-eating birds or mammals (EU, 1998a). Studies of toxicity in long-term tests on fish and sediment-dwelling organisms will be starting shortly under the EU programme. Studies of effects on soil organisms have also been recommended.

OctaBDE and decaBDE are persistent. Lower-brominated components (hexaBDEs), which occur in octaBDE, are bio-accumulative. The toxicity for aquatic organisms has been inadequately investigated and there are no data concerning effects in concentrations below water solubility. Preliminary exposure estimates for soil and the aquatic environment, together with extrapolated effect data under the EU's existing substances programme, point, however, to the existence of risks (EU, 1997a, b). Within the EU programme, the results of pentaBDE studies are now being awaited and should be ready in the spring of 1999. An assessment will then be made of the need for tests for octaBDE and decaBDE. The above also applies to toxicity to terrestrial organisms. In the health assessment data, octaBDE present effects on reproduction in rabbit at doses exceeding 2 mg/kg body weight and day. DecaBDE display similar effects but at far higher (50 times) doses.

4.2 PBBs

Commercially available PBB consists mainly of decaBB (>94%), but nonaBB and traces of octaBB can also occur.

Exposure to PBBs

Just as with PBDEs, human and environmental exposure can occur in connection with the use of products, in the recycling of plastics containing PBBs and after disposel to landfills. Emission is probably very slow, but PBBs can be released after degradation of PBB-bearing material.

DecaBB and hexaBB have been found in several sediment samples from the deltas of large rivers in Western Europe. Outside the PBB production plant in France, biphenyls with between five and ten bromines have been found in mussels, algae and seaweed. HexaBB have been found in biological materials, but the sources of this occurrence are uncertain. HexaBB have been identified in edible fish from northern Europe (Jansson et al., 1993). Although hexaBB have previously been used as a flame retardant, the possibility of their resulting from the debromination of decaBB cannot be excluded. DecaBB are persistent, but there are studies to suggest that debromination can take place in UV light. Microbial debromination in an anaerobic environment is also a possible transformation path. DecaBB have a potential for airborne distribution, but there are no data to confirm this.

Health risks of PBBs

Uptake of decaBB can occur through inhalation, from food or by dermal contact. Uptake from food and dermal uptake is relatively limited where decaBB are concerned, but it increases with reduced bromination.

DecaBB have a low acute toxicity. In the few animal studies which have been performed, liver is the main target organ (NOAEL 35 mg/kg body weight/day), with effects such as increased liver weight, cell destruction and reduced glycogen content. At higher exposure levels, thyroid enlargement was also seen. DecaBB have also produced slight irritation of the skin and eyes in experimental animals. In the absence of lifetime animal experiments or studies of reproductive toxicity, nothing can be said concerning possible carcinogenicity or effects on reproduction (Elf, 1998). For technical nonaBB, however, there are animal studies indicating that nonaBB is carcinogenic, with the liver as target organ (WHO, 1994a).

Studies of industrial workers exposed to decaBB and decaBDE have pointed to effects on the thyroid system (hypothyroidism) resembling those seen in experimental animals (Bahn et al., 1980).

The few studies performed with octaBB show higher liver toxicity compared with decaBB (NOAEL<2.5 mg/kg) and reproductive toxicity (foetal mortality and reduced survival among progeny) (WHO, 1994a). For biphenyls with even lower bromination (tetra-heptaBB), there are a host of studies indicating very high toxicity. Some of these are structurally similar to the chlorinated dioxins and co-planar PCB and have the same effects in experimental animals, i.e. they produce malformations, liver injuries (including liver tumour formation), immune defence reduction, reproductive disturbances, disturbed thyroid function, skin injuries and “wasting syndrome”, i.e. emaciation and serious weight loss at acutely toxic doses.

Environmental risks of PBB

PBB compounds are stable and persistent. They are fat-soluble and practically insoluble in water. Some PBB compounds metabolise very slowly in the body and therefore accumulate in the fat of organisms. After release into the environment they can reach the food chain and accumulate there. (KemI Report 5/96).

Bio-accumulation of different PBB compounds increases with increasing bromination up to at least tetraBB. Biphenyls with a higher degree of bromination can be expected to be still more bio-accumulative if absorbed by living organisms. Uptake will be less efficient, however, if the molecule is too large, as for example in the case of decaBB. Bio-accumulation of decaBB in fish, therefore, is unlikely to occur to any significant extent (BCF<5). Molecular size can be one reason for low uptake through the gill membranes. Bio-accessibility through food or for other aquatic organisms is regarded as a possible exposure path.

