Risk Reduction Strategy and Analysis of Advantages and Drawbacks for Octabromodiphenyl Ether

Final Report

Prepared for
Department for Environment, Food
and Rural Affairs

Contract Reference: 16/13/33

RPA

June 2002

OCTABROMODIPHENYL ETHER

RISK REDUCTION STRATEGY AND ANALYSIS OF ADVANTAGES AND DRAWBACKS

FINAL REPORT

June 2002

prepared for

Department for Environment, Food and Rural Affairs

by

Risk & Policy Analysts Limited,
Farthing Green House, 1 Beccles Road, Loddon, Norfolk, NR14 6LT, UK
Tel: +44 1508 528465 Fax: +44 1508 520758
Email: post@rpaltd.demon.co.uk
Web: www.rpaltd.co.uk

RPA REPORT - ASSURED QUALITY	
Project: Ref/Title	J355I/Octa
Approach:	In accordance with tender specification, RPA proposal and Steering Group input
Report Status:	Final Report
Prepared by:	Caspar Corden, Consultant Meg Postle, Director
Approved for issue by:	Meg Postle, Director
Date:	24 June 2002

If printed by RPA, this report will be printed on 100% recycled, chlorine-free paper

EXECUTIVE SUMMARY

1. Introduction

Under Regulation 793/93/EEC, octabromodiphenyl ether is a priority substance for risk assessment and, where necessary, risk management, at the European Union level. The UK and France are jointly responsible for addressing the risks associated with octabromodiphenyl ether (for the environment and human health respectively).

Both the human health and environmental risk assessments have identified areas where there is a need for risk reduction. Furthermore, both have identified areas where there is a need for further information and/or testing and, given the uncertainties, where there may be a need for precautionary action to be taken to reduce the risks.

The Department for Environment, Food and Rural Affairs (DEFRA) has contracted Risk & Policy Analysts Limited (RPA) to develop the risk reduction strategy for octabromodiphenyl ether. The present report is the Final Report on the study, recommending the risk reduction strategy formulated during the course of the project.

2. The Risks of Concern

There are two areas where a definite need for risk reduction measures - conclusion (iii) - has been identified in the draft risk assessments for human health and the environment (subject to any further changes).

Firstly, for the environment, there is a risk for secondary poisoning via the earthworm route for the hexabromodiphenyl ether component in the commercial product. This is related primarily to the settling out of dust during the mixing stages of polymer processing and subsequent washing down of floors and equipment to waste water. This leads to the deposition of octabromodiphenyl ether on soil through sewage sludge into which the substance is partitioned.

Secondly, in relation to human health, there is a risk relating to systemic, developmental, female fertility and local toxicity, resulting from repeated inhalation and dermal exposure to octabromodiphenyl ether as a dust in the workplace (although local toxicity only relates to inhalation exposure). This risk arises during bag emptying as part of compounding and master batching activities. Whilst worker protection measures are likely to be in place already, it cannot be confirmed that these are universally applied.

Additionally, there are several areas where a need for further information and/or testing has been identified, relating to both human health and environmental risks. For these areas, it has been concluded that there is a possible need for precautionary action and that consideration should be given at a policy level to investigating risk management options now in the absence of adequate scientific knowledge. Key concerns for the environment are the suitability of the current risk assessment approach for secondary poisoning and the possible debromination of octabromodiphenyl ether in the environment.

For human health, there are concerns regarding the presence of octabromodiphenyl ether (and lower congeners in particular) in breast milk and subsequent breast feeding and also for prolonged exposure. This also relates to humans exposed to the substance via the environment, from all life-cycle stages including in-service use and disposal of products.

At the first Steering Group meeting in December 2001, it was agreed that consideration should be given in the risk reduction strategy both to measures that will target the areas where there has been identified a definite need for risk reduction and also to measures that would target the possible risks for which there is a need for further information and/or testing.

Therefore, the study has considered a number of risk reduction options that could address those areas where there is a definite need for risk reduction (for health and the environment) and also those where the need for risk reduction is less clear. Any decision taken upon the need for implementing measures to address the latter would ultimately be a political one. Thus, the aim herein has been to identify the possible implications of risk reduction measures in order to provide a basis for any such decision.

For the environment, where a definite need for risk reduction has been identified[1], the concern relates predominantly to emissions at the local level. However, for the areas where there is less certainty about the conclusions, the full range of environmental emissions need to be taken into account. Diffuse sources, particularly during the service life and from 'waste remaining in the environment' contribute more than polymer processing to total emissions at the regional and continental level. Risk reduction measures considered for the areas where less certainty exists have, therefore, been wider in scope than for the area where a definite need for risk reduction has been identified. This also applies to the potential measures considered to address the human health concerns.

3 Summary of Markets for Octabromodiphenyl Ether

Table 1 summarises data on the quantities and values of octabromodiphenyl ether sold in the EU, the flame-retarded plastics in which it is used and the final electrical and electronic equipment products. The data include total estimated usage of octabromodiphenyl ether, including that imported to the EU within products.

4. Availability of Substitutes for Octabromodiphenyl Ether

Table 2 presents information on the suitability of various alternatives to octabromo-diphenyl ether in terms of technical performance, health and environmental risks and cost implications. It should be noted that this table is based upon the *available* information, which in many cases is significantly less than that for octabromodiphenyl ether.

1 Relating to secondary poisoning via the earthworm-based food chain for the hexabromodiphenyl ether congener released to waste water mainly during use in polymer processing.

Table 1: Summary of Estimated Market Data for Octabromodiphenyl Ether		
	Quantity	**Value (€m)**
Octabromodiphenyl ether	1,350 tpa [a]	4.9
ABS containing octabromodiphenyl ether	9,000 tpa	12.5 [b]
E&E products containing ABS with octabromodiphenyl ether	3,000,000 (#)	900

Notes: [a] *Only around 450 tpa imported as the substance itself, with remainder in polymers.*
[b] *Value of ABS assumed at €1 per kg, with octabromodiphenyl ether at €3.6 per kg and used at a concentration of 15% w/w. # = number of items.*

Based upon this analysis, there are alternatives to octabromodiphenyl ether available for which existing data do not indicate an equivalent or higher level of risk to health or the environment. This is especially true of reactive type flame retardants that will have significantly lower emissions during the service life of products.

However, for all of the potential substitutes identified, the existing data on toxicological and ecotoxicological effects are fewer than for octabromodiphenyl ether. Given that none of these substances have yet undergone a risk assessment as rigorous as those carried out under ESR, it is inevitably not possible to compare the risks on a like-for-like basis (and thus to assure absolutely that substitution would result in an overall reduction in risks to health and the environment). The results of the further testing and assessment that is ongoing for some of the potential substitutes should help to resolve the differences in data availability to a degree.

Nonetheless, based on the information presented in Annex 3, it is evident that some of the substances do have data available on some of the key endpoints of concern for octabromodiphenyl ether (e.g. developmental toxicity) and that these indicate lower toxicity.

There are also other options for replacing octabromodiphenyl ether, without utilising a substitute flame retardant. These include redesign of the electrical or electronic products or use of polymers with lower rates of combustion. Whilst we have inadequate data to estimate the likely costs of such techniques, it is considered that they are likely to be more expensive than using octabromodiphenyl ether in most cases (at least in the short-term).

It would appear that most of the substitution options could result in some adverse cost implications. This is true both of substitutes for octabromodiphenyl ether where used in ABS (except for TBBPA) and also for alternatives that would require substitution of the polymer as well (such as ABS for PC/ABS blends).

5. Identification and Assessment of Possible Risk Reduction Measures

A number of potential risk reduction measures were identified during the previous stages of this study. The following options have been considered for the present report:

Table 2: Summary of Potential Substitution Options Compared to Octabromodiphenyl Ether

Substance	Potential Health Risks [a]	Potential Environmental Risks [a]	Cost and Other Considerations
Tetrabromobisphenol-A [b]	No evidence of equal or greater risks	Data indicate may be classified as 'very toxic to aquatic organisms, may cause long term adverse effects in the aquatic environment' [c]	Less expensive but greater FR loading required. ESR risk assessment ongoing and concerns expressed about substance in some member states
1,2-bis (pentabromophenoxy) ethane [b]	No evidence of equal or greater risks	PBT properties appear of less concern than octa. However, fewer data and BCF values questioned	More expensive
1,2-bis (tribromophenoxy) ethane [b]	No evidence of equal or greater risks	Very limited data	Greater FR loading probably required
Triphenyl phosphate	No evidence of equal or greater risks	High toxicity and relatively high potential for bioaccumulation but is readily biodegradable	Less expensive but polymer/FR system expected to be more expensive overall. Poorer plastic recyclability
Resourcinol bis (diphenylphosphate)	No evidence of equal or greater risks	Acutely toxic or very toxic but biodegradable	Less expensive but polymer/FR system expected to be more expensive overall. Poorer plastic recyclability
Brominated polystyrene	No evidence of equal or greater risks (but some concerns expressed re: impurities in commercial product)	No data but losses and exposure expected to be lower	Slightly more expensive

Notes: [a] *Note that in most cases, the information available on toxicological and ecotoxicological effects is less than that for octabromodiphenyl ether.*
[b] *Can be used in ABS as well as other polymers. Other flame retardants listed are not suitable for use in ABS (see Table 5.1).*
[c] *Note that in-service losses will be lower where used as reactive FR in non-ABS polymers.*

- restrictions on the marketing and use of octabromodiphenyl ether;
- legislation to reduce environmental emissions from polymer processing;
- reducing the concentration of lower brominated congeners in the commercial product;
- worker protection measures resulting from classification and labelling;
- reducing the application of sewage sludge containing octabromodiphenyl ether to land; and
- economic instruments as a means of providing users with an incentive to move away from octabromodiphenyl ether.

These options have been assessed against four key decision criteria: their effectiveness, practicality, economic impact and monitorability. Tables 3a and 3b summarise the results of this assessment.

6. Proposed Risk Reduction Strategy

Overview

As indicated above, there are areas where the environmental and human health risk assessments have identified a definite need to reduce the risks associated with the use of octabromodiphenyl ether. Additionally, for both human health and the environment, there are several areas where a need for further information and/or testing has been identified and the concerns for these areas are such that there is a possible need for precautionary action. Thus, it was decided by the risk assessors that consideration should be given at a policy level to the need to investigate risk management options now in the absence of adequate scientific knowledge.

Therefore, the steering group for this project considered two possible risk reduction strategies for addressing the risks, based upon the Stage 3 report. The first possible strategy is that which represents the best balance of advantages and drawbacks in addressing the areas where conclusion (iii) has been reached and the second represents the best balance where conclusion (i) has also been reached.

Possible Strategies Considered

Based upon the assessment of possible measures, there is a number of options that could address the risks to human health and the environment. Of these, the option providing the best balance of advantages and drawbacks for reducing the conclusion (iii) risks appears to be for octabromodiphenyl ether to be supplied in a non-powder form. This would significantly reduce the generation of dust during polymer processing and, therefore, should reduce both risks to human health and to the environment.

It is understood that the supplier of octabromodiphenyl ether to the EU market could work with their customers to provide the substance in this form and that this could be done without incurring disproportionate costs.

This option would reduce the risks to an acceptable level without there being costs incurred to the same level as would be experienced under marketing and use restrictions (a ban). The outcome is more certain than reduction of environmental emissions through measures adopted under the Water Framework Directive or through reducing the concentration of lower brominated congeners (and these two measures do not directly target the human health risks[2]). Other worker protection measures that may be adopted as a result of a revised classification and labelling would not be certain of addressing the environmental risks (for example, if companies decided to use personal protective equipment, with losses to the environment not reduced). Likewise, introducing restrictions on spreading sewage sludge on land where the concentration of octabromodiphenyl ether is above a certain limit would only address the environmental risks and could result in significant costs.

In order to partially address the areas where the need for risk reduction is less clear (where conclusion (i) has been reached), the above measure could be combined with an economic instrument in the form of an input-based product charge. This would encourage companies to move away from use of octabromodiphenyl ether where it is financially viable to do so.

In relation to the areas where there exists considerable uncertainty regarding the need for risk reduction, the only means by which the risks could be reduced to an 'acceptable' level would be to ensure that no emissions of the substance to the environment occur and that no human exposure takes place[3].

There are only two measures that would ensure that the environmental risks associated with octabromodiphenyl ether are reduced accordingly. A ban through marketing and use restrictions would prevent any environmental emissions from occurring as a result of the substance no longer being used in the EU. Alternatively, if octabromodiphenyl ether were to be classified as a priority hazardous substance under the Water Framework Directive, a cessation or phase-out of discharges, emissions and losses would be required, thus reducing the risks to an acceptable level (since there could effectively be no entry into the environment).

However, measures under the WFD would not necessarily address all of the human health issues and could potentially take over 20 years to address all of the concerns[4]. Therefore, the only measure that could address all of the areas where a potential need for precautionary action has been identified would be a ban through marketing and use restrictions (given that it is not possible to identify an 'acceptable' level of risk for these concerns). The potential costs to EU industry of this strategy have been estimated at around €7.5 to €12 million over five years. If these increased costs were passed on to the

---

2 Although the former is expected to take into account humans exposed via the environment in the procedure for setting quality standards for Priority Substances (formal proposals are expected in autumn 2003).

3 Since it has not been possible for the risk assessment to reach a quantitative estimate of the risk, it is not possible to provide an estimate of the degree to which emissions would need to be reduced in order to remove the concern.

4 Under the WFD, the timetable for cessation of discharges, emissions and losses is within 20 years of the adoption of measures. However, Member States should aim for compliance with quality standards for all Priority Substances (including octabromodiphenyl ether), which would partially address the environmental concerns and some of the human health concerns.

consumer, the percentage increase in the average price of products would be between 0.19% and 0.30%, based on an estimated 3 million products on the market per year.

Recommended Risk Reduction Strategy

The results of this report will be taken into account by the UK and French Competent Authorities in recommending Community-level measures to reduce the risks associated with octabromodiphenyl ether.

In deciding upon the option to take forward, it has been necessary to take into account the strategy that represents the best balance of advantages and drawbacks for reducing the risks where a definite need for risk reduction has been identified (for secondary poisoning related to the hexabromodiphenyl ether congener and for worker protection). Additionally, it has been necessary to take into account the strategy that best deals with the areas where the need for risk reduction is less certain.

To address the first concern (conclusion iii areas), there are measures that could be implemented that potentially provide a better balance of advantages and drawbacks than a ban, especially given that the cost implications of such a restriction are not insignificant. However, in order to address all of the risks and potential risks (conclusion (iii) and conclusion (i) areas), it was decided by the steering group that a ban through marketing and use restrictions represents the best balance of advantages and drawbacks overall. Industry, however, did not agree that a ban on the substance was justified on the basis of the conclusion (i) areas.

It is therefore recommended by the majority of the Steering Group that the marketing and use of octabromodiphenyl ether be banned under Directive 76/769/EEC.

Table 3a: Summary of Advantages and Drawbacks			
	Ban on Marketing and Use	**Reduce Environmental Emissions**	**Reduce Conc. of Lower Congeners**
Effectiveness	Would reduce all risks for human health and the environment and would address areas where need for risk reduction is uncertain (conclusion i) and that where a definite need has been identified (conclusion iii). Suitable substitutes appear to be available.	Control as a PS could reduce conclusion (iii) risks to acceptable level. If octa classified as a PHS, all environmental risks could be addressed (since cessation of all discharges, emissions and losses would be required). Timeframe potentially over 20 years for cessation of discharges, emissions and losses.	Could address conc. (iii) risks for earthworm-based food chain if reduced by percentage said to be possible by supplier (however, risk assessment conclusions may change). Would not address human health risks or areas where conclusion (i) has been reached.
Practicality	Procedures well established in the EU. Controlling imports of finished products could be more problematic.	Procedures for implementing measures will be developed under the WFD.	Technically feasible for the supplier to reduce concentration from <12% to <8%.
Monitorability	Monitoring success amongst EU companies should be straightforward. Again, imports in articles are harder to monitor.	Procedures for monitoring success assumed to be developed under the WFD.	Relatively simple to monitor since only one supplier.
Economic Impact	**Suppliers**: Loss of sales of around €1.6m directly and €3.2m relating to master batch and finished products. However, would be offset by increase in sales of alternatives. **Compounders/master batchers/polymer processors**: Possible costs of substitution estimated at around €7.5 million over five years for cost of substitute and R&D. Could also be one-off costs for mould replacement (e.g. up to €5 million as an indicative estimate). Possible increase in product price of 0.19% to 0.30% if passed on to **consumers**. **Regulators**: Costs of developing legislation and ensuring compliance.	**Suppliers**: No direct costs expected since not produced in the EU. **Compounders/master batchers/polymer processors**: Costs of implementing measures uncertain (but will tend to be less than for M&U restrictions). Costs will be greater if classified as a PHS. **Regulators**: No additional costs since measures will already be developed.	**Suppliers**: Could reduce concentration in a cost-effective manner. **Compounders/master batchers/polymer processors**: Some costs associated with need for process modification but not thought to be prohibitive. **Regulators**: Costs associated with ensuring compliance.
Balance of Advantages and Drawbacks	Provides most effective means of addressing both conclusion (i) and conclusion (iii) risks/potential risks. However, cost implications may be disproportionate if only conclusion (iii) risks are to be addressed, given the lower cost effectiveness compared to some other measures.	Only addresses risks for the environment for conclusion (iii). Would not address the risks in a timely fashion.	Provides a cost-effective means of addressing risks for hexa congener via earthworm-based food chain but uncertain whether reduction in concentration possible would reduce risks to acceptable level (since risk assessment conclusions subject to change).

Table 3b: Summary of Advantages and Drawbacks (Worker Protection, Sludge Directive, Input-Based Product Charge and Tradeable Permits)				
	Worker Protection	**Sludge Directive**	**Input-Based Product Charge**	**Tradeable Permits**
Effectiveness	Measures introduced through revised classification and labelling could reduce conclusion (iii) risks for health to an acceptable level. Supply of octa in a non-powder form could reduce all conclusion (iii) risks for health and the environment to an acceptable level. Would not directly address conclusion (i) risks.	Would target risk of secondary poisoning for hexa congener - conclusion (iii) (but level of any limit value unknown at present). Could reduce secondary poisoning for conclusion (i) via the earthworm-based food chain but not to an 'acceptable' level.	Effectiveness will depend on rate at which charge is set; cannot be guaranteed to deliver risk reduction. Will address risks associated with use of octa in polymer processing, but will not necessarily address worker safety or conclusion (i) risks; although some reductions may take place owing to lower levels of usage.	Would place a restriction on the amount of octa that could be used and be linked to emission control and worker safety requirements. The latter would reduce the conclusion (iii) risks to an acceptable level. Provides for some certainty compared to other economic instruments. Would not directly address the conclusion (i) risks.
Practicality	Various worker protection measures are already in place for implementation under the Chemical Agents Directive. Supplier could relatively easily supply octa in a non-powder form.	Means for implementing currently being developed. Timetable for implementation unknown at present.	Should be relatively easy to implement and monitor given low number of users. Would require establishment of a duty to declare imports.	Assumes regulators able to establish an 'acceptable' level of usage. Also requires that a system for monitoring trading is put in place and that trades are approved by regulators. Number of companies involved may mean that no trading takes place.
Monitorability	Systems for monitoring are in place under the CAD.	Expect that future legislation will contain provisions for monitoring.	Systems required to monitor imports, with some potential for charge evasion. Systems for charge collection also required.	Systems required to register and monitor trades, and to ensure that any emissions/worker safety controls are in place.

Table 3b: Summary of Advantages and Drawbacks (Worker Protection, Sludge Directive, Input-Based Product Charge and Tradeable Permits)				
	Worker Protection	**Sludge Directive**	**Input-Based Product Charge**	**Tradeable Permits**
Economic Impact	**Suppliers**: Costs of producing octa in a non-powder form. **Compounders/master batchers**: Costs of utilising octa in granular form not expected to be prohibitive (can be used in existing equipment). **Polymer processors**: No additional costs imposed. **Regulators**: Costs associated with monitoring compliance.	**Suppliers, compounders and polymer processors**: No additional costs expected. **Regulators**: Difficult to estimate costs due to uncertainty regarding limit value set and distribution of octa in EU sludge. Indicative costs of diversion from spreading on land to incineration or landfill are around €19m to €130m per year.	**Suppliers:** Main costs would be from any lost sales and from need to report imports. **Polymer Processors**: Would bear either costs of the charge or the costs of moving to a substitute FR. If paying charge, then would further costs in making an import declaration. **Regulators:** Would need to monitor and validate imports and establish system for charge collection.	**Suppliers:** If ceiling on use is set below current levels then this would affect sales of octa. Otherwise no impact. **Polymer Processors:** Would be costs of ensuring adequate emissions control and any transaction costs associated with trading. Costs should be lower than under M&U restrictions. **Regulators:** Costs of approving trades and monitoring usage.
Balance of Advantages and Drawbacks	Measures adopted under the CAD should address conclusion (iii) risks for health cost effectively. Supply in a non-powder form would address all conclusion (iii) risks without prohibitive cost.	Would address only conclusion (iii) risks for environment (hexa congener). Costs for authorities in diverting sludge may be significant and more than marketing and use restrictions.	On balance, this option should achieve some reductions in risks at lower cost than M&U restrictions.	If linked to emission controls should ensure that conclusion (iii) findings addressed and provide for ceilings on usage with regard to conclusion (i) findings.

TABLE OF CONTENTS

GLOSSARY OF ACRONYMS

ABS	Acrylonitrile-Butadiene-Styrene
ACFSE	Alliance for Consumer Fire Safety in Europe
BCF	Bioconcentration Factor
TBPI	Bis-tetrabromo-phthalimide Ethylene
DEFRA	Department for Environment, Food and Rural Affairs
EEE	Electrical and Electronic Equipment
EU	European Union
FR	Flame Retardant
HDPE	High Density Polyethylene
HIPS	High Impact Polystyrene
HPV	High Production Volume (chemical)
HB	Horizontal Burning fire safety test
IPPC	Integrated Pollution Prevention and Control
ICCA	International Council of Chemical Associations
LOAEL	Lowest Observed Adverse Effect Level
NOAEC	No Observed Adverse Effect Concentration
NOAEL	No Observed Adverse Effect Level
NOEL	No Observed Effect Level
OEL	Occupational Exposure Limit
OECD	Organisation for Economic Co-operation and Development
OSPAR	Oslo and Paris Commission
PC	Personal Computer
PF	Phenol-Formaldehyde (resin)
PBB	Polybrominated Biphenyl
PBDD	Polybrominated Dibenzo Dioxin
PBDF	Polybrominated Dibenzo Furan
PBDE	Polybrominated Diphenyl Ether
PBT	Persistent, Bioaccumulative, Toxic (substances)
PBT	Polybutylene Terephthalate
PC	Polycarbonate
PS	Priority Substance
PEC	Predicted Environmental Concentration
PNEC	Predicted No-Effect Concentration
PHS	Priority Hazardous Substance
R&D	Research and Development
RDP	Resorcinol Bis(diphenylphosphate)
RoHS	Restriction on Hazardous Substances (EEE)
RPA	Risk & Policy Analysts
RAR	Risk Assessment Report
SMEs	Small and Medium-sized Enterprises
TGD	Technical Guidance Document
TBBPA	Tetrabromobisphenol A
TPP	Triphenyl Phosphate
UV	Ultraviolet

UK	United Kingdom
UPE	Unsaturated Polyester
V0	Vertical Burning fire safety test
VIC	Voluntary Industry Commitment
WEEE	Waste Electrical and Electronic Equipment
WFD	Water Framework Directive

1. INTRODUCTION

1.1 Background

Octabromodiphenyl ether is one of the group of polybrominated diphenyl ether (PBDE) flame retardants. The other two commercial PBDEs are pentabromodiphenyl ether and decabromodiphenyl ether. Octabromodiphenyl ether contains a range of different PBDE compounds, with varying degrees of bromination. It is used as a flame retardant almost exclusively in acrylonitrile-butadiene-styrene (ABS) polymer products employed in the housings of office equipment and business machines.

Under Regulation 793/93/EEC, octabromodiphenyl ether is a priority substance for risk assessment and, where necessary, risk management, at the European Union level. The UK and France are jointly responsible for addressing the risks associated with octabromodiphenyl ether (for the environment and human health respectively).

Both the human health and environmental risk assessments have identified areas where there is a need for risk reduction measures. Furthermore, both have identified areas where there is a need for further information and/or testing and, given the uncertainties, where there may be a need for precautionary action to be taken to reduce the risks.

The Department for Environment, Food and Rural Affairs (DEFRA) has contracted Risk & Policy Analysts Limited (RPA) to develop the risk reduction strategy for octabromodiphenyl ether.

The final strategy recommended by the UK and France will be presented to other Member States of the EU and to the European Commission who together will decide on the risk reduction measures to be implemented.

1.2 Objectives and Approach

The objective of the study is to assess the advantages and drawbacks of different risk reduction options, for the environment and human health, on the use of octabromodiphenyl ether to:

(i) enable judgement as to whether the benefits of adopting the restrictions outweigh the consequences to society as a whole of imposing the controls; and

(ii) determine whether the chosen risk reduction strategy is the best option and, offers the greatest net benefits.

The risk reduction strategy is being developed in four stages as follows:

- ***Stage 1*** - data gathering on uses and current control measures;
- ***Stage 2*** - establishment of the range of potential risk reduction options and qualitative comparison of advantages and drawbacks;

- ***Stage 3*** - a semi-quantified or fully-quantified examination of one or more of the options taken forward; and
- ***Stage 4*** - preparation of the final risk reduction strategy.

The current report is a Final Report detailing the results of the study and recommending the risk reduction strategy formulated through the previous stages. The range of possible options taken forward were decided upon completion of Stage 2 of the project and through a meeting of the Steering Group for the project in December 2001 (members of the Steering Group are detailed in Annex 1 to this report). Following this, a report on Stage 3 was prepared in April 2002, with a second meeting of the Steering Group on 19 April 2002. At this meeting, the Steering Group decided upon the risk reduction strategy that would be taken forward, as outlined in this report. A report on Stage 4 was produced on 21 May 2002 and the current report takes into account comments of the Steering Group on that report.

Data gathering for this project has involved an extensive review of relevant literature and consultation with the range of stakeholders that may be affected by any policy measures taken to address the risks associated with the substance. Consultees have included the producer of the flame retardant, companies and associations from the industry sectors for the users of octabromodiphenyl ether in plastics, manufacturers of electrical and electronic equipment and the traders and users of the final products. A list of the organisations contacted is included as Annex 2 to this report.

1.3 Structure of this Report

The remainder of this report is organised as follows:

- Section 2 provides an overview of the risks for human health and the environment that have been identified for octabromodiphenyl ether;
- Section 3 details the measures that are already in place or are likely to be implemented which will address the identified risks to some extent;
- consideration is given to the use of octabromodiphenyl ether as a flame retardant, its markets and the markets for the products in which it is used in Section 4;
- Section 5 provides an overview of the suitability of potential alternatives for octabromodiphenyl ether, should the need arise to replace the substance;
- Section 6 discusses the possible risk reduction options that have been taken forward to this stage of the study, as agreed at the first meeting of the whole Steering Group;
- an appraisal of the relative advantages and drawbacks of these potential measures is provided in Section 7; and
- Section 8 details the proposed risk reduction strategy, with this being the one which appears to represent the greatest net benefits to society as a whole.

2. RESULTS OF THE RISK ASSESSMENTS

2.1 Risks of Concern

2.1.1 Risks for the Environment

A summary of the latest risk assessment for the environment (Environment Agency, 2002a) indicates that there is a need for risk reduction measures relating to the assessment of secondary poisoning via the earthworm route for the hexabromodiphenyl ether component in the commercial octabromodiphenyl ether product. The assessment indicated that it should be investigated if the levels of this component in the commercial product can be reduced.

Based on the previous draft of the risk assessment (Environment Agency, 2001a), this risk arises predominantly from the use of octabromodiphenyl ether as an additive in polymer processing (handling of the raw material and compounding and conversion of the plastic). There are expected to be losses both to air and to waste water. It is the latter which is of most concern for local risks associated with polymer processing. Dust generated is understood to be lost initially to atmosphere but then the particles are expected to settle out and be lost to waste water through washing down of equipment and floors. The risk of secondary poisoning arises mainly through the application of sewage sludge (in which octabromodiphenyl ether from waste water is retained) to soil, with subsequent entry to the food chain. The PEC/PNEC[1] ratio for the hexabromodiphenyl ether in relation to secondary poisoning is marginally above unity (at around 1.2).

The summary of the risk assessment also indicates that there is a need for further information and/or testing in relation to the risk of secondary poisoning from all sources of octabromodiphenyl ether. Although the risk assessment indicates that the PEC/PNEC ratios are all much less than unity, the suitability of the current risk assessment approach for secondary poisoning is questioned in that there is insufficient confidence in both the PEC and PNEC estimates to reach either conclusion (ii) or conclusion (iii). Furthermore, there is evidence that the higher brominated congeners in octabromodiphenyl ether can degrade under some conditions to form lower brominated congeners which may be more bioaccumulative and toxic than the parent compound. Thus, it is concluded that any significant formation of these substances would be a cause for concern.

There is a wide range of sources of octabromodiphenyl ether in the environment and, at the regional and continental level, diffuse emissions from products during their service life and through ‘waste remaining in the environment’ contribute more to total environmental emissions than polymer processing.

Further work that could be undertaken to address the uncertainties in the risk assessment is highlighted in the summary and is as follows (although this possible further work is only a draft proposal):

[1] Ratio of predicted environmental concentration to predicted no-effect concentration.

- a more widespread monitoring project to determine whether the finding in top predators (including birds' eggs) is a widespread or localised phenomenon, and trends;
- further toxicity testing on birds;
- an investigation of the rate of formation of degradation products under environmentally relevant conditions over a suitably prolonged time period (e.g. years); and
- further toxicological work on the non diphenyl ether products, to determine if they pose a hazard or risk.

The former two points relate to the uncertainties with the approach for secondary poisoning and the latter two relate to the potential for debromination in the environment. On this basis, it is concluded that:

> *"It is not possible to say whether or not on a scientific basis there is a current of* [sic] *future risk to the environment. However, given the persistent nature of the substance, it would be of concern if once the further information had been gathered the analysis indicated a risk to predators, since it could then be difficult to reduce exposure.*
>
> *Thus, although it is concluded that further information should be gathered in order to refine the risk assessment, in light of the persistence of the substance, the time it would take to gather the information and the fact that there is no guarantee that the studies would provide unequivocal answers, consideration should be given at a policy level of the need to investigate risk management options now in the absence of adequate scientific knowledge."*

2.1.2 Risks for Human Health

The draft risk assessment for human health (Ministère de l' Emploi et de la Solidarité, 2000) considered risks in terms of workers, consumer and humans exposed indirectly via the environment.

Worker exposure is the only case where a definite need for risk reduction was identified. This relates to systemic, developmental, female fertility and local toxicity, related to repeated inhalation and dermal exposure (although local toxicity only relates to inhalation exposure). The activity of concern relates to compounding and master batching during processing of plastics where octabromodiphenyl ether is used as an additive.

The draft risk assessment indicated the following in relation to risks for workers during polymer processing:

> *"It should be noticed that the estimated exposure does not take into account the normal safety practices which should strongly reduce the exposure and provided that the substance is provisionally labelled with appropriate risk and safety phrases, appropriate precautions can be expected to be taken during handling (according to the risk reduction measures already applied in EU)."*

As with the environmental risk assessment, there are certain areas where the level of risk is less clear. In particular, this relates to the presence of octabromodiphenyl ether (and lower congeners in particular) in breast milk and subsequent breast feeding and also for prolonged exposure. This also relates to humans exposed to the substance via the environment, from all life-cycle stages including in-service use and disposal of products. It has also been indicated for the human health assessment that the need for precautionary action should be considered, given the uncertainties in the level of risk.

Furthermore, based upon the draft human health risk assessment, a revised classification and labelling of octabromodiphenyl ether has now been adopted. The substance will now be classified as Category 2 in relation to developmental effects and Category 3 for effects on fertility and the following risk phrases will apply respectively:

- Toxic ('T') and R61 ('may cause harm to the unborn child') in relation to developmental effects; and

- Harmful ('Xn') and R62 ('possible risk of impaired fertility') in relation to effects on fertility.

2.2 Implications for the Need for Risk Reduction

There are two areas where a definite need for risk reduction measures has been identified in the risk assessments for human health and the environment. Firstly, for the environment, there is a risk for secondary poisoning via the earthworm route for the hexabromodiphenyl ether component in the commercial product. Secondly, in relation to human health, there is a risk for developmental toxicity related to bag emptying during compounding and master batching activities.

In addition, both assessments are likely to conclude that there is a need for further information and/or testing, given the uncertainties associated with the substance, as identified above. In considering these uncertainties, the environmental risk assessment in particular has indicated that consideration should be given to the need to investigate risk reduction measures in the absence of adequate scientific knowledge.

At the Steering Group meeting in December 2001, it was agreed that consideration should be given in the risk reduction strategy both to measures that will target the areas where there has been a definite need for risk reduction and also to measures that would target the possible risks for which there is a need for further information and/or testing.

Therefore, this Stage of the study has considered a number of risk reduction options that could address those areas where there is a definite need for risk reduction (for health and the environment) and also those where the need for risk reduction is less clear. Any decision taken upon the need for implementing measures to address the latter would ultimately be a political one. Thus, the aim herein has been to identify the possible implications of risk reduction measures in order to provide a basis for any such decision.

For the environment, in relation to the area where a definite need for risk reduction has been identified[2], the concern relates predominantly to emissions at the local level. However, for the areas where there is less certainty about the conclusions, the full range of environmental emissions need to be taken into account. Diffuse sources, particularly during the service life and from 'waste remaining in the environment' contribute more than polymer processing to total emissions at the regional and continental level. Risk reduction measures considered for the areas where less certainty exists have, therefore, been wider in scope than for the area where a definite need for risk reduction has been identified.

---

[2] Relating to secondary poisoning via the earthworm-based food chain for the hexabromodiphenyl ether congener released to waste water mainly during use in polymer processing.

3. EXISTING RISK REDUCTION MEASURES

3.1 Overview

There is a range of legislative and non-legislative measures in place at the Community, national and international levels to control the risks associated with octabromodiphenyl ether. Furthermore, there is a number of other controls that are currently under development that may impact on the risks.

In the following sections, consideration is given to Community-level measures already in place that affect the usage of the substance and/or the risks associated with its use. This is followed by a discussion of the measures that are currently in development or that may be implemented as a result of the risk assessment conclusions (revisions to the classification and labelling). Following this, consideration is given to national measures for controlling the risks and lastly to international measures.

3.2 Existing Community-level Measures

3.2.1 The Water Framework Directive

Directive 2000/60/EC[3] introduced a new framework for controls on certain 'priority substances' that present a significant risk to or via the aquatic environment. A list of 33 substances (or groups thereof) was accepted towards the end of 2001[4]. Amongst the priority substance (PS), there are certain priority hazardous substances (PHS), for which the Commission will submit proposals for a cessation or phase-out of discharges, emissions and losses. This is to be achieved within 20 years of the adoption of such measures by the European Parliament and the Council (the controls will be introduced through Daughter Directives).

For the PS, by comparison, the Commission is required to submit proposals for the progressive reduction of discharges, emissions and losses. The list of PS includes brominated diphenyl ethers, amongst which only pentabromodiphenyl ether has been identified as a PHS. For octabromodiphenyl ether, therefore, the aim is for a progressive reduction in discharges, emissions and losses. Controls of discharges, emissions and losses is to be achieved through a combination of emission limit values and environmental quality standards.

Measures adopted under this Directive are likely to predominantly focus upon industrial sources of priority substances. However, it does provide for product and process controls on both point and diffuse sources.

3 Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, OJ L 237, 22/12/2000, page 1.

4 Decision No 2455/2001/EC of the European Parliament and of the Council of 20 November 2001 establishing the list of priority substances in the field of water policy and amending Directive 2000/60/EC, OJ L 331, 15/12/2001, page 1.

3.2.2 Ecolabels

The EU ecolabel is a voluntary initiative. Manufacturers, retailers or service providers can apply for award of the ecolabel and, if all relevant criteria are met, can market their product using the ecolabel's Flower logo (European Commission, n.d.).

Criteria for the award of the ecolabel have been developed for several product categories. Perhaps of most relevance to the use of octabromodiphenyl ether, criteria have been developed for personal computers and portable computers, with the most recent revisions of the criteria published in 2001[5].

The criteria for award of the ecolabel to personal and portable computers require that plastic parts heavier than 25g do not contain any of the PBDEs (specific reference is made to all ten congeners).