Few toxicity data are available from short-term tests on aquatic organisms. These data suggest moderate toxicity but the tests were performed on concentrations well above water solubility.

Possibly, therefore, the effects may be of a physical nature instead of describing the true toxicity of the substance. (Elf, 1998).

5. ALTERNATIVES

Official fire safety regulations often make it impossible to remove a flame retardant without modifying the technical design or substituting another flame retardant. Flame retardant requirements are laid down in guidelines and standards. Within the scope of these requirements, PBDEs and PBBs can be replaced with other flame retardants, or else the products can be developed in a way which reduces the need for flame retardants.

Technical design can be modified so as to obviate the addition of flame retardant. This can be done by altering the design in such a way that there will be less risk of overheating, or else by switching to a more heat-resistant material. Casings can be lined with less flammable metal, but this can add to the difficulties of materials management at the waste stage. Plastic can in certain cases be replaced with ceramics, but these are several times more expensive and are only used in adverse surroundings, for example in electrical components for pacemakers or for aerospace applications.

Other flame retardants can take the place of PBDEs and PBBs. Phosphorus-based flame retardants are used, for example, in covers and casings. Other substances which can be used are magnesium hydroxide, aluminium hydroxide and silicon elastomers. There are also several other brominated flame retardants which can be considered as alternatives. Many of them can be expected to have unwanted properties, due to their structure and fat solubility. There is no flame retardant which can replace PBDEs or PBBs in every situation. Alternatives have to be tried out for different materials and applications.

Where textiles are concerned, there are several alternatives. Woollen materials have good flame protection without additives. It is only in situations with very exacting safety requirements, such as aircraft, that extra protection is needed. Potassium zirconium hexafluoride or potassium hexafluorotitanate are used. Cellulose fibres (cotton, for example) or mixtures of cellulose and synthetic fibres can be flame-proofed with organic phosphonates which are fixed on the fabric. Polyester can be manufactured in grades with flame-retardant properties.

Most of the decaBDE imported in Sweden are used as flame retardant for rubber cable. The cable manufactures state that, where standard products are concerned, this will have been fully discontinued by 2000. Possible alternatives for this application are metal hydrates such as aluminium trihydrate and zinc borate. Technical solutions will be attainable for special purpose cables, e.g. those with high-temperature applications.

The Inspectorate has not investigated health-endangering or environmentally hazardous properties of possible alternatives. In the light of the available knowledge, the Inspectorate believes that in many cases there should be good possibilities of finding alternatives which entail less risk. In other cases, no such alternatives are available today. A prohibition introduced within a specified time should be a means of bringing pressure to bear for the development of alternatives. The supplier is responsible for the alternatives used being sufficiently investigated for safe handling to be possible.

6. DISCUSSION

6.1 Reasons for additional phase-out measures

Persistent organic pollutants

PBDEs and PBBs are persistent organic substances. In addition, pentaBDE and low-brominated biphenyls are highly bio-accumulative. Experience from substances of this type, e.g. PCB, has shown that exposure reduction takes a long time, due to the slow degradation of the substances, once the environmental concentrations have reached a level giving rise to serious effects. In addition, there is diffuse new supply from products.

Widespread distribution and exposure

The widespread distribution of these substances in the community makes sources of exposure hard to locate. Their occurrence in areas where exposure sources are lacking suggests long-distance airborne transport of PBDEs and PBBs. It is impossible to tell how much of this incidence is due to historical use.

One large application field is the encapsulation of components for printed circuit boards, which are fitted to various electrical devices. Electronics and automotive wiring are other applications where flame retardants are used. In addition, the upholstery and interior fittings of many cars are fitted with PBDE flame retardant.

Both PBDEs and PBBs occur in the environment. HexaBB and tetra- and pentaBDE have been found in many animal species from a wide variety of regions, including both seal from Svalbard, reindeer from the north of Sweden and pike, perch and eel from more industrialised regions. Air samples collected on the island of Gotland and in the Scandinavian mountain range contain tetra- and pentaBDE.

There is a base exposure to octaBDE. OctaBDE have been measured in the bloodstream of occupational categories employed on premises where there are computers and television receivers, and also among hospital cleaning staff. No single exposure source, however, can be reliably identified. The source may be computers and television receivers emitting octaBDE, but food may also be a source of uptake. Among occupational categories employed on the dismantling of electronics, however, the blood concentration of heptaBDEs, the commonest compound in technical octaBDE, was 65 times higher than among hospital cleaning staff, which suggests a connection between professional handling of products containing PBDEs and concentrations of these PBDEs found in the bloodstream.