3.3 Community-level Measures Under Development

3.3.1 Proposed Restrictions on Pentabromodiphenyl Ether

The European Commission (2001b) submitted a proposal for a Directive to restrict the marketing and use of pentabromodiphenyl ether. In addition to introducing controls on the pentabromo derivative, the proposal indicated that commercial octabromodiphenyl ether contains some pentabromodiphenyl ether. The proposed restriction suggested that the Directive should not apply to technical grade octabromodiphenyl ether, provided that it does not contain more than 5% of the pentabromo derivative. However, in a recent report, the European Parliament (2001a) indicated that:

> *"In order to protect human health and the environment the use of octaBDE with more than 0.1 % pentaBDE can no longer be admitted from the moment pentaBDE is restricted."*

More importantly, the European Parliament also proposed that the marketing and use of octabromodiphenyl ether be banned, along with any products in which it is contained. This was justified on the basis that:

> *"The initial results of the octaBDE risk assessments currently in progress in the United Kingdom (environmental impact) and France (public health) also reveal definite risks for human health and the environment. Application of the precautionary principle thus requires that we should not wait for final validation of the study to ban the substance."*

---

5 OJ L 242, 12.9.2001, p. 4 and OJ L 242, 12.9.2001, p. 11.

The European Commission then submitted an amended proposal[6], whereby they accepted the concentration of pentabromodiphenyl ether could be less than 0.1% by 2003. However, the Commission did not accept the proposed amendments extending the scope of the proposed Directive to include bans on other substances (including octabromodiphenyl ether), indicating that *"these other substances could be the subject of a subsequent proposal of the Commission when risk assessments have been completed and the availability of safe substitutes analysed."*

The Council adopted a Common Position on the issue (CEU, 2001a) which was based upon the Commission's amended proposal, stating that *"the Council does not consider it appropriate to discuss extending the scope of the Directive to octabromodiphenyl ether (octaBDE) and decabromodiphenyl ether (decaBDE) before the risk assessment has been completed."*

Following this, the European Parliament published a draft recommendation for second reading on the Council common position (European Parliament, 2002a). Amendments to the common position were proposed as follows:

- it was stated that *"although the risk assessment for octaBDE is officially not yet complete, the substance must be banned since the current assessment reveals definite risks for human health and the environment."*

- it was also therefore proposed that the marketing and use of octabromodiphenyl ether, and preparations and articles containing more than 0.1% of the substance, be banned.

3.3.2 Electrical and Electronic Equipment

The European Commission (2000b) has issued proposals for legislation governing the use of certain substances in electronic and electrical equipment (EEE) and also for waste electronic and electrical equipment (WEEE).

In relation to WEEE, the Commission's proposal encourages producer responsibility for waste management, separate collection of WEEE, improved treatment and reuse/recycling, and improved information dissemination to users.

In implementing the proposed Directive, producers would be required to set up systems to treat WEEE, which would include, amongst other things, removal of plastic containing brominated flame retardants from separately collected WEEE.
In relation to the other proposed Directive, relating to restriction of the use of certain hazardous substances in EEE (RoHS), there are proposed measures that would impact upon octabromodiphenyl ether. Article 4.1 reads as follows:

---

6 Amended proposal for a Directive of the European Parliament and of the Council amending for the twenty-fourth time Council Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations (pentabromodiphenyl ether), (2002/C 25 E/04), COM (2001) 555 final - 2001/0018(COD), OJ C 25, 29.1.2002, page E/472.

> *"Member States shall ensure that with effect from 1 January 2008 the use of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB)and poly-brominated diphenyl ether (PBDE)in electrical and electronic equipment is substituted by other substances."*

The proposal has undergone several review stages with the European Parliament and Council, amongst others, commenting on the proposed measures. It is currently uncertain as to whether any final Directive would require the substitution of octabromodiphenyl ether in electrical and electronic equipment. It should also be noted that the 2008 date for implementation may be brought forward.

If it is required that octabromodiphenyl ether no longer be used in EEE, there would be significant implications for the outcome of this risk reduction strategy. The proposals for WEEE would also have (indirect) implications for the use of octabromodiphenyl ether in EEE products.

3.3.3 New Classification and Labelling of Octabromodiphenyl Ether

As indicated in Section 2, the classification and labelling of octabromodiphenyl ether has recently been revised. As such, the substance will now be classified as Category 2 for developmental effects and Category 3 in relation to fertility effects.

Based on Directive 67/548/EEC[7], a substance is classified as 'dangerous' where (amongst others) it is toxic for reproduction. Following on from this, the 'Chemical Agents Directive' (Directive 98/24/EC[8]) defines a 'hazardous chemical agent' as:

> *"any chemical agent which meets the criteria for classification as a dangerous substance according to the criteria in Annex VI to Directive 67/548/EEC, whether or not that substance is classified under that Directive, other than those substances which only meet the criteria for classification as dangerous for the environment"*

Article 6 of the Chemical Agents Directive details the specific protection and prevention measures that employers are to take as regards 'hazardous chemical agents.' In particular, Article 6(2) contains the following:

> *"... substitution shall by preference be undertaken, whereby the employer shall avoid the use of a hazardous chemical agent by replacing it with a chemical agent or process which, under its condition of use, is not hazardous to workers' safety and health, as the case may be."*

---

7 Council Directive 67/548/EEC of 27 June 1967 on the approximation of laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous preparations, OJ L 196, 16.8.1967, page 1.

8 Council Directive 98/24/EC of 7 April 1998 on the protection of the health and safert of workers from the risks related to chemical agents at work (fourteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC), OJ L 131, 5.5.98, page 11.

Various other options for reducing the risks to a minimum are detailed in Directive 98/24/EC where the nature of the activity does not permit a risk to be eliminated by substitution. However, it is understood that classification as 'dangerous' according to Directive 67/548/EEC is often a key driver for companies to substitute a chemical with one that is not classified as such.

In the corresponding French legislation, the following is required for substances that are classified as Category 1 or 2:

- at first, consider substitution with a less dangerous substance;
- if substitution is not possible, use in a closed system; and
- if use in a closed system is not possible, the employer has to ensure that the level of exposure of workers is reduced as low as technically possible by application of a series of measures.

In the UK, employers are required to take steps to control substances hazardous to health[9]. These controls are in line with the Chemical Agents Directive and similar to the French legislation. Specifically, employers should prevent exposure to the substance or, where this is not reasonably practicable, they should adequately control exposure. It should be noted that the EU legislation represents the *minimum requirements* for control of such substances, with Member States being allowed to implement more stringent controls. Indeed, it appears that the French legislation is more prescriptive about the requirements for prevention of risks.

As detailed in Section 2, there is a possible concern in relation to effects on breast feeding. The Pregnant Workers Directive[10] requires that the risk assessment conducted should include an assessment of any risks for pregnant or breastfeeding workers. As a result, the employer shall ensure that, by temporarily adjusting working conditions and/or working hours, exposure to the substance is avoided[11]. Similar requirements are mirrored in the UK legislation. The respective French legislation will require that exposure of pregnant or breastfeeding women to the substance is not allowed.

The classification and labelling will, therefore, have significant implications for the use of octabromodiphenyl ether in the workplace. It should be noted, however, that whilst this classification will place requirements upon use of the substance and of preparations containing the substance (including master batches), it will not affect *articles* (flame retarded plastic products) that contain octabromodiphenyl ether.

There will also be implications for the export and import of the substance under Council Regulation (EEC) No 2455/92.

9 Under the Control of Substances Hazardous to Health Regulations 1999.

10 Council Directive 92/85/EEC on the introduction of measures to encourage improvements in the safety and health of pregnant workers and workers who have recently given birth or are breastfeeding (tenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC, OJ L 348, 28.11.1992, p. 1.

11 And, if this is not possible, the worker should be moved to another job or granted leave.

The measures resulting from revised classification and labelling should be considered as one of the potential risk reduction options, since these controls will not yet have been introduced. Thus, Section 5 provides further background to the possible controls that could be introduced based on the classification and labelling requirements for the substance.

3.4 National Measures

3.4.1 General

As mentioned in Section 3.3.3, the national legislation for protection of workers from the risks of chemical agents at work may go beyond the minimum requirements set out in the Community legislation. For example, it has been highlighted above that the French legislation places greater requirements upon employers.

3.4.2 Sweden

The Swedish National Chemicals Inspectorate (Kemi, 1999) has made the following proposals:

- a ban, referring to specified areas of use, on the sale, supply or use of PBDEs or polybrominated biphenyls (PBBs) 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 the EU level as soon as possible; and

- 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.

Further, at the Environment Council meeting in December 1999, Sweden and Denmark both formally proposed that other EU member states phase out the use of these substances.

3.4.3 Denmark

In Denmark, there is an objective to phase out the use of all 'problematic' brominated flame retardants. The Danish EPA (2001) indicates that:

> *"In the case of PBB and PBDE, current knowledge about the substances and their effects is so worrying that the objective is to phase them out within the space of a few years."*

3.4.4 Germany

The German Chemical Industry Association and Association of the Plastics Producing Industry voluntarily agreed to discontinue the use of polybrominated diphenyl ethers in 1986 (VKE, 1997). The German Federal Environmental Agency (German UBA, 2001a) indicate that this voluntary agreement has led to a marked decrease in the consumption of PBDEs in Germany, but that these substances remain available on the market.

3.5 International Measures

3.5.1 OECD Voluntary Industry Commitment (VIC)

Under the auspices of the OECD, major European and US manufacturers of brominated flame retardants have taken voluntary action to *"further reduce the possibility of negative environmental impact"* (OECD, 1995). The specific actions that relate to octabromodiphenyl ether include:

- an undertaking not to manufacture or import/export the non-commercial PBDEs, except when present as part of the three commercial products;
- to use the best available techniques, without incurring excessive costs, to improve the purity of deca- and octabromodiphenyl ether (specifically minimising levels of hexa- and lower brominated congeners in commercial octabromodiphenyl ether); and
- to evaluate the ways in which the levels of hexa- and lower brominated congeners in commercial octabromodiphenyl ether can be reduced.

A similar initiative was undertaken by Japanese industry, which involved a commitment to keep to a minimum the concentration of low-brominated substances during manufacture of octabromodiphenyl ether. It also involved treatment and disposal of waste products from octabromodiphenyl ether manufacture using the best available techniques to minimise releases into the environment and further provided for the most recent information on the products to be obtained and supplied to the primary users. Furthermore, in reducing environmental contamination, they committed to devoting maximum effort to preventing contamination and accidents during manufacture, transport and handling and to maintaining a close relationship with users so that octabromodiphenyl ether will be used properly.

It has been suggested that no production of octabromodiphenyl ether occurred in Japan in 1998 or 1999.

The VIC committed manufacturers to minimise levels of hexa and lower brominated congeners in commercial octabromodiphenyl ether, with the current concentrations in the commercial product given as a baseline[12]. The one company currently supplying

[12] Decabromodiphenyl ether at 0.0 to 3.0%; nona- at 8.0 to 14.0%; octa- at 26.0 to 35.0%; hepta-at 43.0 to 58.0%; and hexa/penta at 1.4 to 12.0%.

octabromodiphenyl ether to the EU market reports that the concentration of pentabromodiphenyl ether in their product is currently less than 0.5% and is expected to be less than 0.1% within two years. Table 3.1 compares the baseline concentrations from the VIC with the current concentrations in the commercial product.

Table 3.1: Concentrations of PBDE Congeners in OECD (1995) and Current Concentrations

	OECD (1995)	Current
Pentabromodiphenyl ether	1.4 to 12.0	≤ 0.5% [a]
Hexabromodiphenyl ether		≤ 12%
Heptabromodiphenyl ether	43.0 to 58.0	≤ 45%
Octabromodiphenyl ether	26.0 to 35.0	≤ 33%
Nonabromodiphenyl ether	8.0 to 14.0	≤ 10%
Decabromodiphenyl ether	0 to 3.0	≤ 0.7%

Note: [a] *Expected to be ≤ 0.1% within the next two years*

Thus, it appears that progress has been made in reducing the concentration of pentabromodiphenyl ether in the commercial product. However, it is unclear whether any progress has been made in reducing the concentration of the hexabromo derivative. Reduction of the lower brominated congeners' concentrations in the commercial product is considered further in sections 4 and 5.

3.5.2 OSPAR Convention

Under the OSPAR Convention for the Protection of the Marine Environment of the North East Atlantic, brominated flame retardants are amongst a list of 'Chemicals for Priority Action' (OSPAR, 2000a). The OSPAR Commission's aim for these substances is to achieve, by 2020, a "cessation of discharges, emissions and losses".

3.6 Voluntary Occupational Exposure Limit

The manufacturer of octabromodiphenyl ether, on the relevant material safety data sheet, specifies an exposure limit of 0.12 mg/m^3 (8 hour time weighted average) for use of the substance. This is based upon the standard applied internally by the company for the manufacturing process. It can be compared to the estimated worker exposure used in the risk assessment for polymer processing of 5 mg/m^3. Adherence to this standard would significantly reduce the risk for workers.

However, it is not known to what extent this exposure limit is applied in practice (since users of the substance were reluctant to provide any information for this study). It should be noted that adherence to this exposure limit (or indeed any limit that might be required by law) would not address the areas where there exists uncertainty regarding the risks, as described in Section 2.

3.7 Summary of Existing Measures

Table 3.2 provides a summary of the existing (and proposed) risk reduction measures described above. The measures are listed, along with their implications for the risks of concern, and possible risks associated with the areas where the need for risk reduction is less certain in the risk assessments.

Table 3.2: Summary of Existing Risk Reduction Measures

Measure	**Implications for Risks**
Control as a Priority Substance under Water Framework Directive	Progressive reduction in discharges, emissions and losses of the substance
Ecolabels	Voluntary exclusion of substance in e.g. computers
Proposed restrictions on penta-BDE	Requires that <0.1% penta-BDE be present in commercial octa-BDE. There are proposals to extend the ban to commercial octa-BDE under the Directive
Electrical and electronic equipment	Removal of plastic containing octa-BDE from collected WEEE. Possible requirement to remove from all E&E products by 2008 or before
Classification and labelling	Employers to substitute (octa-BDE is Category 2 for reproductive toxicity) or, to otherwise control exposure. Additional requirements for e.g. pregnant workers
National measures	Proposed bans/phase outs in Sweden and Denmark. Voluntary agreement not to use in Germany
OECD Voluntary Industry Commitment	Various including reducing concentrations of hexa and lower brominated congeners
OSPAR Convention	Cessation of discharges, emissions and losses by 2020
Voluntary OEL	Would reduce risks by a factor of ~42 as compared to risk assessment but unknown if applied

A number of these existing or proposed measures may result in a reduction in overall use of octabromodiphenyl ether. In particular, possible extension of restrictions on pentabromodiphenyl ether to include octabromodiphenyl ether would prevent all use, as would (effectively) restrictions on electronic and electrical equipment. Similarly, national measures would have the same effect in the countries in which they might apply. Other measures may reduce the level of use, including ecolabels and the implications of the revised classification and labelling. Control under the Water Framework Directive and the OSPAR Convention will reduce or eliminate emissions to the environment. The OECD VIC would reduce the (definite) risk identified for the hexa congener, although it is unknown whether the reduction would eliminate the concern. The voluntary OEL, if it is being applied, will significantly reduce risks as compared to those in the risk assessment.

It is not possible to say, in quantitative terms, what the effects - or likely effects - of these measures will be on the risks identified for human health and the environment. However, all of the above measures are likely to reduce the risks to an extent, and in some cases to below the threshold of concern. However, regardless of the level of exposure reduction there would still remain uncertainty regarding the risks for areas where the risk assessments have indicated a possible concern in the absence of adequate scientific knowledge. Only a reduction of exposure to nil would reduce this concern, although reducing by any extent would reduce the overall level of risk.

4. OCTABROMODIPHENYL ETHER USAGE AND MARKETS

4.1 Utility of Flame Retardants

4.1.1 Background and Method of Action

Various legislation and standards exist relating to the fire safety performance of certain products and materials. Flame retardants are employed in order to inhibit (though not necessarily prevent) the burning of otherwise flammable products when exposed to a source of ignition. The types of flame retardant applied to particular products depend largely upon the fire safety tests which the product must pass (though in some cases companies produce products to a higher level of fire safety than is necessarily required).

A recent study (Environment Agency, 2001b) identified six key categories of flame retardant, which are as follows:

1. Inorganic;
2. Brominated organic;
3. Chlorinated organic;
4. Organophosphorus (mainly phosphate esters);
5. Halogenated phosphorus (chlorinated and brominated); and
6. Nitrogen-based.

Octabromodiphenyl ether is a brominated flame retardant. Brominated flame retardants act, when added to materials such as plastics, by breaking down when heated, leading to the evolution of bromine free radicals[13]. These free radicals prevent the otherwise self-sustaining combustion processes by reacting with the free radicals involved in the combustion process to yield stable products. These flame retardants are sometimes used in conjunction with antimony trioxide (Sb_2O_3), as is the case with octabromodiphenyl ether, which acts synergistically with the flame retardants through the production of an antimony halide that scavenges free radicals and also prevents access to oxygen (Nicholson, 1997).

Octabromodiphenyl ether is an 'additive' flame retardant in that it is mixed with the polymer product. Other types of flame retardant are known as 'reactive' types because they form part of the polymer structure. An example of a reactive flame retardant is tetrabromobisphenol-A (TBBPA).

Octabromodiphenyl ether is one of the group of polybrominated diphenyl ether (PBDE) flame retardants. The other two commercial PBDEs are pentabromodiphenyl ether and decabromodiphenyl ether. All of the commercial products contain a range of different isomers of varying degrees of bromination, as indicated in Table 3.1.

---

13 Free radicals are chemical species (atoms or molecules) which have an unpaired electron, making them very reactive. They are often involved in chain branching reactions since their reaction with other chemical species frequently leads to formation of another free radical.

4.1.2 Fire Safety Standards for Electrical and Electronic Equipment

Octabromodiphenyl ether is used as a flame retardant almost exclusively in acrylonitrile-butadiene-styrene polymer products employed in the housings of office equipment and business machines.

In the EU, the commonly applied fire safety standard for IT appliances is European standard EN 60950, which allows for three possible methods for controlling fires related to exterior casings (German UBA, 2001a):

- use of flame retardant materials;
- use of interior flame-protection housings made of flame retarded plastic or of metal which act by blocking the spread of fire to other components; and/or
- design measures such as protective barriers or gaps that separate components with high temperatures.

Companies are reported to generally manufacture their products in order to avoid the risk of internal rather than external ignition. For monitor housings (representing the largest fuel source in these types of products), companies are reported to generally manufacture their products in order to meet the Underwriters Laboratory (UL) standard V0 for products that pass a 'vertical burning test' (ACFSE).

By comparison, it is reported that less stringent standards are applied for TV sets in the EU, where products often only meet the less stringent horizontal burning (HB) test. In some cases, no flame retardants are required in the housings of TV sets in order to meet the lesser HB standard (but at the cost of some level of fire safety). The more stringent V0 standard is reportedly more widely applied for TV sets outside the EU, such as in the USA. However, it should also be noted that some companies are increasing the level of fire safety of TV sets' housings due to concerns with exterior ignition sources potentially causing fires in TV sets (German UBA (2001b), Troitzch (n.d.)).

It should be noted that fire safety legislation within the Member States sometimes differs from that set out in these types of standards. For example, in France, the Regulation of 25 June 1980 in public buildings specifies fire safety standards for each part of the building. The safety class required (and hence the level of flame retardancy needed) thus depends upon which parts are concerned[14]. Only large and fixed furniture are covered, with smaller furniture and products such as personal computers generally excluded from the requirements (although seats are included). Additionally, the Order of 4 November 1975 concerns the toxicity of combustion gases that can be emitted from materials and includes related provisions regarding the materials to be used.

4.1.3 Benefits of Flame Retardants

Several organisations have undertaken testing to compare the fire safety of IT appliances and TV sets that meet different fire safety standards. For example, the Swedish National

[14] For example, minimum standards (M4) are applied for the floors, with a higher class (M2) for the walls and a still higher class (M1) for the ceiling.

Testing and Research Institute (SP, 1999) compared the small and large-scale fire behaviour of a number of computer monitors with enclosure materials classified under the HB and V0 ratings. They concluded that:

> "*Monitors manufactured with material classified as V0 according to UL94 ... were not able to be ignited using the three small ignition sources tested. In these cases the small scale fire behaviour is mirrored in the large scale behaviour of the product. The two monitors manufactured with material that does not pass the UL 94 V ratings ... were easily ignited with a match and burned until the test room flashed over. These screens represent a significant fire load when burning ...*"

Likewise, Fire and Environment Protection Services in Germany (Troitzch, n.d.) compared TV sets and PC monitors in terms of their ignition and post-ignition behaviour from a variety of ignition sources. They concluded that:

> *"... both internal and external fire sources may cause fully developed fires in a very short period of time if housings and backplates are not flame retarded sufficiently to fulfil vertical materials flammability UL 94 V tests. TV sets sold in the US and Japanese markets, and PC monitors sold worldwide, are flame retarded and fulfil these vertical flammability test requirements."*

However, at workshops held by the German Federal Environmental Agency (German UBA, 2001b), it was concluded that:

> *"The connections between the frequency of TV fires and flame retardant equipment of the casings, reported in the publications available on the subject, are inconclusive."*

Nonetheless, it is likely that products that conform to the more stringent standards do offer genuine benefits in terms of fire safety. Indeed, the Alliance for Consumer Fire Safety in Europe (ACFSE) is currently encouraging companies that have stopped using flame retardants in TV set casings (and now only meet the HB standard) to increase the fire safety performance of their products to meet the V0 standard[15].

In terms of the overall benefits of flame retardants for fire safety, a number of studies have been undertaken to analyse the societal benefits of flame retardancy of products, though not generally for electrical and electronic equipment. For example, research at the University of Surrey in the UK (Emsley *et al*, 2002) suggests that the introduction in 1988 of the furniture fire regulations in the UK[16] has led to a minimum 989 lives and 9,840 injuries saved between 1988 and 2000 (though they state that the actual number of lives saved may be closer to 3,162).

---

15 They report that this will not necessarily require the use of brominated flame retardants and indeed some companies in the EU are reported to be using phosphorus-based flame retardants in order to meet this higher standard.

16 Which led to the increased use of flame retardants in fabric coverings and foams.

A report by Benjamin/Clarke Associates (1997) for the United States Brominated Flame Retardant Industry Panel estimated the total life-loss reduction associated with the use of brominated flame retardants in certain products. Table 4.1 summarises their results, which indicate, for example, that an estimated 190 lives are saved per year from the use of brominated flame retardants in TV sets and appliances.

Table 4.1: Estimated Lives Saved in USA Associated with use of Brominated Flame Retardants

Product	**Total Estimated Lives Saved**
Television sets/appliances	190 p.a.
Electrical insulation	80 p.a.
Draperies	10 p.a.
Backcoating (upholstery fabric)	10 p.a.

Source: Benjamin/Clarke Associates (1997). Estimates were derived by analysis of historical fire statistics following the introduction of certain fire safety standards.

Table 4.2 details the numbers of fires occurring associated with a selection of electrical equipment as the source of first ignition in the UK.

Table 4.2: Selected Numbers of 'Electrical' Fires between 1995 and 1999 in the UK

	1995	**1996**	**1997**	**1998**	**1999**
Total accidental fires	51,479		56,762	56,083	58,284
Television			693	638	602
Audio visual			209	151	135
Computer/VDU	11		28	15	13

Source: DETR (2000a)

In 1997, the economic benefit per incident in terms of reduction in fire deaths was estimated at around £780,000 (€1.25 million) and for serious casualties at around £92,000 (€150,000) (CFSTF, 1997). There were 8 fatal casualties and 362 non-fatal casualties per 1,000 fires in the UK associated with TV sets in 1999 (DETR, 2000a), equating to 4.8 fatal casualties and 218 non-fatal casualties in total. Using these figures, it is possible to estimate the cost associated with the incidence of fires in 1999 for the ignition sources detailed in Table 4.3.

Table 4.3: Estimated Cost Associated with Casualties from Certain Fires in the UK in 1999						
	No of fires	**# Fatal**	**# Non-fatal**	**€m Fatal**	**€m non-fatal**	**Total (€m)**
Television	602	4.8	218	€ 6.0	€ 32.1	€ 38.0
Audio visual	135	1.1	49	€ 1.3	€ 7.2	€ 8.5
Computer/VDU	13	0.1	5	€ 0.13	€ 0.70	€ 0.83
Source: DETR (2000a). Note: it has been assumed that the casualty rates for audio visual and computer/VDU fires are the same as for TVs. It is also assumed that non-fatal casualties as referred to in DETR (2000a) are the same as serious casualties referred to in CFSTF (1997).						

Since these data relate to the incidence of fires with the stated appliances as the source of ignition, it is likely that any change in the fire safety behaviour of these appliances (e.g. an increase or reduction in the fire safety standards met) could have effects on the numbers of fires occurring. This could, in turn, impact upon the number of casualties resulting from these fires. It is preferable, therefore, that any risk management measures proposed for octabromodiphenyl ether ensure that at least the current level of fire safety is retained. Substitutes for octabromodiphenyl ether are considered in Section 5, where the issue of fire safety is also considered.

4.2 Markets for Flame Retardants

4.2.1 Overall Flame Retardants Market

According to the risk assessment, several years ago, there were eight producers of PBDEs globally (WHO, 1994 cited in Environment Agency, 2001a). However, the risk assessment also indicates that industry suggested the figure should be nine producers. In relation to octabromodiphenyl ether specifically, there were two EU-based producers until 1999. Production of octabromodiphenyl ether now only takes place outside the EU, as the two reported producers in the EU (IUCLID, 1994) stopped production in 1996 and 1998.

The European flame retardants (FRs) market was estimated to be between 200,000 and 300,000 tpa and worth over €800 million in 1995. That year, 64,000 tonnes of brominated FRs were consumed and their market accounted for around €280 million (Stevens & Mann, 1999). Table 4.4 provides details on the size of the European flame retardants market in terms of quantities consumed and associated values.

4.2.2 Market for Octabromodiphenyl Other

Table 4.5 presents data on the historical and current usage of octabromodiphenyl ether and PBDEs in general. Data are based upon the risk assessment and more recent literature produced by the flame retardants industry (BSEF, 2000).

Table 4.4: Estimated Annual EU Flame Retardant Consumption *			
Flame Retardant Type	**Consumption, kt**	**Value (€m)**	**Unit Value (€/kg)**
Alumina trihydrate	120	96.0	0.8
Ammonium phosphates	7.5	36.0	4.8
Antimony oxides	18	91.2	5.1
Brominated compounds	64	278.6	4.4
Chlorinated organophosphorus compounds	22	60.5	2.7
Magnesium compounds	2.5	6.9	2.8
Melamine	11	35.2	3.2
Other chlorinated compounds	35	48.0	1.4
Other organophosphorus compounds	27.5	115.2	4.2
Red phosphorus	4	32.0	8.0
Zinc compounds	3	9.6	3.2
Other compounds	1.5	2.4	1.6
All types	316	811.5	2.6

Source: Stevens and Mann (1999)
** Values converted from £UK at £1 equivalent to €1.6*

Table 4.5: European Usage of Total PBDEs and of Octabromodiphenyl Ether (tonnes)				
Year (Source)	**Total PBDEs**		**Octabromodiphenyl Ether**	
	EU	**Global**	**EU**	**Global**
1986 (WHO, 1994)	8,586	-	-	-
1987 (WHO, 1994)	7,116	-	-	-
1988 (WHO, 1994)	9,021	-	-	-
1989 (WHO, 1994)	10,946	-	-	-
1992 (WHO, 1994)	-	40,000	-	6,000
1999 (RAR)	-	-	2,550	-
1999 (BSEF, 2000)	8,160	67,125	450	3,825
1999 (industry estimate)			<1,000	
2000 (industry estimate)			<7000	
2001 (industry estimate)			<500	

Notes: Data from WHO (1994) relate to production plus import quantities
Data from Risk Assessment Report (RAR) include imports in finished articles/master batch but do not include imports of the substance within products

Whilst the total usage of PBDEs appears to have risen on a global scale in recent years, use in the EU appears to have decreased. The apparent global increase in PBDEs is believed to be due to an increase in the use of decabromodiphenyl ether[17]. Both in the EU and globally, the *relative* amount of octabromodiphenyl ether used has decreased.

Based upon the data in Table 4.5, it is reasonable to conclude that the quantity of octabromodiphenyl ether used directly and imported into the EU is significantly less than the 2,550 tpa estimated in the risk assessment (since that quantity accounts for two thirds of global usage). Industry has provided further estimates (GLCC, 2001a) of the total quantity of octabromodiphenyl ether on the EU market as follows:

- 450 tpa enters Europe as direct imports of the substance; and
- twice this amount (900 tpa) is imported into Europe in polymers.

This gives a total estimated quantity of octabromodiphenyl ether on the European market (including that in products) of 1,350 tpa, representing around 33% of the global market[18].

Table 4.6 illustrates the value of the market for octabromodiphenyl ether sold on the EU market and the value of the substance that is contained within products imported into the EU.

Table 4.6: Quantity and Estimated Value of Octabromodiphenyl Ether on the EU Market

	Quantity (tpa)	**Value (€m)**
All PBDEs (IAL, 1997)	8,000	31.4
Octabromodiphenyl ether	450	1.6
Octabromodiphenyl ether in Polymers	900	3.2
Total on EU market	1,350	4.9

Note: It is assumed that values for imports in polymers to W/E Europe relate only to the EU.
Note: Value of octabromodiphenyl ether taken as €3.6 per kg.

Data in Table 4.6 can be compared to the total figures for use of flame retardants in the EU for as detailed in Table 4.5. The 450 tpa sold on the EU market represents around 5% of the total value of PBDEs, 0.6% of the value of brominated flame retardants and 0.2% of the total value of all flame retardants.

4.3 Markets for Downstream Products

4.3.1 Overview

Use of octabromodiphenyl ether in ABS polymers represents around 95% of total EU usage. However, it is also used in high impact polystyrene (HIPS), polybutylene

17 Total global usage of decabromodiphenyl ether was reported as 30,000 tonnes in 1992 (Arias (1992) in WHO, 1994), compared to 54,800 tonnes in 1999 (BSEF, 2000).

18 It is understood that these data relate to Western and Eastern European markets, rather than just the EU.

terephthalate (PBT), polyethylene and polyamide polymers. An OECD (1994) Risk Reduction Monograph also indicates potential usage in polycarbonate (PC) plastics, unsaturated polyesters (UPE), phenol-formaldehyde (PF) resins and coatings. For the purposes of the current analysis, it will be assumed that the key usage is in ABS polymers in the housings of office equipment and business machines.

The following sections detail the European markets for polymers in general and for plastics in electrical and electronic equipment.

4.3.2 Flame Retarded Plastics

Based upon a Use Category Document for the UK, the environmental risk assessment (Environment Agency, 2001a) estimated that:

- 75,000 tpa of ABS are processed in the UK;
- 6,000 tpa (8%) are processed in open systems, to make mainly ‘white goods’ which do not generally contain flame retardants;
- the remaining 69,000 tpa (92%) are processed in closed systems; of which
- 27,600 tpa are used to make ‘brown goods’ (televisions, videos, etc.).

Thus, the majority of octabromodiphenyl ether used is likely to be in closed systems. Typical concentrations in the final product are 12 to 18% and it is generally used in combination with a synergist (antimony trioxide).

A certain amount of octabromodiphenyl ether is used in master batches. Master batch production involves mixing the polymer (e.g. ABS resin) with additives, including flame retardant. These master batches contain higher concentrations of the flame retardant (typically 70% polymer and 22% flame retardant and 8% synergist) (Environment Agency, 2001a).

Compounding, involves blending of the various polymer components (raw materials or master batch with other additives) to form pellets. These pellets are then used in moulding (usually injection moulding) of a semi-finished product, which is then used in final equipment manufacture (Ministère de l’ Emploi et de la Solidarité, 1999).

Table 4.7 shows the EU consumption of the plastic materials in which brominated FRs were applied in 1995.

Table 4.7: European Consumption of Brominated Flame Retardants by End Use Sector, 1995		
Polymer	**Tonnes/year**	**Annual Value (Millions)**
ABS	5,000	€22.4 (£14.0)
UP	1,000	€4.2 (£2.8)
PET/PBT	4,500	€20 (£12.5)
HIPS	14,000	€61 (£38.0)
PC	3,000	€14 (£8.5)
Phenolics	Y	Y
PA	1,000	€4.2 (£2.8)
Source: Stevens & Mann, 1999 *Notes: Y indicates that BFRs are used but that no specific data are available* *Exchange rate of £1 = €1.60 used*		

A key consideration in understanding the impacts upon businesses of any risk management measures that are introduced is the implications for small and medium-sized enterprises (SMEs). In this respect data are available for the numbers of companies and average turnover of companies manufacturing rubber and plastics in the UK[19]. Figure 4.1 details the number of companies falling into a number of size classes (defined by number of employees), as well as the average turnover of companies within those classes.

From these data, a total of 5,260 companies within this sector fall within the category of small companies (those with fewer than 50 employees), of which the majority (3,365) are micro-enterprises (0-9 employees).

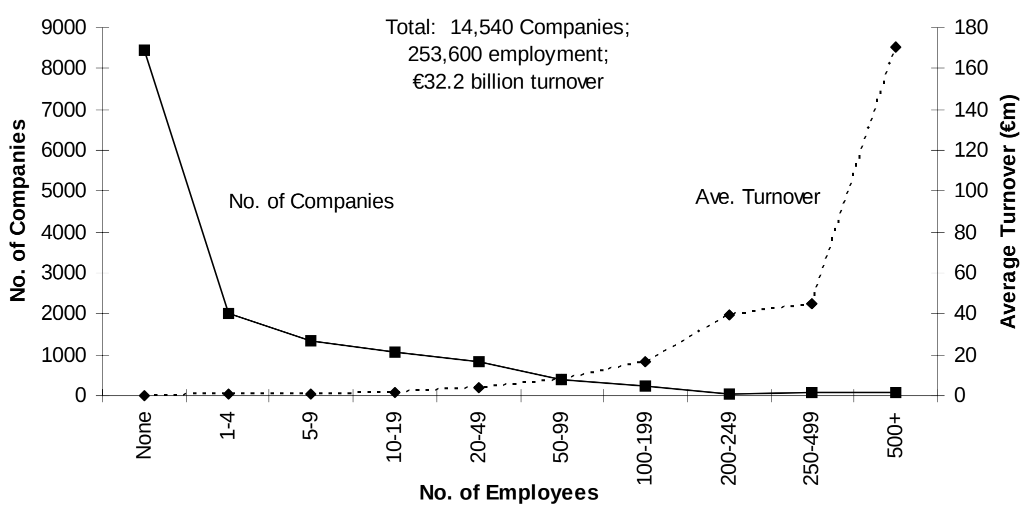

Figure 4.1: Number of Companies and Average Turnover for Manufacture of Plastics in the UK (DTI, 2001)

19 Note that this includes manufacturers of all plastics and rubber, not just those that are flame retarded.

In relation to the situation for the EU as a whole, it is reported (European Commission, 2002) that there are 55,000 companies manufacturing rubber and plastics in the EU-19[20]. Of these companies, the average enterprise size is 25 employees, with relative labour productivity of 7% above average for SMEs in general and relative profitability 3% less than the SME average[21].

4.3.3 Markets for Electronic and Electrical Equipment

Applications for Flame Retarded Plastics in E&E Equipment

The flame-retarded plastic materials discussed in the previous section find a wide variety of uses, including several within the electrical and electronics (E&E) industries including:

- housing of household equipment (television sets, video recorders, radio sets, air conditioners, refrigerators, washing machines, etc.);
- housing of office and business equipment (facsimile sets, telephones and pay telephones, answering systems, telex, copying equipment, etc.); and
- housing and components of IT equipment (computer casings, printed circuits, keyboards, printers, note-pad computers, electrical and electronic typewriters, pocket and desk calculators, etc.) (BSEF, 2000).

Table 4.8 provides details of the approximate value of production of electrical and electronic (E&E) goods in the European Economic Area. From this table, it is evident that the types of products in which octabromodiphenyl ether is used represent a very substantial market within the EU. In reality, octabromodiphenyl ether will only be used in a small proportion of the products in question, with other flame retardants being used in the majority of the products.

Figure 4.2 provides an overview of the market for office machinery and computers in the EU (domestic markets plus imports).

In terms of quantities, Stevens and Mann (1999) provide indications of the quantities of all BFRs (including octabromodiphenyl ether amongst others) used in the European E&E industry in 1999:

- 2,400 tonnes were used in TV backcasings;
- 400 tonnes were used in printed circuit boards (mainly TBBPA);
- more than 545 tonnes were used in business machines intended for home use; and
- more than 545 tonnes were used in other consumer products (such as vacuum cleaners, plugs, sockets).

---

[20] EU plus Iceland, Liechtenstein, Norway and Switzerland.

[21] In the report (European Commission, 2002), labour productivity relates to the value added per occupied person and the relative profitability relates to the difference between value added and labour costs, as a percentage of value added.