Among the various PBDE compounds, decaBDE are the least volatile but can evaporate from flame-retarded devices, even if emission is a slow process. Elevated concentrations, not only of octaBDE but also of nona- and decaBDE, have been found in the bloodstream of personnel employed on the dismantling of electronics, suggesting that decaBDE can also be absorbed by inhalation. Insofar as food contains decaBDE, uptake is probably slight.

The mother´s milk of Swedish women contains tetraBDEs and pentaBDE. Concentrations have risen steeply in recent years. Growth has been exponential since 1972, with concentrations doubling every five years.

Where these chemicals are concerned, then, exposure is life-long. Quantitative information is lacking, however, concerning the magnitude of exposure, nor do we know the potential future consequences of lifetime exposure for human health.

Most PBDE data refer to tetraBDEs and pentaBDE. The occurrence of octaBDE and decaBDE are less well-known, because analyses are often lacking, due possibly to analyses of highly brominated compounds being more complicated and requiring additional analytical stages.

Serious effects which can entail risks

According to preliminary assessments under the EU programme for existing substances, pentaBDE can entail a risk to aquatic and terrestrial organisms and, locally at least, can lead to secondary poisoning, e.g. of fish-eating birds or mammals.

Teratogenic effects on rabbit have been demonstrated in the case of octaBDE and decaBDE as well as hexaBB. Hormonal levels in the thyroid gland are affected by pentaBDE and hexaBB. Liver tumours in rat have been caused by decaBDE and hexaBB.

During the past year, new data have been obtained which indicate behavioural effects on mice. A single, very small dose of tetraBDEs and pentaBDE given to newborn mice has been found to affect these animals' behaviour in adulthood. In similar animal experiments, PCB has also affected the animals' behaviour in the same way as PBDEs, and in the case of PCBs these effects are accompanied by biochemical changes in the brain of the experimental animals. In the case of PCB there is strong evidence that the behavioural effects induced in experimental animals can also occur in human beings. In addition, it is possible that the effects of these persistent compounds on the brain may be additive.

Restriction of individual commercial mixtures is not enough

Thus individual commercial PBDE mixtures can give rise to several serious effects. OctaBDE and decaBDE uptake in living organisms proceeds slowly through the food. The accounts of decaBDE in blood samples show that decaBDE can be absorbed by inhalation. Critical for the fate of highly brominated diphenyl ethers in the environment is the possibility of debrominating them to less brominated compounds. If this happens, it means that administration of the highly brominated diphenyl ethers indirectly contributes to rising concentrations of the lower-brominated compounds. Debromination can occur under the influence of sunlight. It is not impossible that anaerobic debromination also takes place with the aid of microorganisms. The degree of debromination hinges on several factors, e.g. the time it takes for the microorganisms to start up the enzyme systems, and the concentration of diphenyl ethers.

There are great similarities between less brominated PBBs such as hexaBB and certain PCB compounds as regards biological effects, chemical structure and occurrence in the natural environment. If, therefore, decaBB are debrominated to less brominated PBBs of this kind, there is a risk of injuries, resembling those which PCB has caused, occurring in human beings and in the environment.

Conclusion

The less brominated technical PBDE compounds, mostly containing pentaBDE, are persistent, bio-accumulative and toxic in the aquatic environment. They present effects above all on the liver, but also on thyroid hormone, and they have behavioural effects on mice. They occur widely in the environment, in human blood and in mother´s milk. The highly brominated compounds included in technical octaBDE and decaBDE are persistent, have effects on reproduction and can cause tumour formation in the liver. There are data to corroborate the suspicion that these compounds can be transformed into less brominated compounds.

Lower-brominated PBB compounds have high toxicity and produce effects resembling those of chlorinated dioxins and PCB. Just as with PBDEs, it is suspected that decaBB, the PBB compound used technically, can be transformed into lower-brominated biphenyls.

The above are strong reasons for hastening the phase-out of PBDEs and PBBs as groups.

6.2 Choice of direction for continued phase-out

There are several paths on which the ongoing phase-out of PBDEs and PBBs can continue. The present phase-out strategy implies continuing efforts on a voluntary basis, coupled with action through international bodies. There is much to suggest that a new strategy is needed so as to accelerate the phase-out.

Present strategy

Voluntary measures at national level

The business organisations which have taken part in the Inspectorate's reference group have expressed strong desires for the phase-out to continue on a voluntary basis. They have not been able, however, to present figures showing how large a proportion of PBDEs or PBBs have been phased out or concrete plans for a continuing phase-out resulting in far-reaching abolition.