Table 4.8: Approximate Value of Production of Electrical and Electronic Goods in the EEA		
Product Types	**Value (€ bn)** [1]	**Ave Price (€)** [2]
Pumps and compressors	25	700
Electrical domestic appliances	30	600
Office machinery	10	50
Computers and other IT equipment	80	300
Electricity distribution and control equipment	47	50
Electrical motors, generators and transformers	30	150
Insulated wires and cables [3]	16	10
Lighting equipment and electric lamps	13	40
Electrical equipment for vehicles	20	20
TV and radio transmitters	88	3,000
Consumer electronics (incl. TV and radio receivers)	33	500
Industrial process control equipment	8	150
Electric instruments and medical equipment	40	3,000
Other electrical equipment	18	700
Total	450	500

[1] *Figures given to nearest €1 billion (except total, which is given to two significant figures)*
[2] *Average product price is calculated from the total value of the products divided by the number of products produced and given to the nearest €50 (except where the per produce value is less than €50, where given to one significant figure)*
[3] *Data from producers of insulated wires and cables is often given in terms of length produced (rather than number); the average product price given here is a guide only*
Sources: Eurostat (2000); information correlated with that from numerous other sources including RegTP (1999 and 2000); EACEM and GfK (2000); Sessi (2001); plus RPA's analysis

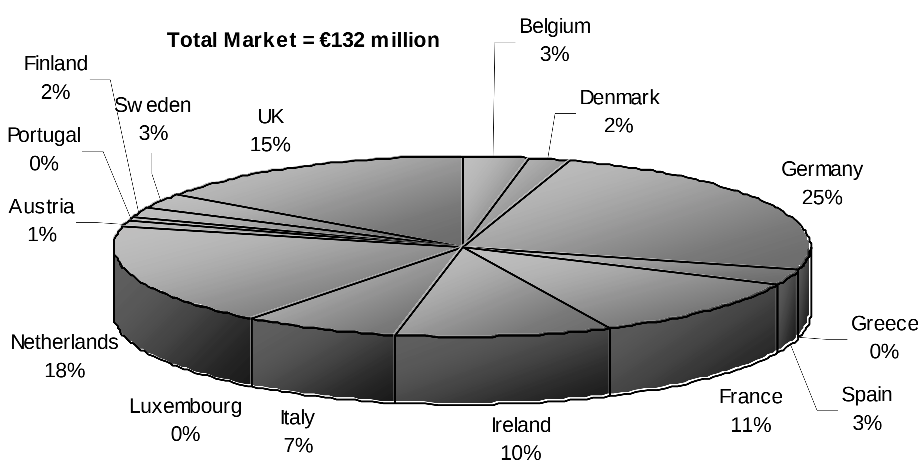

Figure 4.2: EU Market for Office Machinery and Computers (NACE Code 30)[22]

[22] These data are not all correct (for example, some countries are reported to have no market). However, the proportions for most of the countries are believed to be correct.

A total of 2.2 million people are employed in the European E&E sector (APME, 2001). In this sector, around 12% of all plastics used contain flame retardants, mainly in products such as television housings and computer monitors and cases (AMPE, 2001). As indicated in Table 4.9, around 65% of plastics used in PCs and monitors are treated with flame retardants, whereas only around 1% of plastics used in the inner parts of large household appliances contain flame retardants.

Table 4.9: Use of Flame Retardants in E&E Equipment (after APME, 2001)

Equipment	**% Treated with FR**	**Treated Plastics (tonnes)**
Data processing - PCs and monitors	65%	110,000
Office equipment - printers and copiers	20%	18,000
Consumer equipment - TVs/audio equip	55%	74,000
Small household equipment - inner parts	2%	3,000
Large household appliances - inner parts	1%	5,000
Total		*210,000*

Overview of Plastics Use in the E&E Sector

Figure 4.3 details the usage of various plastics in the E&E sector in 2000. ABS is the most widely used plastic in the sector, accounting for almost 0.5 million tpa. This is followed by polystyrene, polypropylene and polyurethane.

From Table 4.10, it can be seen that plastics consumption in E&E equipment is significantly higher in some Member States than in others. Germany represents the greatest use, followed by the UK, France and Italy. Together, these four Member States account for over two thirds of plastics usage in E&E equipment.

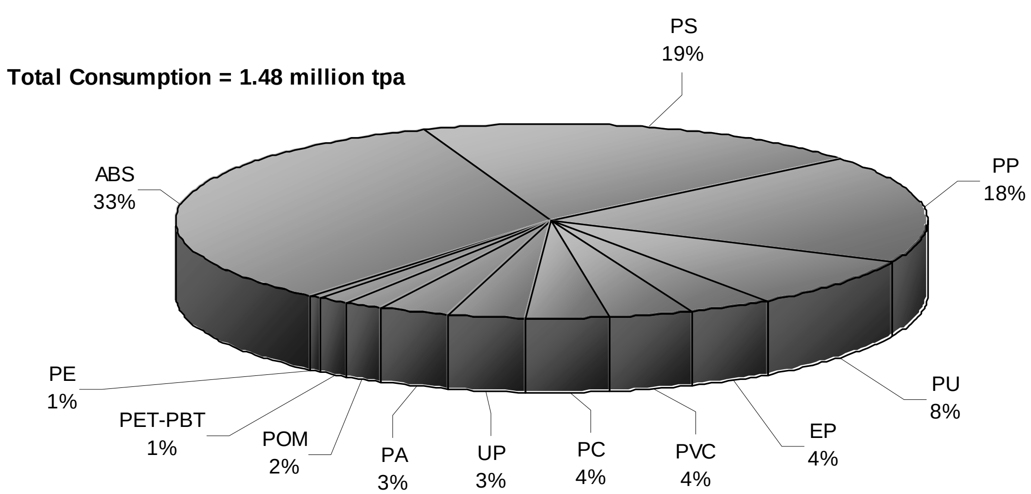

Figure 4.3: European Plastics Consumption in E&E Equipment (APME, 2001)

Table 4.10: Plastics Consumption in E&E Equipment by Country	
Member State	**Consumption**
Germany	24%
UK	16%
France	16%
Italy	12%
Spain	8%
Netherlands	5%
Others	19%
Source: APME (2001)	

Estimates of Markets Related to Octabromodiphenyl Ether Consumption

Total use of octabromodiphenyl ether in the EU, including that imported in products, is estimated as 1,350 tpa as a maximum. Assuming a concentration in use of 15% by weight, this corresponds to around 9,000 tpa of ABS polymer treated with octabromodiphenyl ether. As detailed in Table 4.11, this represents around 0.6% of total plastics used in electrical and electronic equipment and just under 2% of ABS plastics used.

Table 4.11: Relative Markets for ABS Plastics Containing Octabromodiphenyl Ether	
Percentage of total *plastics* used in E&E equipment	0.6%
Percentage of total *ABS* used in E&E equipment	1.8%
Percentage of total FR-treated plastics used for PCs/monitors	8.0%

Based upon the data presented above, it is possible to estimate the number of products and the respective value for the types of products in which ABS flame-retarded with octabromodiphenyl ether is used. These estimates are provided in Table 4.12. The service life of these types of products could be expected to be around three years for computers, for example, but would be longer for other office machinery such as photocopiers. The total number of products on the market at any one time, therefore, could be around 13 million.

Table 4.12: Estimated Downstream Markets for Octabromodiphenyl Ether	
Number of E&E products that contain octabromodiphenyl ether	3.3 million
Value of E&E products that contain octabromodiphenyl ether	€900 million
Note: It is assumed that 3kg of flame retarded plastic is used in each product. It is further assumed that the average product price is €300, based upon that for computers and other IT equipment in Table 4.8	

4.4 Summary of Markets for Octabromodiphenyl Ether

Table 4.13 summarises the data from the above sections on the quantities and values of octabromodiphenyl ether, the flame-retarded plastics in which it is used and the final electronic and electrical equipment products. The data include total estimated usage of octabromodiphenyl ether, including that imported within products.

Table 4.13: Summary of Estimated Market Data for Octabromodiphenyl Ether

	Quantity	**Value (€m)**
Octabromodiphenyl ether	1,350 tpa [a]	4.9
ABS containing octabromodiphenyl ether	9,000 tpa	12.5 [b]
E&E products containing ABS with octabromodiphenyl ether	3,000,000 (#)	900

Notes: [a] *Only around 450 tpa imported as the substance itself, with remainder in polymers.*
[b] *Value of ABS assumed at €1 per kg, with octabromodiphenyl ether at €3.6 per kg and used at a concentration of 15% w/w. # = number of items.*

5. POTENTIAL SUBSTITUTES FOR OCTABROMODIPHENYL ETHER

5.1 Overview

5.1.1 Key Considerations in Substituting Octabromodiphenyl Ether

Fire retardancy of plastic products is recognised as a key element of an effective policy to reduce deaths and injuries associated with fires, particularly in the home. There are other factors that can also contribute to improved fire safety, such as the use of smoke alarms and reducing the level of smoking amongst the population. Whilst these latter factors are important contributors to fire safety, consideration is only given here to the fire safety of products. In particular, consideration is given only to those options that would not be likely to lead to a reduction in overall fire safety.

The potential health and environmental risks associated with use of alternatives to octabromodiphenyl ether are another key consideration. If companies were to replace the substance, it should be ensured that the level of risk to health and the environment does not increase.

Furthermore, the economic implications of substituting octabromodiphenyl ether (or the plastic/flame retardant system) should be taken into account. Any strategy aimed at reducing the environmental and human health risks should not lead to costs that are disproportionate to the benefits achieved.

The key criteria in appraising potential substitutes for octabromodiphenyl ether are, therefore, as follows:

- level of fire retardancy achieved with the alternative;
- risks to human health and to the environment[23]; and
- costs or savings to industry in substituting octabromodiphenyl ether.

5.1.2 Potential Options for Substitution

During the course of this study, a number of potential alternatives for octabromodiphenyl ether has been identified, where this includes possible direct substitutes or substitute flame retardants that are suitable for use in other polymer types.

Thus, for the present report consideration is given to the most likely substitutes, based upon those identified in Stage 2 and on other possible substitutes identified during this stage. Key possibilities for substitution of octabromodiphenyl ether that are considered in this section are shown in Table 5.1.

---

[23] The appraisal of substitutes considered herein is only intended to be a quick hazard profiling of alternatives based upon available data, rather than an exhaustive evaluation of the data. This review is based almost exclusively on secondary data, rather than an detailed evaluation of primary toxicological and ecotoxicological studies.

Table 5.1: Possible Substitutes and Suitable Polymers Considered in this Report	
Substance	**Suitable Polymers**
Tetrabromobisphenol-A	ABS, HIPS, PC, etc
1,2-bis (pentabromophenoxy) ethane	ABS, HIPS, PC
1,2-bis (tribromophenoxy) ethane	ABS, HIPS
Triphenyl phosphate	PC/ABS, etc.
Resourcinol bis (diphenylphosphate)	PC/ABS, HIPS
Brominated polystyrene	PC, polyesters, polyamides
Design-based solutions	Not applicable
Note: This list is not exhaustive	

In the following sections, consideration is given to the above possibilities for replacement of octabromodiphenyl ether in the products of concern. The suitability of these potential options is assessed against the three criteria identified above.

In the discussion of comparative purchase prices for substitute flame retardants and polymers, it should be noted that the prices paid by companies often depends upon their ability to negotiate with suppliers. There will thus be some variability in actual prices paid.

5.1.3 Existing Trends in Substitution

Housings for electronic and electrical equipment is reported to be one of the areas where the most pronounced shifts away from the use of brominated flame retardants has taken place. There has been a general move away from use of PBDEs (deca and octabromodiphenyl ether) to tetrabromobisphenol-A, as well as to non-halogenated flame retardants (Danish EPA, 1999).

The German Dioxin Directive of 1994 established maximum concentrations of polybrominated dibenzodioxins and dibenzofurans (PBDDs and PBDFs respectively) in products to be placed on the market. This is reported to be one of the reasons for substitution of PBDEs in these products (Danish EPA, 1999). Elevated temperatures during the processing of plastics can lead to the formation of PBDDs and PBDFs and studies to determine the levels of these compounds formed when processing flame retarded ABS or PBT revealed that:

- where deca and octabromodiphenyl ether were used, the highest levels of PBDDs and PBDFs were produced;

- levels observed with TBBPA or bis-tetrabromo-phthalimide ethylene (TBPI) were several orders of magnitude lower; and

- PBDDs/PBDFs were not detected during processing of ABS containing brominated styrene or 1,2-bis(tribromophenoxy)ethane (WHO, 1998).

Another key driver away from the use of octabromodiphenyl ether is reported (Danish EPA, 1999) to be the fact that it is used in conjunction with antimony trioxide, a substance that is classified as R40[24] and is a Category 3 carcinogen. Preparations containing over 1% by weight of a Category 3 carcinogen are classified as dangerous under the Dangerous Preparations Directive, with subsequent requirements to control the risks to workers under the Chemical Agents Directive (with substitution being the preferred option under Article 6(2) of that Directive).

5.2 Substituting the Flame Retardant used in ABS

5.2.1 Potential Substitutes Considered

It has been widely acknowledged in the literature that the use of non-halogenated flame retardants in ABS plastics is currently not possible (Danish EPA (1999), German UBA (2001a)). Consideration is therefore given here to three brominated flame retardants that can reportedly be used in ABS for the housings of electrical and electronic equipment:

1. Tetrabromobisphenol-A;
2. 1,2-bis (pentabromophenyl) ethane; and
3. 1,2-bis (tribromophenoxy) ethane.

It is understood that essentially an equivalent level of flame retardancy can be met with all of these brominated flame retardants, as compared to octabromodiphenyl ether[25]. Thus, consideration is given in the following sections to the likely human health and environmental effects associated with these substances.

These substances may also be used in polymers other than ABS. However, for the present discussion, only use in ABS is considered in order to represent the 'simplest' substitution option.

5.2.2 Tetrabromobisphenol-A

Use and Regulatory Status

An estimated 40,000 tpa of tetrabromobisphenol A (TBBPA) are used in the EU each year (Environment Agency, 2001b).

[24] "Limited evidence of a carcinogenic effect".

[25] In other words, the V0 standard can be met for ABS housings that are flame retarded with one of these three compounds.

TBBPA is on the fourth priority list[26] for risk assessment under the Existing Substances Regulation, with the UK as rapporteur. For the purposes of this risk reduction strategy, a draft of the environmental risk assessment (Environment Agency, 2002b) has been made available.

TBBPA, and derivatives thereof, can be used as flame retardants in a range of different plastics, including ABS, HIPS and PC. Such use can either be as an additive type flame retardant or a reactive type, although where used as a substitute for octabromodiphenyl ether in ABS, use will only be as an additive type. Similarly, it is used as an additive type in polyolefins (Danish EPA, 1999).

However, the majority of TBBPA on the market is used as a reactive type flame retardant with only around 10% used as an additive type. The European Brominated Flame Retardants Industry Panel (EBFRIP, 2002a) indicates that the main use is as a reactive flame retardant in printed circuit boards, of which an estimated 96% of those on the market contain TBBPA.

TBBPA is on the OSPAR Commission's life of 'Chemicals for Priority Action'. In addition, the Chemicals Stakeholder Forum in the UK has identified TBBPA as a PBT chemical (DEFRA, 2002) during screening for chemicals of possible concern in the UK.

The German Federal Environment Agency (German UBA, 2001a) has recommended a phase-out of the use of TBBPA where used as an additive flame retardant and indicates that 'reduction is expedient' and 'substitution is desirable' for use as a reactive flame retardant.

It is understood that the Dutch Ministry of Housing, Spatial Planning and the Environment recently introduced a ban on the use of tetrabromobisphenol A bis(2,3-dibromopropyl ether), a derivative of TBBPA.

Potential Human Health Risks

Annex 3 provides a summary of some of the key properties of TBBPA, as well as other potential substitute flame retardants. Based on the available data, TBBPA does not appear to be harmful in acute toxicity tests and repeated dose toxicity is indicated as being 'very low' (WHO, 1995).

TBBPA is not irritating or sensitising. No evidence of teratogenic effects have been observed and no mutagenic effects have been observed in a number of in-vitro tests (WHO, 1995). There are reported to be no data on carcinogenicity of TBBPA (German UBA, 2001a).

Based on the available toxicological data, there is no evidence to suggest that the risks to human health associated with TBBPA are likely to be greater than those of octabromodiphenyl ether.

[26] Commission Regulation (EC) No 2364/2000 of 25 October 2000 concerning the fourth list of priority substances as foreseen under Council Regulation (EEC) No 793/93, OJ L 273, 26.10.2000, page 5.

Potential Environmental Risks

A number of acute toxicity tests have determined $L/E/IC_{50}$ values less than 1 mg/l for TBBPA and the substance does not appear to be readily biodegradable. Based on these findings, it could be expected that TBBPA will be classified[27] as N; R50/53 ('very toxic to aquatic organisms' and 'may cause long term adverse effects in the aquatic environment') in the future.

Losses during polymer processing could be expected to be similar to those for octabromodiphenyl ether if TBBPA were to replace octabromodiphenyl ether as an additive flame retardant in ABS. This is due to the very similar values for vapour pressure, which was used in the risk assessment (Environment Agency, 2002a) to estimate volatile loss from products.

As noted above, TBBPA can also be used as a *reactive* type flame retardant in other types of plastic (it is used as an additive type in ABS). Where it is used as a reactive flame retardant, losses during the service life could be expected to be much lower than those for octabromodiphenyl ether because the flame retardant forms part of the polymer itself.

The draft environmental risk assessment for TBBPA (Environment Agency, 2002b) does not indicate any areas where there is a need for risk reduction measures. However, PEC/PNEC ratios above unity have been calculated for a number of scenarios and the rapporteur has indicated that there is a need for further information on EU releases in order to refine the PEC values and also further testing to refine the PNECs used for surface water, sediment, soil and sewage treatment microorganisms.

Economic Considerations

TBBPA is a high production volume chemical, with preliminary information from the ESR risk assessment suggesting total usage of around 40,000 tpa in the EU. As a result, the price of this substance is relatively low, with the price per tonne expected to be around half that of octabromodiphenyl ether (see, for example, IAL, 1999).

5.2.3 1,2-bis (pentabromophenyl) ethane

Use and Regulatory Status

It is reported that 1,2-bis (pentabromophenyl) ethane is manufactured in the United States, with European sales estimated at 2,500 tpa (German UBA, 2001a). Sales of this flame retardant are reported to be increasing. This substance can be used in ABS plastics but is often used in other polymer systems, such as high impact polystyrene.

---

[27] According to: Commission Directive 2001/59/EC of 6 August 2001 adapting to technical progress for the 28th time Council Directive 67/548/EEC on the approximation of the laws, regulations and administrative provisions relating to the classification, packaging and labelling of dangerous substances, OJ L 225, 21.8.2001, page 1.

Potential Human Health Risks

Acute toxicity of this substance appears to be low and it reported to be not irritating. It was negative in a number of *in-vitro* mutagenicity tests. Repeated dose toxicity appears to be low, with a NOAEL of 1,000 mg/kg observed for a 90 day sub-chronic study in rats (Albemarle, 2001b).

Developmental toxicity also appears to be low with no effects observed up to 1,250 mg/kg in rats and rabbits. There is no evidence to suggest concerns regarding reproductive toxicity.