The main advantage of voluntary measures continuing is that firms can gain competitive advantages by incorporating environmental thinking in their production from an early stage. Other firms in the same line of business will then follow suit. Then again, voluntary measures do not give rise to technical trade barriers.

Voluntary measures - like the measures previously taken in the textile industry, for example - may have a good chance of succeeding, but there are certain favourable preconditions which need to be in place. In the present instance, the following adverse circumstances are involved.

The questionnaire survey which the Inspectorate conducted during the autumn of 1998 indicated a lack of knowledge as to which products can contain PBDEs or PBBs. There are several possible reasons for this. The main one, probably, is that Swedish importers have difficulty in obtaining this information from their foreign suppliers, but also that companies are not in the habit of thinking in terms of where in the product chemicals may be present which may be hazardous from the viewpoint of health or the environment.

There are several ways in which business enterprises can pursue the phase-out of PBDEs and PBBs on a voluntary basis. Commitments by individual enterprises or business organisations are one such example. One important drawback is that commitments of this kind have to be made by many players in the market, since the use of PBDEs and PBBs is so widespread. This is labour-consuming. Ongoing information and dialogue are needed, and the question has to be continuously debated in the media etc. if new suppliers are also to have a chance of finding out about the commitment. Since full coverage cannot be achieved through the business organisations, the commitments need to be made by individual firms.

Another drawback is that in many cases it is the behaviour of subcontractors at the very bottom of the production chain that needs to be influenced. When those subcontractors are located in the Asian countries, the Swedish importer has difficulty in gaining a hearing.

Furthermore, a commitment is not legally binding in the sense that action can be taken against a defaulting party. Experience has shown that not everyone lives up to commitments. This can lead to a distorted competitive situation, where firms opting to abide by the settlement thereby place themselves at an economic disadvantage. Vigorous action is hard to achieve on the basis of a purely voluntary commitment.

Firms have been aware for several years of the need to find alternatives for PBDEs and PBBs. A good many measures have been taken already. For example, partly with the aid of environmental product declarations, PBDEs have been phased out of casings for computers etc. To be able to declare that the product does not contain PBDEs or PBBs, firms have to make demands on their suppliers. Those demands mean that the casings and components for computers, copying machines, fax transceivers etc. must not contain PBDEs or PBBs. Another means of bringing pressure to bear is to stipulate, as many local authorities are now doing, the exclusion of brominated flame retardants from office machinery, furniture and textiles. The European motor industry is jointly involved in a project where alternative chemicals are being tested in the electronics for an experimental vehicle. The results of these tests may take several years to come through.

Despite the measures which have already been taken, exposure to PBDEs and PBBs has not ended. There has been a certain phase-out of these substances, but the Inspectorate does not consider it sufficient to counteract, for example, the rising concentrations of PBDEs in mother´s milk. More and more products contain electronic components, and this can lead to several new applications, thus augmenting the spread of products which may contain PBDEs and PBBs. Inadequate information from foreign suppliers makes it difficult for Swedish firms to pursue the national phase-out much further on a voluntary basis.

International work

Previously, under the aegis of OSPAR and the OECD, Sweden has actively campaigned for a phase-out. The work of the OECD at present involves discussions of how industry has performed on its commitment to reduce the risks of PBDEs and PBBs. This commitment does not include a phase-out. Within the EU, this work is being conducted under the programme for existing substances. Sweden has contributed to the PBDE evaluation work of the UK and France and is taking part in the discussion of risk assessments at Community level. Meanwhile no work is in progress within OSPAR. PBBs are not at present a subject of investigation or practical discussion within the EU and, consequently, are not automatically included on the agenda.

It is impossible, on the basis of the work now in progress under the programme for existing substances, to judge the extent to which a risk management strategy may lead to a ban on the use of all commercial PBDE mixtures. Besides, it could take a long time, anything up to ten years, for such a prohibition to begin taking effect. This is the time needed for discussions in order to agree on risk assessment and risk management strategy, for further drafting, including discussions under the Directive 76/769/EEC, relating to limitations on marketing and use, and for the introduction and entry into force of a ban on use. During this time, for example, the concentration in mother´s milk can quadruple, given the present growth rate.

In addition to restrictions on use, other measures such as emission limits or waste disposal stipulations may need to be considered. Neither disposal at the waste stage nor emission-limiting measures, however, will prevent the influx of these substances to Sweden or exposure during the utilisation phase. Nor are these measures sufficient for quickly guaranteeing an end to the diffuse discharge of these substances into the environment.

New strategy

A new strategy is justified by the various measures presented in 6.1 and by the difficulty of influencing, through voluntary phase-out, the importation of PBDEs and PBBs through products. The Inspectorate's survey shows that goods containing PBDEs or PBBs are to a great extent manufactured outside Europe. This points to the need for widespread international action. Mandatory rules at national level should therefore be combined with contacts with organisations and national authorities in other countries, both in Europe and elsewhere.

National ban with co-operation at EU level

A ban entering into force in a few years' time will come as a very distinct signal to business enterprises to step up the pressure on their foreign suppliers. Even though Sweden, globally speaking, is a small market for electronics, demands by the Swedish importers will result in these substances being put on the agenda for reasons of health and environment protection. Pressure from Swedish importers can be expected to speed up developments. It will carry more weight if it is based on statutory requirements. In 1982, for example, Sweden banned cadmium, and this led to a development of alternatives and a reduction of cadmium use in other countries as well.

A ban generates knowledge of previously unknown applications, as witness, for example, the experience gained from regulations on mercury.

If the ban is accompanied by penal sanctions, this can have a deterrent effect and also compel other business enterprises to take action.

Notification of a Swedish prohibition can have a pushing effect on the work of the EU. Any ban on the use of PBDEs and PBBs, in order to have any real impact, will have to be introduced at EU level. Sweden should therefore co-operate with other Member States and work for the introduction of a ban on use within the EU as quickly as possible. The Swedish market is too small to be able to prevail on non-European suppliers to any great extent to find alternatives. The larger European market has a much better chance of bringing pressure to bear on suppliers in Asia and elsewhere.

Although the business organisations would prefer to continue the phase-out on a voluntary basis, they do not object to a prohibition if it can be introduced at EU level.

PBBs are not at present a subject of investigation or practical discussion within the EU. Notification of a Swedish ban on the use of PBBs can be a way of getting this issue on to the agenda.

There are also disadvantages to proposing a national ban. If the EU programme for existing substances arrives at other risk-limiting measures or a ban on use which are less far-reaching, Sweden may be forced to reconsider the construction of its national prohibition.

Another question is whether such a prohibition - coming at a time when work is in progress in the EU under the existing substances programme - might in some way affect Sweden's future prospects of securing understanding for national measures. There is no simple or straightforward answer to this question.

The Government's Environment Policy Bill 1997/98:145 declares intentions of increasing the participation of agents in the market. This expedient has been used and has resulted in the phasing out of PBDEs and PBBs in the textile industry and from covers and casings for computers, for example. An extensive phase-out, on the other hand, is difficult to achieve on a voluntary basis, due not least to flame-retarded components/products passing through a long sequence of intermediaries with many players in different countries, and also to their having an immense number and variety of uses.

Enforcement will be difficult. In order to verify compliance, it must be possible to analyse whether PBDEs or PBBs are present in the products. There are simple analytical methods for detecting bromine, but the detection of different bromine compounds is more difficult. Further methods development will be needed before analyses of this kind can be performed on a routine basis. Supervisory activities can also be made to concentrate on verifying that firms have an effective system of internal control. In addition to a firm's own analyses, this system can be based on certificates from the foreign suppliers.

Influencing countries outside the EU

At international level, Sweden should in various ways actively endeavour to achieve a real impact for phase-out, especially on markets of importance for the inflow of PBDEs and PBBs to Sweden through product imports. Suitable strategies need to be defined for this work. Ways of influencing developments include, for example, direct contacts with national authorities and other organisations in strategic countries, with regional organisations for important markets outside the EU, and with international organisations in which Sweden is already active.

Conclusion

Experience of the work undertaken by the National Chemicals Inspectorate for several years now has shown that the voluntary approach is slow and prodigal of resources, due to the presence of so many different players in the market. In addition to Swedish activities, both international bodies and individual European countries have for about ten years now been pursuing questions relating to brominated flame retardants. And yet there is still a great deal of exposure to PBDEs and PBBs, resulting among other things in rising concentrations in mother´s milk. Even if voluntary national work is combined with active participation in various international fora, above all within the EU, the Inspectorate believes that PBDEs and PBBs will not be phased out quickly enough.

As regards the EU programme for existing substances, it is unclear at present when the risk assessments will be ready and what the conclusions will be. Sweden has contributed to the risk assessments, partly by supplying newly acquired knowledge concerning occurrence in mother´s milk and concerning lasting behavioural effects on experimental animals after exposure at a very early age. Even if the risk assessment leads to the conclusion that risk-limiting measures are needed in the form of a ban on the use of PBDEs, it can take a long time, perhaps anything up to ten years, for such a prohibition to be introduced and implemented by the Member States.