The available data on the toxicology of the substance do not indicate that risks for human health are likely to be greater than for octabromodiphenyl ether. For key concerns regarding octabromodiphenyl ether (e.g. developmental toxicity), the available data suggest lower toxicity for 1,2-bis (pentabromophenyl) ethane. It should be noted, however, that there are fewer data available on this substance than for octabromodiphenyl ether.

Potential Environmental Risks

There are very few available data on the ecotoxicological properties of this substance. The only measured endpoint is for an acute toxicity test in fish, in which the LC_{50} was reported as being significantly greater than the solubility limit.

The potential for bioaccumulation appears to be less than for octabromodiphenyl ether. The bioconcentration factor (BCF) appears to be lower than for octabromodiphenyl ether, especially as concerns the hexabromodiphenyl ether component. However, the validity of the test data on BCF values has been questioned due to the use of a surfactant to disperse the test substance.

Losses to the environment during polymer processing could be expected to be similar to those for octabromodiphenyl ether. It is unknown what the losses from products during their service life are likely to be but it could be expected that they will be of a similar magnitude. The substance is not readily biodegradable.

Overall, there is no data to suggest that risks for the environment are likely to be higher than those for octabromodiphenyl ether. It should be noted, however, that there are fewer data available on this substance.

Economic Considerations

In terms of purchase price, 1,2-bis (pentabromophenyl) ethane is understood to be around 30% more expensive than octabromodiphenyl ether.

5.2.4 1,2-bis (tribromophenoxy) ethane

Use and Regulatory Status

The quantity of 1,2-bis (tribromophenoxy) ethane used in the EU is unknown. It is a brominated flame retardant with high bromine content and good thermal and UV stability. It is used in plastics such as HIPS, ABS, PC, thermoplastic, elastomers and unsaturated polyesters. It is reported to be most suitable where thermal stability at high processing temperatures is important (GLCC, n.d.).

Potential Human Health Risks

The substance appears to be of low acute toxicity based on oral, dermal and inhalation tests on rodents and rabbits. It is not irritating to skin nor to eyes. Two *in-vitro* assays were negative for mutagenic effects and a teratology study indicated no signs of teratogenicity.

Repeated dose toxicity appears to be lower than for octabromodiphenyl ether, since no effects were observed in three and four week tests on rats (inhalation and dietary respectively). Also, no effects were observed at 1% (or 10,000 ppm) concentration in food, although liver cell enlargement was observed at 10%. This can be compared to the LOAEL for repeated dose toxicity for octabromodiphenyl ether of 100ppm.

In general, there is no evidence to suggest that the risks for human health associated with use of 1,2-bis (tribromophenoxy) ethane are likely to be greater than for octabromodiphenyl ether. Once again, however, it should be noted that there are fewer available data on the toxicology than for octabromodiphenyl ether.

Potential Environmental Risks

Few data are available on the environmental hazards of this substance. Acute toxicity to fish appears to be low[28]. The substance has a moderate potential for bioconcentration in the aquatic environment with BCF values up to 44 measured for fish.

Based on the results of a structure activity relationship for this substance (using US EPA, 2000), it is not expected to be readily biodegradable.

As with human health risks, there is no evidence to suggest that the risks are likely to be greater than for octabromodiphenyl ether, although the data available are far fewer.

Economic Considerations

The cost of the substance compared to octabromodiphenyl ether is unknown. However, it is likely to be of a similar order.

---

[28] The lowest TL_{50} value for six tests in two species of fish suggest a value of 1,140 mg/L in rainbow trout (GLCC, 2001c). This is above the limit of solubility for the substance which is less than 1,000 mg/L.

5.2.5 Other Possible Substitutes

The supplier of octabromodiphenyl ether to the EU market has identified a number of other flame retardants that could be used in ABS thermoplastics in order to meet an equivalent level of fire safety:

- **Brominated epoxy oligomers**: have a lower cost than octa, with better UV stability and surface properties. However, a higher loading is needed and productivity during compounding and processing is reported to be lower; and

- **1,3,5-triazine-tris (2,4,6-tribromophenoxy)**: has similar processing and performance characteristics with good UV stability, but is of higher cost than octabromodiphenyl ether.

5.3 Substituting Polymer and Flame Retardant

5.3.1 Key Substitution Possibilities

A range of potential substitute flame retardants for use in other polymers are also available on the market, including for use in housings of electrical and electronic equipment. It should be noted that all of the potential substitutes considered in Section 5.2 can also be used in polymers other than ABS.

A key potential substitute identified for polymers other than ABS is the use of triphenyl phosphate, particularly in PC/ABS blends. Another potential substitute is resorcinol bis(diphenylphosphate) (RDP), which can also be used in PC/ABS blends, amongst others. The final substitute considered in this section is brominated polystyrene.

It is understood that non-halogenated flame retardants cannot be used effectively in ABS plastics, at least for certain types of materials. Therefore, in order to use flame retardants such as triphenyl phosphate or RDP, it would be necessary to substitute both the flame retardant and the polymer. Consultation indicates that the choice of polymer and flame retardant is determined by a number of factors, particularly the colour, physical performance and cost-effectiveness. During the design process for the types of products in question, therefore, companies will generally choose a particular polymer, with associated additives (including flame retardant) to meet the needs of the product.

5.3.2 Triphenyl Phosphate

Use and Regulatory Status

Triphenyl phosphate (TPP), along with tricresyl phosphate, is currently undergoing assessment under the ICCA HPV programme, involving collation and generation of data on the hazards of certain high production volume (HPV) chemicals.

The PC/ABS polymers in which TPP is often used have higher impact strength than ABS flame retarded with octabromodiphenyl ether and are also reported to have greated UV stability. However, during recycling of in-house and post-consumer scrap, there is reported to be a greater loss of performance as compared to ABS flame retarded with octabromodiphenyl ether

Potential Human Health Risks

Based on the available toxicological data on TPP, the substance does not appear to be particularly hazardous for human health. Acute toxicity data do not appear to indicate the need for classification as harmful or toxic. The substance has tested negative in several in-vitro mutagenicity tests and is not irritating skin (but slightly irritating to the eyes).

Developmental toxicity appears to be lower than that of octabromodiphenyl ether and repeated dose toxicity tests reveal a NOAEL significantly higher than the LOAEL for octabromodiphenyl ether.

Thus, the available data do not suggest that the human health risks associated with TPP are likely to be greater than those of octabromodiphenyl ether. Once again, however, there are fewer data available than for octabromodiphenyl ether.

Potential Environmental Risks

Based on the short-term ecotoxicological data available, TPP would appear to be very toxic for aquatic organisms. The substance also has a high chronic toxicity for the aquatic environment.

Losses during polymer processing would be expected to be similar to those for octabromodiphenyl ether, assuming that it is used in the same way. In service losses of this substance are likely to be greater than for octabromodiphenyl ether, based on the approach used in the environmental risk assessment. The vapour pressure of TPP is 3×10^{-5} Pa, as compared to that for octabromodiphenyl ether which is 6.59×10^{-6} Pa. Since the in service loss of flame retardant is assumed to be proportional to the vapour pressure, one might expect the loss of TPP from products to be a factor of 4.6 greater than that for octabromodiphenyl ether.

Thus, the acute toxicity of TPP is greater than that of octabromodiphenyl ether and it could be expected to be released into the environment in quantities at least as great. In the environment, however, is likely to undergo biodegradation much more rapidly. The potential for bioconcentration appears to be less than for the hexabromodiphenyl ether component but more than the other components of commercial octabromodiphenyl ether.

Economic Considerations

The purchase price of TPP is expected to be the same as that for octabromodiphenyl ether or up to around 25% less expensive. However, the price of the entire polymer-flame retardant system, could be greater (e.g. up to 10 percent higher). As indicated above, the price paid in practice is likely to depend upon companies ability to negotiate prices with suppliers.

5.3.3 Resorcinol Bis(diphenylphosphate)

Use and Regulatory Status

Resorcinol Bis(diphenylphosphate) (RDP) can reportedly impart superior flammability performance and lower volatility than is obtainable with conventional triaryl phosphate flame retardants (GLCC, 2001b). It is an oligomeric phosphate-based flame retardant and could be expected to have a molecular weight from 575 to 2069 (based on Akzo Nobel, 1998).

It is reported to be suitable for use in a range of polymers, such as PC/ABS blends and polyphenylene oxide. However, during recycling of in-house and post-consumer scrap, there is reported to be a greater loss of performance as compared to ABS flame retarded with octabromodiphenyl ether (as with TPP).

Potential Human Health Risks

Acute toxicity of RDP appears to be low and it is not irritating or sensitising to skin (although it is slightly irritating to the eyes). No reproductive or developmental effects have been observed through oral administration in laboratory animals. It does not appear to be genotoxic. Longer term toxicity through inhalation appears to be lower than that for octabromodiphenyl ether[29].

RDP does not appear to require labelling for human health effects under Directive 67/548/EEC, although it should be noted that the level of information available on the health effects of this substance is likely to be less than that for octabromodiphenyl ether.

It is indicated (GLCC, 2001b) that several mutagenicity tests have been conducted and the results found to be negative[30].

Potential Environmental Risks

Based upon the available ecotoxicological data, it could be expected that RDP could be classified as 'harmful' to aquatic organisms. Indeed, in the EU, it is self-classified as R52/53 (harmful to aquatic organisms, may cause long-term adverse effects in the aquatic environment)[31]. It is a liquid and so dust will not be generated in the same manner as for octabromodiphenyl ether during polymer processing (volatile losses may differ however, although there appear to be no data available on volatility, except maximum values for vapour pressure). It is not possible to estimate losses from products in the same manner as undertaken for octabromodiphenyl ether.

---

29 A NOEL of 100 mg/m^3 is reported for RDP in a 28 day inhalation toxicity study (GLCC, 2001b), as compared to the NOAEC of 0.6 mg/m^3 for a 14 day inhalation study on octabromodiphenyl ether, as used in the human health risk characterisation for the identification of risks from polymer processing.

30 These were an Ames test, mouse micronucleus test and a chromosome aberration test.

31 The substance might actually warrant classification as very toxic to aquatic organisms, based upon the 48h EC_{50} of 0.76 mg/L for *Daphnia magna*.

RDP also contains a small proportion of TPP which, as described above, is more toxic to aquatic organisms than RDP itself.

Economic Considerations

The specific price of RDP as compared to octabromodiphenyl ether is unknown. However, phosphorus-based flame retardants are generally of a similar price to that of PBDEs. It might thus be assumed that there would be no price increase for purchase of the flame retardant itself. However, there could be a cost premium associated with purchase of the polymer-flame retardant system which could be expected to be no greater than 10% more than ABS that contains octabromodiphenyl ether.

5.3.4 Brominated Polystyrene

Use and Regulatory Status

Quantities of brominated polystyrene used on the EU market are not known. This polymeric substance is used as an additive flame retardant in plastics such as ABS, HDPE, polyamide and PBT. It is generally used in conjunction with antimony trioxide, as is octabromodiphenyl ether (Danish EPA, 2000a).

Potential Human Health Risks

Brominated polystyrene is a comparatively high molecular weight substance (since it is a polymer). In part due to this property, the associated toxicity of brominated polystyrene is considered to be low (Danish EPA, 2000a).

Acute toxicity tests do not reveal a cause for concern. The substance is, however, a slight to moderate irritant. Based on the available data, test results on repeated dose toxicity, reproductive toxicity and developmental toxicity all indicate a lower toxicity than octabromodiphenyl ether. However, it should be noted that the available data are less than for octabromodiphenyl ether.

Brominated polystyrene is considered to be non-mutagenic to salmonella (Australian Government, 2001). However, some commercial preparations of the substance have shown mutagenic effects in some tests, with these results suggested to occur as a result of the presence of contaminants including monomers such as brominated styrene monomer (Danish EPA, 2000a).

In general, the risks to human health associated with brominated polystyrene could be expected to be lower than for octabromodiphenyl ether, if only because the molecular size is so much greater. It should be noted from above, however, that the presence of impurities and residual monomers within the commercial product may result in increased toxicity in certain tests. Indicators of potential concern for impurities and residual monomers in brominated polystyrene are the extractivity in water and percentage of low molecular mass species in the product.

Potential Environmental Risks

There do not appear to be any data available on the ecotoxicological properties of brominated polystyrene. However, one would expect the level of environmental exposure to be significantly less than that of octabromodiphenyl ether, especially in relation to losses during the service life of products. One would also expect the environmental risks associated with the substance to be relatively low given the large size of the molecule.

However, as with human health effects, the presence of impurities and residual monomers could be expected to contribute more to potential environmental risks than the polymer itself. Again no information has been found in this regard.

Economic Considerations

Brominated polystyrene is understood to be slightly more expensive than octabromodiphenyl ether.

5.3.5 Other Possible Substitutes

The supplier of octabromodiphenyl ether to the EU market has identified a number of other flame retardants that could be used polymers other than ABS in order to meet an equivalent level of fire safety:

- **Bisphenol A polyphosphates**: used in PC/ABS have higher impact strength and good moulding properties but are of higher cost for the polymer system with some loss of properties during recycling of in-house and post consumer scrap;

- **Brominated carbonate oligomers**: used in polycarbonate, which is of higher impact strength than ABS but the polymer system is of higher cost;

- **A proprietary silicone technology**: used in PC, which is of higher impact strength than ABS but the cost of the polymer system is reported to be much higher and the effectiveness has been questioned;

- **Brominated epoxy oligomers**: used in HIPS have lower cost for the polymer system and good UV stability but poorer physical properties; and

- **Decabromodiphenyl ether**: used in HIPS is of lower cost than octabromodiphenyl ether but reportedly has poorer physical properties.

5.4 Design Options for Fire Safety

As discussed in Section 4, only around 65% of plastics used in PCs and monitors are flame retarded. This represents an upper level for plastics used in the E&E sector, with most other types of products comprising significantly less flame retarded plastic (for the overall markets). The outer housing of E&E components such as PC monitors represents the greatest source of fuel within these products and consultation indicates that fire safety protection against both internal and external sources of ignition are important for these types of plastics.

It is reported (Danish EPA, 1999) that fire safety solutions that do not employ flame retardants can be (and are) also used. For example, one method of reducing the risk of fire from internal sources (internal components of the equipment) is to shield the outer casing from the inner components with metal, such as aluminium. An alternative method is to use plastics that are inherently more resistant to ignition. A further method (German UBA, 2001a) is to produce the entire case out of metal, such as is done with some laptop computers.

Another possible option for improving fire safety of these types of products is the maintenance of certain distances between high voltage parts of the products and the outer casings (German UBA, 2001a). It should be noted that, although the use of metal shields or maintenance of safe distances from high voltage parts will provide increased protection against internal sources of fire, they may not provide protection against exterior sources of fire (such as candles, for example).

Other possible options for maintaining fire safety without the use of flame retardants include the use of materials with low rates of combustion, such as certain amino-, pheno-, fluoro- and silicone-based polymers. Furthermore, changing use of fuses to prevent short circuits, reducing operating temperatures and use of materials that conduct heat away from 'hot-spots' can all help to improve the fire safety of products (Tavlet and Santaoja, 1999).

These types of design options potentially provide a suitable alternative to use of octabromodiphenyl ether, reducing more generally any human health or environmental issues associated with use of flame retardants in the products (although such effects might arise in relation to other additives used).

We have insufficient information to estimate the costs associated with altering designs as an alternative to flame retarding with octabromodiphenyl ether. However, there will inevitably be costs associated with research and development for the use these types of design options for fire safety and some options are likely to be more expensive in terms of materials, such as use of metal casings for laptop computers (and may be less acceptable to consumers if they result in increased size and weight, for example). It is also possible that some cost reduction may be achieved, if plastics without flame retardants were used (in meeting the same level of fire protection), because flame retardants tend to be more expensive than the plastics in which they are used. Again, no data are available to quantify any such changes in costs.

5.5 Summary of Substitutes for Octabromodiphenyl Ether

Table 5.2 summarises the information from the preceding sections on the suitability of various alternatives to octabromodiphenyl ether in terms of technical performance, health and environmental risks and cost implications. It should be noted that this table is based upon the *available* information, which in many cases is significantly less than that for octabromodiphenyl ether. Reference should also be made to the above discussion and the information presented in Annex 3.

Based upon this analysis, there are alternatives to octabromodiphenyl ether available for which the available data do not indicate an equivalent or higher level of risk to health or the environment. This is especially true of reactive type flame retardants that will have significantly lower emissions during the service life of products.

However, for all of the potential substitutes identified, the existing data on toxicological and ecotoxicological effects are fewer than for octabromodiphenyl ether. Given that none of these substances have yet undergone a risk assessment as rigorous as those carried out under ESR, it is inevitably not possible to compare the risks on a like-for-like basis (and thus to assure absolutely that substitution would result in an overall reduction in risks to health and the environment). The results of the further testing and assessment that is ongoing for some of the potential substitutes should help to resolve the differences in data availability to a degree.

Nonetheless, based on the information presented in Annex 3, it is evident that some of the substances do have data available on some of the key endpoints of concern for octabromodiphenyl ether (e.g. developmental toxicity) and that these indicate lower toxicity.

There are also other options for replacing octabromodiphenyl ether, without utilising a substitute flame retardant. These include redesign of the electrical or electronic products or use of polymers with lower rates of combustion. Whilst we have inadequate data to estimate the likely costs of such techniques, it is considered that they are likely to be more expensive than using octabromodiphenyl ether in most cases (at least in the short-term).

Based on consultation with industry, it is evident that most companies have already replaced octabromodiphenyl ether in their products with other flame retardants and some companies utilise design measures, rather than flame retardants, for certain types of products[32]. Overall, there does not appear to be any major technical obstacle to replacement of the substance, although some of the flame retardant/polymer combinations considered in this section may have inferior technical performance in certain applications.

It would appear that most of the substitution options, however, could result in some adverse cost implications. This is true both of substitutes for octabromodiphenyl ether where used in ABS (except for TBBPA) and also for alternatives that would require substitution of the polymer as well (such as ABS for PC/ABS blends).

---

[32] Consultation indicates, however, that whilst certain plastic products can be produced without flame retardants (and still maintain the required level of flame retardancy), other plastic products can not and will continue to require the use of flame retardants.