A new strategy is called for by the aggregate health and environmental risks which have been shown and by the difficulty of influencing importation of PBDEs and PBBs in products by means of a voluntary phase-out. Most of the products containing PBDEs or PBBs are imported, and a broad-based policy package is therefore needed which will not only aim at restricting national use but will also ensure that foreign suppliers can offer alternatives. In addition to co-operation at EU level, contacts are needed with national authorities and organisations representing manufacturers, above all in the USA and Asia.

A ban entering into force in a few years' time will come as a very distinct signal to business enterprises to step up the pressure on their foreign suppliers.

6.3 Framing a regulation

A ban can be framed in two different ways, either as a general prohibition of all use, or as a prohibition referring specifically to the various applications. In an EU perspective, it is important to consider the impact of both alternatives on implementation of the proportionality principle, which says that the restrictions must not affect the free movement of goods more than is necessary for the achievement of their purpose.

General prohibition

A prohibition of all use has been the traditional approach in Sweden. The main advantage of this approach is its clarity. The prohibition applies to all fields which are not expressly excluded.

A general prohibition will require the empowerment of a national authority to issue provisions on general exemptions. The list of exemptions in the provisions is liable to be a long one, emasculating the prohibition. Problems of interpretation can arise regarding the scope of the exemptions. This can impair the clarity of the prohibition. The list will identify areas in which viable alternatives have not yet been developed. For example, it is uncertain how much progress foreign suppliers of electronics components will have made in replacing PBDEs and PBBs within the transitional period. The same uncertainty applies to certain interior fittings in imported cars. If the problems persist or if unforeseen problems arise after a prohibition has entered into force, there should be a faculty for granting exemptions for limited periods. A balance will need to be struck here, however, so that exemptions do not undermine the prohibition or seriously delay its implementation. The same applies to any individual exemptions. The European Commission may come to demand an account of the fields for which general or individual exemptions can be made.

A general prohibition will also include areas which are of minor importance from the viewpoint of risk but where replacement nonetheless entails heavy expenditure. This can give rise to objections that the prohibition does not meet the requirements of proportionality.

Prohibition of specific applications

A common approach in EU work with the Directive 76/769/EEC, relating to limitations on marketing and use, is instead to concretise a prohibition with reference to particular fields of application. Small specific fields which are of minor importance from the viewpoint of risk and would entail unjustifiable expense are not included in the prohibition list. This technique reduces the need for a list of exemptions. Enumeration of the fields in which the substances may not be used makes the regulation more transparent and predictable compared with a general ban accompanied by possibilities of exemption, and therefore will probably have more chance of acceptance within the EU than a general prohibition. It is then easier for the enterprises concerned to see how their products will be affected by the regulation.

If this method is applied, the areas of use should be defined so as to cover all fields that are known to make a significant contribution to exposure. Applications of this kind include, for example, electrical and electronic components, covers and casings for electrical and electronic equipment, cables, apparatus containing electrical and electronic components, textiles, upholstery and padding for furniture, vehicles, vehicle fittings and insulation or lagging round pipes of different kinds. Guidance on the definition of these fields can be obtained from existing fire safety requirements. From an official point of view, specified areas will facilitate supervision, give rise to fewer problems of interpretation and concentrate attention more on certain specific branches of activity.

In certain cases, areas where use has not been confirmed may also need to be included. This applies, for example, to toys, which are often labelled as being flame-proof. There are no data suggesting the occurrence of PBDEs and PBBs, but from the point of view of risk it is important that substances of this kind should be prevented from occurring in toys.

The disadvantages of this method are that the list of prohibitions can be a long one and may include fields both large and small. The prohibitions will focus exclusively on the fields which are known today, with the result that the prohibition list and with it the regulation must be amenable to revision in the event of further applications being revealed.

Entry into force

A suitable timing for entry into force can be within a five-year period. The five years preceding the entry into force date are necessary to give foreign suppliers time to develop feasible alternatives for applications where alternatives are at present lacking.

A prohibition referring to specific areas of use is no guarantee that individual exemptions will not be needed. The groups of products which, in the light of present-day knowledge, can pose problems are electrical and electronic components together with apparatus and vehicles in which they are included. Cables which have to withstand high temperatures may be another problem area. In cases of this kind, the regulation should be framed with different entry into force dates, so as to avoid a time-consuming exemption procedure.

Conclusion

A regulation which is transparent, distinctly prohibits certain areas of application and allows few exemptions should be opted for, as having greater chance of acceptance in a European perspective.

7. CONCLUSIONS AND PROPOSALS

After factoring in the results of several years' voluntary efforts, the National Chemicals Inspectorate does not believe that the phase-out process can be pursued far enough on a purely voluntary basis. Swedish industry has made a great deal of headway in its abolition of PBDEs and PBBs, but it is imports through products, not least from markets outside the EU, that still constitute a problem. This argues the need for a new phase-out strategy of a more dynamic nature, at both national, EU and international levels, to halt the flow of PBDEs and PBBs into Sweden.

At national level, specified areas of use should be prohibited. This is judged necessary, not least as a strong message to the market and as a means of hastening discussions of common rules within the EU. A suitable juncture for the entry into force may be within a five-year period from the notification date. The five years preceding the entry into force date are necessary to give foreign suppliers time to develop feasible alternatives for applications where alternatives are at present lacking.

In the context of EU co-operation with other Member States, Sweden should actively endeavour to bring about a ban on use at EU level as soon as possible. The EU market is far greater than the one per cent or so constituted by Sweden of the global market for electronic components, and can thus exert greater pressure to obtain a phase-out.

Sweden, then, should not await the final outcome of work now in progress under the EU programme for existing substances, considering the long time it can take for that work to be capable of resulting in an operational ban on use. In the work now in progress for a directive on waste from electrical and electronic equipment, Sweden should continue to press for the directive to be framed so as to contribute towards a phase-out of PBDEs and PBBs.

At international level, Sweden should in various ways actively endeavour to achieve a real impact for phase-out, especially on markets of importance for the inflow of PBDEs and PBBs to Sweden through product imports. Suitable strategies need to be defined for this work. Ways of influencing developments include, for example, direct contacts with national authorities and other organisations in strategic countries, with regional organisations for important markets outside the EU, and with international organisations in which Sweden is already active.

Proposals

- A ban, referring to specified areas of use, on the sale, supply or use of PBDEs or PBBs should be introduced in Sweden. The professional sale or supply of products containing or treated with these substances should not be permitted. A suitable juncture for entry into force is within a five-year period from the notification date.
- Through contacts with other Member States and through its participation in the work of the EU, Sweden should continue its active efforts to bring about a ban on use at EU level as soon as possible.
- Sweden should also actively endeavour to bring about a far-reaching phase-out also in other markets which are important suppliers of PBDEs and PBBs. This can be done through direct contacts with strategically important countries, through regional bodies and through the work of international organisations.

8. CONSEQUENCES

8.1 Health and the environment

A prohibition will compel the creation of alternative methods or products, which in turn will reduce exposure to PBDEs and PBBs. This will also mean a reduction of human exposure through inhalation, food and mother´s milk, as well as a reduction of the negative effects which this exposure can lead to. The actual reduction cannot be quantified.

Since, however, PBDEs and PBBs are built into products which continue to be used for several years, it will be some time before the effect of a prohibition can be demonstrated. These substances also reach Sweden in the form of long-range, transboundary airborne pollution, which will not be affected by a Swedish ban on use.

PBDEs and PBBs are likely to be replaced, not by single alternatives but by a large number of different substances. Exactly what substances are substituted will depend on applications and materials. In the case of materials which have to withstand high temperatures, it is not impossible that other halogenated flame retardants will come to be used. Information concerning possible alternatives is very limited at present, which makes it hard to judge any negative properties which those alternatives may possess.

8.2 Other chemical options

The availability of alternatives varies, according to the applications involved. The applications where most headway has been made in finding alternatives are the use of PBDEs for the covers and casings of computers etc. and in cables. First-time use in covers and casings has been virtually discontinued as a result of voluntary measures in the IT industry.

Even if alternatives are available, the transition may be impeded by the technical requirements of standards. As a result of product development, for example, electrical and electronic equipment no longer has the same heat emission as it used to. This means that less flame retardant needs to be added. If the requirements of standards do not keep up with this development, this can result in the product being manufactured with more flame retardant than is necessary.

Swedish industry is progressing towards a replacement of PBDEs and PBBs in its own manufacturing. For example, PBDEs are no longer used in the Swedish textile industry. Swedish manufacturers of standard cables aim to discontinue the addition of PBDEs after 1st January 2000. Uncertainty surrounds special-purpose cables, such as those intended for temperature measurement in smelting plants, but the industry anticipates that technical solutions to these problems will also be available within a five-year period, in which case practically all imports of PBDEs as pure substance can be discontinued. The IT industry has reduced its use of PBDEs and PBBs in covers and casings by means of environmental product declarations.