Table 5.2: Summary of Potential Substitution Options Compared to Octabromodiphenyl Ether

Substance	Potential Health Risks [a]	Potential Environmental Risks [a]	Cost and Other Considerations
Tetrabromobisphenol-A [b]	No evidence of equal or greater risks	Data indicate may be classified as 'very toxic to aquatic organisms, may cause long term adverse effects in the aquatic environment' [c]	Less expensive but greater FR loading required. ESR risk assessment ongoing and concerns expressed about substance in some member states
1,2-bis (pentabromophenoxy) ethane [b]	No evidence of equal or greater risks	PBT properties appear of less concern than octa. However, fewer data and BCF values questioned	More expensive
1,2-bis (tribromophenoxy) ethane [b]	No evidence of equal or greater risks	Very limited data	Greater FR loading probably required
Triphenyl phosphate	No evidence of equal or greater risks	High toxicity and relatively high potential for bioaccumulation but is readily biodegradable	Less expensive but polymer/FR system expected to be more expensive overall. Poorer plastic recyclability
Resourcinol bis (diphenylphosphate)	No evidence of equal or greater risks	Acutely toxic or very toxic but biodegradable	Less expensive but polymer/FR system expected to be more expensive overall. Poorer plastic recyclability
Brominated polystyrene	No evidence of equal or greater risks (but some concerns expressed re: impurities in commercial product)	No data but losses and exposure expected to be lower	Slightly more expensive

Notes: [a] *Note that in most cases, the information available on toxicological and ecotoxicological effects is less than that for octabromodiphenyl ether.*
[b] *Can be used in ABS as well as other polymers. Other flame retardants listed are not suitable for use in ABS (see Table 5.1).*
[c] *Note that in-service losses will be lower where used as reactive FR in non-ABS polymers.*

6. POSSIBLE FURTHER RISK REDUCTION MEASURES

6.1 Range of Risk Reduction Options

Section 2 provided details of the risks that need to be addressed.

The Technical Guidance Document (TGD, European Commission, 1998) outlines a range of possible options for controlling risks to human health and the environment. A number of these options was considered during Stage 2 of this study, with the list being amended at the Steering Group meeting. It was decided that the following options should be taken forward for further assessment:

- restrictions on the marketing and use of octabromodiphenyl ether;
- legislation to reduce environmental emissions from polymer processing;
- reducing the concentration of lower brominated congeners in the commercial product;
- worker protection measures resulting from classification and labelling;
- reducing the application of sewage sludge containing octabromodiphenyl ether to land; and
- economic instruments as a means of providing users with an incentive to move away from octabromodiphenyl ether.

As described in the preceding sections, there is already a trend away from the use of octabromodiphenyl ether amongst companies and Member States. This is a result of historical concerns with use of PBDEs in general and through measures taken forward by a variety of bodies (as discussed in Section 3).

It is possible that, without any further action being taken as a result of this risk reduction strategy, the identified risks associated with octabromodiphenyl ether could be reduced to an 'acceptable' level (i.e. one where there is no concluded need for risk reduction measures). This could occur principally through a reduction in the overall level of usage of the substance (which would need to be monitored on an annual basis). This has been borne in mind in considering each of the possible measures above.

The following sections provide an overview of how these possible measures could be implemented in practice.

6.2 Marketing and Use Restrictions

Directive 76/769/EEC[33] provides for the introduction of restrictions on the marketing and use of certain dangerous substances and preparations. This Directive has been adapted several times and, in particular, it is currently proposed that the Directive be amended in order to restrict the marketing and use of pentabromodiphenyl ether (as discussed in Section 3).

---

33 OJ L 262, 27.9.1976.

Through this Directive, an outright ban upon the marketing and use of octabromodiphenyl ether, both in terms of the substance and the preparations in which it is found, could be introduced. Furthermore, it allows for measures to restrict the placing on the market of articles containing specific substances. There is a number of other possible measures that could be introduced under this Directive, such as restrictions on:

- the form in which the substance is used;
- the concentration of various components within the commercial product; and
- types of products in which the substance is used.

Discussion of the introduction of marketing and use restrictions in this report only relates to a ban upon such marketing and use. However, consideration has also been given to possible measures regarding the form in which octabromodiphenyl ether is used (see Section 6.5 regarding worker protection measures). It would also, theoretically, be possible to reduce the concentration of the hexabromodiphenyl ether component (Section 6.4) or to restrict the use of octabromodiphenyl ether to a certain concentration. The latter, for example, could reduce the risks associated with emissions from products to a desired degree.

The potential for a 'cap' upon the total level of octabromodiphenyl ether supplied to the EU market was raised as a possible option for controlling the risks. However, it was agreed at this meeting that such a measure would not provide for controls upon imports in products.

Restrictions introduced through Directive 76/769/EEC could prohibit the use of octabromodiphenyl ether, use of preparations containing the substance (e.g. in compounded mixtures intended for use in polymer processing) or use of finished products, such as E&E equipment, that contain the substance.

Obviously an outright ban on the substance would address the risks associated with the substance, both for human health and for the environment, and for all life cycle stages.

6.3 Reducing Environmental Emissions from Polymer Production

There are two key legislative means at the Community level by which standards could be introduced for control of emissions of octabromodiphenyl ether to the environment. Firstly, the Water Framework Directive (WFD), as discussed in Section 3 requires that the Commission submits proposals for a progressive reduction of discharges, emissions and losses of Priority Substances (including octabromodiphenyl ether) to or via the aquatic environment. Such controls would be introduced through Daughter Directives.

A key route of exposure to octabromodiphenyl ether is that which occurs *via* the aquatic environment (i.e. secondary poisoning via the earthworm based food chain). Thus, controls upon discharges, emissions and losses could be introduced through the WFD in order to target the risks.

In addition to the possibility of introducing emission controls and limit values for industrial facilities, measures adopted for control of Priority Substances may also include best environmental practices targeted at diffuse impacts[34].

An alternative to this *progressive reduction* in discharges, emissions and losses would be for the Commission to adopt octabromodiphenyl ether as a priority *hazardous* substance, thus requiring the *cessation* or phasing-out of discharges, emissions and losses. According to Article 16(4) of the Directive, the Commission is required to review the list of priority substances at the latest four years after the entry into force of the WFD, or by 22 December 2004. At this stage, octabromodiphenyl ether could be added to the list of priority hazardous substances. The review process for adding a substance to the list of priority substances or upgrading to a priority hazardous substance will require that certain criteria are fulfilled, such as PBT characteristics or those showing an equivalent level of concern.

Secondly, Directive 96/61/EC[35] concerning integrated pollution prevention and control (the IPPC Directive) allows for the introduction of emissions controls for substances coming under the Directive. These controls relate to certain industry sectors that are listed in Annex I to the Directive. Controls adopted under this Directive would not apply to the diffuse sources of octabromodiphenyl ether in the environment that may need to be controlled (as outlined in Section 2).

Consultation during Stage 3 of this project has indicated that the Directive (and implementing legislation in the Member States) is unlikely to apply to the compounding and processing of plastics containing octabromodiphenyl ether. In some cases, however, these processes will be regulated via IPPC legislation for other reasons, such as the potential to emit other substances, such as lead, to the atmosphere. It is unlikely though that controls under the IPPC regime could be adopted as a result of the risk assessment for octabromodiphenyl ether specifically; this option has not been considered further therefore for the purposes of the risk reduction strategy.

In practical terms, there are a number of measures that plastics compounders and processors could take to reduce their environmental emissions of octabromodiphenyl ether. For example, in relation to losses to waste water and air via settling out of dust and subsequent release through washing, companies could alter their practices such that the dust is collected and disposed of as controlled waste. In relation to volatile losses, companies could ensure that all processes are totally closed, preventing losses to the environment, or they could install abatement technology at the site to ensure that any potential emissions are captured.

---

34 A substantial proportion of the environmental emissions of octabromodiphenyl ether relate to diffuse emissions from products.

35 OJ L 257, 10.10.1996, page 26.

6.4 Reducing the Concentration of Lower Brominated Congeners

As detailed in Section 2, the only area where the *definite* need to apply risk reduction measures for the *environment* has been identified (according to the TGD) relates to the assessment of secondary poisoning via the earthworm route for the commercial hexabromodiphenyl ether product.

As detailed in Section 3, the company manufacturing the octabromodiphenyl ether that is used in the EU has indicated that the current concentration of pentabromodiphenyl ether in the commercial octabromodiphenyl ether product is less than 0.5% and is expected to be reduced to below 0.1% within two years (thus complying with the proposed Directive restricting the marketing and use of pentabromodiphenyl ether).

In relation to the concentration of hexabromodiphenyl ether in the commercial product, the risk assessment assumed a concentration of 5.5%. Industry has provided further information indicating that the actual concentration in the commercial product is up to 12%.

Reducing the concentration of lower brominated congeners in the commercial octabromodiphenyl ether product is already a commitment introduced through the OECD Voluntary Industry Commitment. In terms of a policy vehicle for quantitatively ensuring a reduction in the concentration, this could either be done voluntarily or could perhaps be introduced through an amendment to Directive 76/769 placing a restriction on the marketing and use of the commercial product with concentrations of the penta and hexa congeners above set levels.

Industry has provided additional information on this issue, at the request of the Steering Group. The level of lower brominated congeners can be controlled by variables such as the rate and order of addition of the raw materials, reaction times and temperature, raw material quality, and the methods used to introducing raw materials into the reaction. It is indicated that octabromodiphenyl ether can be produced with less than 0.1% of the penta derivative and that, historically, it has been produced with around six to eight percent hexabromodiphenyl ether. The commercial product was reported to be technically suitable for use; however, in order to use the product more widely, the producer would have to introduce the re-designed product gradually to its customers.

Overall, the producer of octabromodiphenyl ether indicates that the concentration of hexabromodiphenyl ether could be reduced from the current level of <12% to <8% in less than two years[36].

---

[36] Note that, even where the risk assessment assumed a concentration of 5.5% hexabromodiphenyl ether, the PEC/PNEC ratio for secondary poisoning via the earthworm route was above unity.

6.5 Worker Protection Measures

6.5.1 Overview

Further controls on worker exposure to octabromodiphenyl ether can be introduced through a number of possible routes. Firstly, as a result of any revised classification and labelling that is implemented for the substance, certain requirements would be placed upon controls on exposure in the workplace. Various Community legislation can be used to introduce such requirements; for example, obligations can be placed on employers with regard to hazardous chemical agents through the Chemical Agents Directive (98/24/EC), amongst others, as discussed in Section 3.

Secondly, there are other means by which worker protection controls could be introduced for the processing of plastics where octabromodiphenyl ether is used. For example, given the relatively small number of users of octabromodiphenyl ether in the plastics industry, a voluntary agreement could be sought in order to ensure that exposure levels will be below those that pose a risk to human health. Alternatively, guidance could be published by the relevant industry associations, indicating that companies should ensure that exposure to octabromodiphenyl ether is kept below a certain level. Indeed, the company producing the substance already mentions (on the safety data sheet) their own voluntary occupational exposure limit, as detailed in Section 3.6. Another possible measure would be to introduce restrictions requiring that personal protective equipment be worn wherever the substance is used.

Given the need to take action to address the risks in a timely fashion, however, consideration is given herein to:

- the extent to which a revised classification and labelling of octabromodiphenyl ether under Directive 67/548/EEC would impact on the required controls in the workplace; and

- provision of octabromodiphenyl ether in alternative physical forms in order to reduce the generation of dust during polymer processing (this would also target the localised risks resulting from washing of settled-out dust to waste water, since losses are understood to mainly occur early in the mixing cycle).

6.5.2 Revised Classification and Labelling

In relation to the obligations resulting from a revised classification and labelling of octabromodiphenyl ether, the Chemical Agents Directive sets requirements for worker protection and prevention measures when handling substances that are toxic for reproduction (as discussed in Section 3.3.3). It requires that, by preference, substitution of this type of hazardous chemical agent be undertaken by replacing it with a chemical agent or process that is less hazardous for workers' health and safety. If substitution is not possible due to the nature of the activity[37], employers are required to ensure that the

[37] For example, in the case of octabromodiphenyl ether, if the company could not find an appropriate substitute.

risk is reduced to a minimum through one of the following measures (in order of priority):

(a) design of appropriate work processes and engineering controls and use of adequate equipment and materials, so as to avoid or minimise the release of hazardous chemical agents which may present a risk to workers' safety and health at the place of work;

(b) application of collective protection measures at the source of the risk, such as adequate ventilation and appropriate organizational measures; or

(c) where exposure cannot be prevented by other means, application of individual protection measures including personal protective equipment.

Obviously, substitution of octabromodiphenyl ether would eliminate the risks associated with its use (both for health and for the environment). Other measures could also reduce the risk for workers to an acceptable level, such as redesign of the process such that workers are not exposed to the same levels of octabromodiphenyl ether.

6.5.3 Provision of Octabromodiphenyl Ether in an Alternative Form

Since the risks relate predominantly to exposure to dust, consideration has been given to the possibility of supplying octabromodiphenyl ether in an alternative form. At the Steering Group meeting in December 2001, the producer of octabromodiphenyl ether agreed to examine the possibility of supplying the substance in such a form. It has been indicated that octabromodiphenyl ether could be processed for supply through one of the following means:

- compacting under pressure, possibly in combination with a binder;
- melting and creation of pellets, beads or pastilles; or
- making emulsions, solutions, dispersions or concentrates in a carrier matrix (such as water, solvents, polymers or waxes).

Since polymer processors require that additives are in solid form, the latter option is not appropriate. However, it is entirely possible to use the substance in a pelletised granular form in existing processing equipment. Indeed, the substance is most frequently used by the plastic processor in such a form, having been previously processed to form a polymer compound (with the relevant polymer, generally ABS, and any other additives) or a master batch.

The producer of octabromodiphenyl ether indicates that plastics processors will not generally require supply of the substance in a non-dusty form, since they will have existing procedures for dealing with exposure to dust in the workplace[38]. In terms of acceptability to the polymer processor, the company is currently evaluating the potential

[38] This is a view also shared in the human health risk assessment (see Section 2). Additionally, in the UK for example, the Health and Safety Executive has published guidance (HSE, 1997) on possible measures to reduce occupational exposure to dust.

for providing the flame retardant as part of a pre-blended pelletised form (flame retardant, antimony trioxide and other additives). As well as improving yields and simplifying the process, this would significantly reduce occupational exposure as compared to that identified in the risk assessment. Thus, if it is financially viable for the substance to be produced in such a manner from the producer's point of view, this measure could be implemented with relatively little cost imposed.

6.6 Controls on Spreading Sewage Sludge on Land

As mentioned previously, the area where a definite need for risk reduction for the environment has been identified relates to secondary poisoning via the earthworm-based food chain for the hexabromodiphenyl ether component of the commercial product. The key contributor to this risk is local releases during polymer processing which enter waste water treatment with the resulting sludge being deposited on land. Controlling deposition of such sludge could, therefore, control the main environmental risk associated with the substance.

The EU Directive on sludge (Directive 86/278/EEC) encourages the spreading of sewage sludge on land but also regulates its use in order to prevent harm to the environment. The European Commission is currently undertaking an initiative to improve the current situation for sludge management. It is anticipated that the use of sludge should take into account the risk of adverse effects on human, animal and plant health; groundwater and surface water quality; soil quality and biodiversity of soil micro-organisms (European Commission, 2000a).

It is intended that the Directive be amended such that limit values for certain organic compounds be introduced. Use of sludge with concentrations above these limit values should not take place. Whilst there is no specific limit value proposed for octabromodiphenyl ether, a limit value of 500 mg/kg dry weight has been proposed for 'halogenated organic compounds' in general.

Given that the risks identified in the risk assessment were based upon a concentration in dry sludge of 217 mg/kg dry weight, the proposed level for halogenated organic compounds would not specifically provide for avoidance of the identified risks. However, there are already proposed concentration limit values for individual organic compounds (e.g. di-ethylhexyl phthalate) and presumably such a limit could be introduced for octabromodiphenyl ether.

Figure 6.1 provides an overview of the total amount of sewage sludge predicted to be generated and the fractions that are predicted to be re-used across the Member States in 2005.

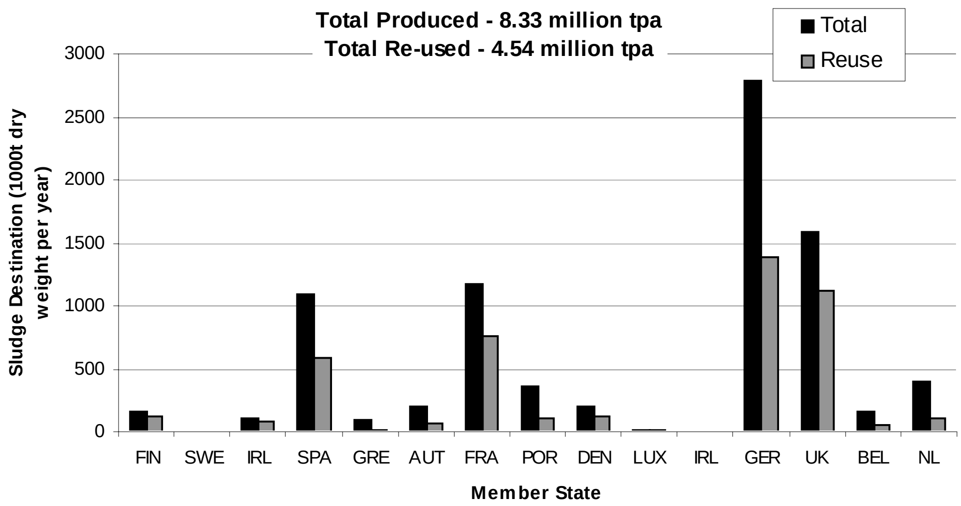

Figure 6.1: Predicted Production and Re-use of Sludge in 2005 (European Commission, 2001c)

6.7 Economic Instruments

In contrast to the various forms of direct regulation discussed above, economic instruments could be used to achieve some of the same end objectives. In essence, economic instruments would act by giving industry a financial incentive to reduce emissions of octabromodiphenyl ether to the environment, shift to the use of substitute flame retardants, or by placing limits on the quantities that could be used or the composition of the commercial product thereby reducing the potential for emissions.

There are four key types of economic instrument that may be relevant to risk management of octabromodiphenyl ether[39].

- **emissions charge**: this type of scheme could be used to levy a per unit charge on emissions of octabromodiphenyl ether to the environment from polymer processing activities;

- **product charge**: this type of charge could be developed in two different ways. The first approach would be to levy a charge on all electrical and electronic goods containing octabromodiphenyl ether as a flame retardant. The second approach would be to levy a charge on the use of octabromodiphenyl ether as an input to production; thus, a charge could be levied on each unit of octabromodiphenyl ether

[39] Other possible types of economic instrument include deposit-refund schemes and ecolabelling. The types of actions that would be promoted under a deposit refund scheme have already been proposed under the draft WEEE and ROHS Directives. Similarly, ecolabels already related to the use of PBDEs in personal and portable computers (see Section 3.2.2). As a result, there is little further scope for the application of these types of instrument.

consumed in the production of electrical and electronic goods or on the level of certain congeners within the octabromodiphenyl ether;

- **tradeable permits**: a permit trading scheme could be developed to place a ceiling on the quantity of octabromodiphenyl ether consumed in the EU, with users then able to trade permit quantities; and

- **liability based regimes**: instruments such as a performance bond could be used to reinforce voluntary commitments to reduce the concentrations of the penta and hexa congeners in octabromodiphenyl ether to acceptable levels from a risk perspective.