One application where alternative flame retardants have not achieved much impact is imported plastic capsules surrounding electronic components. Most assembly and capsulation of electronic components is done by a few business enterprises in Southeast Asia. Those enterprises cater to most of the international electronics market, and thus have little competition to face. The willingness of the existing enterprises to invest in the development of new methodology or new products hinges on demand. In this connection the Swedish electronics market is a small one. Because Swedish importers are dependent on their foreign suppliers, it is possible that the supply of alternatives which are acceptable in terms of technical performance and price will not be sufficient at the time of the prohibition entering into force. If so, this will adversely affect Swedish suppliers of electronic equipment, dependent as they are on a ready supply of components.

Imported cars are treated to varying extents with PBDE and PBB flame retardants. Sweden accounts for only one per cent or so of the international vehicle market, and thus has little chance of influencing motor manufacturers in Asia and the USA. A prohibition excluding imports of cars from these continents, which account for nearly one-third of Sweden's vehicle fleet, will be unenforceable.

8.3 Economic consequences

It has not been possible to obtain documentation from the business enterprise sector on which to base a quantification of the economic consequences. Additional expenses can occur at several stages. These will affect fields where feasible alternatives are at present lacking. Development costs will probably affect the alternative products, at least to begin with, until the market has steadied and demand has begun to rise in consequence. On the other hand, this will not mean any expensive changes of process for companies buying finished products. At a rough estimate, an alternative flame retardant can cost twice as much as a PBDE. The price of the plastic capsule itself is estimated at only one per cent or so of the total price of an electronic component. The Swedish motor industry estimates the cost per vehicle of abolishing PBDEs and PBBs in printed circuit boards alone at about SEK 1,000.

Swedish importers will have to introduce purchasing routines to ensure that the imported goods are free from PBDEs or PBBs. Those routines may necessitate analysis of the products, if adequate information is not obtainable from the supplier. This can involve the Swedish importer in additional expenditure, especially if the technical specifications require compliance with fire safety code UL94 V0.

A unilateral Swedish prohibition can create difficulties above all for smaller firms, partly because they have less chance than large firms of influencing their foreign suppliers. At worst they face, for example, being deprived of certain electronic components and may be forced to go out of business altogether or to discontinue the activity depending on these components, which in turn can have economic consequences in the form of redundancies. In the case of applications where PBDEs or PBBs are absolutely indispensable, this problem can be overcome by means of a fixed-term exemption.

Companies importing electronics containing PBDEs and PBBs and then re-exporting them in finished products will not be affected, since the prohibition does not apply to imports and exports.

Companies will have to introduce internal control so as to ensure that their products do not contain PBDEs or PBBs. This internal control can be based on their own analyses and on certificates from the foreign suppliers. Analysis in particular entails additional expenditure. Internal control is necessary in order for the authorities to be able to carry out their duties of supervision.

GLOSSARY

Substance name

PBDEs	polybromerade diphenyl ethers
decaBDE	dekabromo diphenyl ethers
nonaBDE	nonabromo diphenyl ethers
octaBDE	oktabromo diphenyl
heptaBDE	heptabromo diphenyl ethers
hexaBDE	hexabromo diphenyl ethers
pentaBDE	pentabromo diphenyl ethers
tetraBDE	tetrabromo diphenyl ethers
PBBs	polybromerade bifenyler
decaBB	decabromo biphenyl
nonaBB	nonabromo biphenyl
octaBB	octabromo biphenyl
heptaBB	heptabromo biphenyl
hexaBB	hexabromo biphenyl
tetraBB	tetrabromo biphenyl
PCBs	polychlorinated biphenyls

Other terms

BCF	Bioconcentration factor
BFRIP	Brominated Flame Retardant Industry Panel
CLRTAP	Convention for Long Range Transport of Airborn Pollutants
DIFF	Working Group on Diffuse Sources
EBFRIP	European Brominated Flame Retardant Industry Panel
EU	Europian Union
MISTRA	Foundation for Strategic Environmental Research
NOAEL	No Observed Adverse Effect Level
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo and Paris Conventions for the Prevention of Marine Pollution
PARCOM	Paris Convention for the Prevention of Marine Pollution
POPs	Persistent Organic Pollutants
TCO	The Swedish Confederation of Professional Employees
UL	Underwriters Laboratories, USA
UN	United Nations

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