It is not clear how such instruments could be given legal force within the context of EU legislation. The marketing and use directive 76/769/EEC probably provides the most appropriate legal framework, as this should allow for conditions to be placed on either how a product is market (e.g. with a charge attached to quantities sold or to composition) or to how it is used (e.g. with charges placed on any emissions or with use constrained under a trading scheme).

7. ASSESSMENT OF POSSIBLE FURTHER MEASURES

7.1 Introduction

The TGD specifies that possible further risk reduction options should be examined against the following four decision criteria:

- **effectiveness**: the measure must be targeted at the significant hazardous effects and routes of exposure identified by the risk assessment. The measure must be capable of reducing the risks that need to be limited within and over a reasonable period of time;

- **practicality**: the measure should be implementable, enforceable and as simple as possible to manage. Priority should be given to commonly used measures that could be carried out within the existing infrastructure (though not to the exclusion of novel measures);

- **economic impact**: the impact of the measure on producers, processors, users and other parties should be estimated; and

- **monitorability**: monitoring should be possible to allow the success of risk reduction to be assessed.

The assessment of the options, presented in the following sections, is a *semi-quantitative* assessment. Each of the options is considered in relation to the four decision criteria with quantitative estimates provided as to cost implications, for example, where possible. In addition, quantitative estimates of the level of reduction in risk achieved through the measures is given where possible[40].

7.2 Ban under Marketing and Use Restrictions

7.2.1 Effectiveness

A total ban upon the marketing and use of octabromodiphenyl ether would eliminate any new contribution to environmental and human health risks. Such a restriction could be worded so as to prevent the sale of finished products containing the substance in the EU. In this respect, it would be completely effective in addressing the risks associated with the substance. Those areas where a definite need for risk reduction would be addressed, along with those where the need for risk reduction is less clear.

However, marketing and use restrictions would introduce the need for the use of substitute flame retardants or alternative methods. An analysis of the potential substitutes has been undertaken (see Section 5), using available data. Based on that analysis, there

[40] Although this is limited to some extent because the revised data from the risk assessments will need to be taken into account when these become available.

appear to be suitable substitutes available in technical terms and, taking into account the available data, some of the possible substitutes are likely to represent an improvement in terms of risks to health and the environment as compared to octabromodiphenyl ether. It should be noted, however, that none of the possible substitutes has yet been subject to as extensive a review as octabromodiphenyl ether and for most the level of data available on hazardous effects and exposure is less than that for octabromodiphenyl ether.

7.2.2 Practicality

The procedure for restricting the marketing and use of substances at the EU level under Directive 76/769/EEC is well established, with various substances already subject to restrictions. Furthermore, Member States are considered to have suitable procedures in place for implementing the requirements of the EU legislation (although this issue is currently being examined in more detail by the European Commission).

Whilst procedures exist to prohibit the marketing and use of octabromodiphenyl ether in the EU, it would be more problematic to control the import of finished articles (office equipment and business machines) that contain the substance. It is possible, therefore, that articles containing octabromodiphenyl ether could continue to be used in the EU even if their use was prohibited. Whilst the areas where there is a definite need for risk reduction would be addressed, there might still exist the potential for losses to the environment during the service life of these products.

7.2.3 Economic Impact

In the event that marketing and use restrictions are introduced for octabromodiphenyl ether, there would be a range of cost implications for various stakeholders. These costs would arise primarily through the need to substitute octabromodiphenyl ether with an alternative flame retardant substance or an alternative technology.

Economic impacts will be experienced by the producer of octabromodiphenyl ether. Obviously, there would be a loss of sales related to the substance in the EU amounting to an estimated €1.6 million (see Table 4.6). However, since the company in question also produces a number of potential substitute flame retardants, it could be expected that any loss of sales of octabromodiphenyl ether would be compensated for by an increase in sales of the alternatives. There would also be a probable loss of sales in octabromodiphenyl ether amounting to an estimated €3.2 million relating to use of the substance in master batch (or finished articles) imported into the EU. Again, it could be expected that any such loss would be compensated for by an increase in sales of alternatives.

In some cases, the cost of the substitute flame retardant is likely to be greater than that of octabromodiphenyl ether. Some of the flame retardants that are used in the same plastic (mainly ABS) are up to 30% more expensive than octabromodiphenyl ether. Likewise, where substitution with an alternative polymer-flame retardant system takes place, the costs of the system could increase by up to 10%, as detailed in Section 5.

If another brominated flame retardant were used instead of octabromodiphenyl ether, it may be the case that a higher loading of the substitute in the polymer would be required. This is due to the need to maintain an equivalent concentration of bromine in the product. For example, if TBBPA were used, around 34% extra flame retardant would be required in order to maintain the same level of fire retardancy[41].

There would also be costs associated with research and development (R&D) in order to design products such that the alternative flame retardant or polymer-flame retardant system can be used. These costs would be borne by the plastics processors but also by compounders/master batchers and the producer of the flame retardant itself (given the need to ensure an effective product throughout the supply chain).

Estimates have been made below as to the likely costs of substitution, taking into account the possible increased price of alternatives and the need to undertake R&D to effectively utilise the alternative. Table 7.1 provides a summary of the estimated minimum costs of substitution, that would be borne by industry. This table also provides an estimate of the possible increase in purchase price of a finished product (E&E appliance), although it is not certain that these costs would be passed on to the consumer.

Table 7.1: Estimated Minimum Costs to Industry of Substituting Octabromodiphenyl Ether

	Substitute Flame Retardant	**Substitute FR & Polymer**
Increase in price of substitute flame retardant	25%	-
Increase in price of substitute polymer-flame retardant system	-	10%
Amount of flame retardant used (tpa)	1,350	1,350
Amount of polymer-flame retardant system used (tpa) [b]	9,000	9,000
Number of users [c]	20	20
R&D costs per user (€)	25,000	25,000
Cost due to increased price of substitute (€m per year) [d]	1.2	1.3
R&D costs (€m one-off cost)	0.5	0.5
Total cost (€m) over years 0 to 5 (discounted at 3%)	7.3	7.5
Percent increase in price of E&E appliance	0.19%	0.19%

Notes: [a] *Substitute flame retardant assumed to be 1,2-bis(pentabromophenyl) ethane. This has almost the same % bromine as octa and represents the greatest cost increase of substitutes identified. Whilst 34% more TBBPA would be required, the price is only around one half that of octa, making overall costs lower.*
[b] *Concentration of FR assumed to be 15% w/w.*
[c] *Includes compounders/master batchers as well as processors. Estimated since actual number is unknown (only a handful of compounders but number of plastics processors will be greater.*
[d] *Price of octabromodiphenyl ether assumed as €3.6 per kg and ABS flame retarded with 15% octabromodiphenyl ether at €1.4 per kg.*

41 TBBPA has around 59% bromine content, compared to 79% in the commercial octabromodiphenyl ether product.

It should be noted that the cost estimates derived above represent likely minimum costs. It is possible that there would be additional costs for companies undertaking polymer processing using octabromodiphenyl ether. In particular, it has been highlighted that some companies may need to replace the moulds that are currently used in order to effectively use a substitute. Costs of new moulds, depending upon the size and complexity of the product have been estimated at £50-100,000 (€80-160,000). The British Plastics Federation has indicated that a typical SME in ABS processing would have around 15 to 20 moulds.

Given the reluctance of companies using octabromodiphenyl ether to provide any information for this study, it has been necessary to make some assumptions regarding the likely costs of replacing moulds where required for technical reasons. Using the data from Section 4.3.2 regarding the size distribution of companies in the plastics and rubber industry, along with the above information regarding costs of replacing moulds, it has been possible to make some highly tentative estimates of the costs of replacing moulds in order to use alternative flame retardants or plastics. These cost estimates are outlined in Table 7.2, indicating that the total costs could be around €5m including the costs for mould replacement and machine downtime. This represents an increase in the average product price of around 0.11%, making a total increase of 0.30%. However, these costs are only intended to be indicative.

Table 7.2: *Indicative* Costs of Replacing Moulds for ABS Processing

Number of moulds needing replacement among SMEs [a]	25
Average down-time required for replacement (years)	0.05
Estimated cost of mould replacement	€120,000
Cost of purchasing moulds	€3.0 million
Cost of downtime [b]	€1.8 million
Total cost of mould replacement	€4.8 million
Percent increase in price of E&E appliance	0.30% [c]

Notes: [a] *It is assumed that larger companies (>500 employees) will already have a range of moulds and will thus not need to replace them.*
[b] *Based upon 0.05 x average SME turnover x cost of mould replacement x number of moulds (average turnover for companies with 0 to 250 employees is €1.46 million based on UK data (DTI, 2001)).*
[c] *Takes into account increased price due to R&D and substitute costs from Table 7.1.*

Thus, the total estimated costs to industry, taking into account the likely increased cost of substitutes and the potential need to replace moulds is around €7.5 to €12 million over five years. If these increased costs were passed on to the consumer, the percentage increase in the average price of products would be between 0.19% and 0.30%, taking into account an estimated 3 million products on the market per year.

If the data on average turnover of companies in the plastics and rubber industry are examined it is evident that, for a small company, the costs of substituting octabromodiphenyl ether could be significant, depending upon the replacement route taken. Costs would be minimal where a substitute of equivalent or lower cost (e.g. TBBPA) is used, with no need for use of new moulds. However, the cost of replacing one mould at €120,000 represents over 20% of the annual average turnover of small plastics companies[42], and a greater proportion of those within the smaller size brackets. In the event that marketing and use restrictions were introduced, consideration should be given to the timescales of implementation, in order that the costs are not excessive (since SMEs could bear a proportionately greater cost burden as a result of a ban).

Additionally, there will be costs for legislators and regulators in developing and implementing restrictions on the marketing and use of the substance.

The possible substitutes identified in Section 5 are those that could be used to retain the same level of fire protection as that afforded by use of octabromodiphenyl ether. Thus, there should not be any increase in deaths or injuries associated with use of these alternatives. However, if the level of fire safety is reduced, there could be costs to society associated with an increase in the incidence of fires. As outlined in Section 4, estimates have been made of the benefits associated with a reduction in fire incidence for certain appliances. The estimated benefit of reducing a fatal injury is €1.25m and for a non-fatal injury is €0.15m. Thus, if a compromise in fire safety led to an increase in 100 fires per year, for example, the estimated cost would be around €6.3m per year[43]. It is, therefore, important that at least the same level of fire protection is afforded by any alternative flame retardant.

7.2.4 Monitorability

Whilst monitoring the success of a ban in relation to imports of the substance to the EU should be relatively easy to accomplish, monitoring imports and use of master batch or finished products containing the substance may be more problematic, with the latter being more complicated than the former.

7.3 Reducing Environmental Emissions from Polymer Production

7.3.1 Effectiveness

This option relates to control of environmental emissions through measures introduced via daughter directives under the Water Framework Directive. The Commission will propose measures based upon "appropriate cost-effective and proportionate level and combination of product and process controls for both point and diffuse sources and take

---

[42] Based on data for the UK (DTI, 2001), there are 13,710 companies with between 0 and 49 employees. These companies have a total turnover of €8,046 million, giving an average turnover of €0.59 million per year. It should be noted that these data are characterised by a large number (86% of SMEs) of micro-business-sized companies (0-9 employees), making the average turnover appear relatively low.

[43] An increase in 100 fires per year would lead to an extra 0.8 fatal casualties and 36.2 non-fatal casualties, valued at €1.25m and €0.15m respectively.

account of Community-wide uniform emission limit values for process controls". This could involve one of the following:

- since octabromodiphenyl ether is a priority substance, measures will be proposed in order to achieve a progressive reduction in discharges, emissions and losses to the environment; or

- alternatively, the Commission could classify octabromodiphenyl ether as a priority hazardous substance when the list is reviewed according to Article 16(4) of the Directive.

Since proposals for implementing the requirements of the Directive have not yet been developed, it is currently unclear how emissions of octabromodiphenyl ether will be controlled in practice (although it will be done through a combination of emission limits and quality standards). However, it is likely that measures introduced would take into account the findings of the risk assessment on octabromodiphenyl ether in proposing measures to address discharges, emissions and losses.

In the case that measures are taken forward for a progressive reduction in discharges, emissions and losses of the substance, it should be possible to address the risks to the environment that are associated with the hexa congener (where a definite need for risk reduction was identified). Obviously the extent of any measures proposed should depend upon the level of risk involved and the aim would be to reduce the PEC/PNEC ratio for secondary poisoning via the earthworm based food chain from around 1.2 to below unity. A progressive reduction in discharges, emissions and losses would not target the areas where there is less certainty regarding the environmental risks (a possible risk of secondary poisoning for all life cycle stages, where conclusion (i) has been reached).

If octabromodiphenyl ether were included as a priority hazardous substance, measures could be proposed for the cessation or phasing out of discharges, emissions and losses. This would address all of the concerns for secondary poisoning but the timetable for doing so could extend to 20 years from the date of adoption of measures under the Directive.

7.3.2 Practicality

Whilst measures have yet to be proposed for the control of discharges, emissions and losses of priority substances under the WFD, it is presumed that a suitable framework for introducing controls will be developed in the near future. There should, therefore, be a readily available infrastructure for the introduction of measures to control the risks associated with the substance. The risks identified in the ESR risk assessment could form part of the basis for development of any such measures under the Directive.

7.3.3 Economic Impact

Since octabromodiphenyl ether is already a priority substance under the WFD, there would essentially be no additional economic impacts for the adoption of measures to progressively reduce discharges, emissions and losses. It is understood that the

Commission will examine the socio-economic impacts of measures introduced for individual substances. Given that a specific need for action to address the risks has been identified in the risk assessment, measures could be introduced more rapidly than might otherwise occur, possibly increasing the costs by bringing them forward in time and allowing less time for the development of controls.

7.3.4 Monitorability

It is assumed that suitable mechanisms for monitoring the success of emissions reduction schemes and other legislation will be in place. Monitorability should not, therefore, pose any theoretical problems. However, given that the environmental risks occur via the earthworm-based food chain, there may be some uncertainty with regard to correlating concentrations in water, for example, with the likely level of risk.

Given the uncertainties surrounding some of the risks, it may be difficult to monitor any reduction in risk that relates to a reduction in environmental exposure to or via the aquatic environment.

7.4 Reducing the Concentration of Lower Brominated Congeners

7.4.1 Effectiveness

The basis for reducing the concentration of lower brominated congeners is that there has been a risk identified for the hexabromodiphenyl ether component for the earthworm-based food chain (the PEC/PNEC ratio for this end-point is around 1.2). Thus, reducing the concentration of hexabromodiphenyl ether in the commercial product by more than around 17% should reduce the associated risk to an acceptable level.

Additionally, where there are possible concerns for human health regarding the presence of the substance in breast milk (conclusions are currently uncertain, as discussed in Section 2), reduction of the concentration of lower brominated congeners could also partially reduce risks for human health where the risk assessment has reached conclusion (i).

7.4.2 Practicality

As detailed in Section 6, the company supplying octabromodiphenyl ether to the EU market indicates that it should be feasible to reduce the concentration of hexabromodiphenyl ether in the commercial product from <12% to <8% within two years. This represents a possible reduction in the concentration of the hexa congener of 33%, which would reduce the associated risks to an acceptable level[44].

---

[44] However, the PEC/PNEC ratio (in the draft risk assessment) was based upon a concentration of hexabromodiphenyl ether of 5.5%, whereas the actual concentration is higher. Further information has also been taken into account in the risk assessment so it is currently uncertain what level of reduction in concentration would be sufficient to reduce the risks to an acceptable level.

7.4.3 Economic Impact

The company producing octabromodiphenyl ether for sale in the EU indicates that the concentration of the hexa congener in the commercial product could be reduced by the aforementioned amount both in technical terms and in a cost-effective manner.

If the concentration were required to be reduced to a greater extent, it is possible that the financial implications could be more pronounced.

7.4.4 Monitorability

Since there is only one supplier of octabromodiphenyl ether to the EU market, it should be relatively simple for that company to provide evidence of the composition of its product. The measure would, therefore, be relatively simple to monitor. Provision of such evidence could form part of any agreement - voluntary or otherwise - to implement this measure.

7.5 Worker Protection Measures

7.5.1 Effectiveness

Introducing measures to improve worker protection through reducing exposure to octabromodiphenyl ether as a dust in the workplace would target the risk to human health associated with exposure to the substance (developmental toxicity arising through dermal and inhalation exposure).

The draft human health risk assessment recognised that appropriate worker protection measures could be expected to be in place already to limit workplace exposure to the substance. A revised classification and labelling of the substance could be expected to ensure that such controls are more widely applied. Given that companies using the substance were unwilling to provide any input to this study, it is not possible to determine whether such controls already exist.

There is a range of worker protection measures that would target the risks, such as the following:

- use of local exhaust ventilation;
- wearing of personal protective equipment;
- enclosing the process, particularly mixing of the substance; or
- supply of octabromodiphenyl ether in a non-powder form

It is likely that the presence of any of these measures would ensure that exposure of workers to the substance does not present an unacceptable risk to human health. In addition, measures such as enclosing the process or supplying octabromodiphenyl ether in a non-powder form could also address the need for risk reduction relating to the risk via the earthworm-based food chain for the hexa congener (since there would be significantly less dust generated and this would then not pass to waste water in the same quantities). This measure, therefore, would address all of the areas where there has been a definite need for risk reduction identified.

Since there are some areas, both for human health and for the environment, where further information and/or testing is required (conclusion i), it is uncertain as to whether the associated risks could be reduced to an acceptable level using this measure.

7.5.2 Practicality

General worker protection measures such as use of personal protective equipment are already widely used in various industries, including the plastics processing industry, where appropriate. It should be relatively practicable, therefore, for companies to introduce such measures as a result of any revised classification and labelling of the substance.

In relation to the supply of octabromodiphenyl ether in a granular form, for example, it was indicated in Section 6 that the substance could relatively easily be supplied in such a form and that companies could generally continue to use the substance in existing processing equipment, with little need for process modification.

7.5.3 Economic Impact

In relation to measures taken by companies to meet the requirements of a revised classification and labelling, it is possible that no costs at all would be incurred (in the event that controls are already present to reduce risks to an acceptable level). In other cases, certain controls would have to be introduced, such as the use of personal protective equipment, for example. Depending upon the classification and labelling adopted, the primary measure for worker protection would be substitution of octabromodiphenyl ether with an alternative substance. Thus, the maximum cost of this measure could be expected to be the same as for a ban on the marketing and use of the substance, as outlined in Section 7.2.3.

In relation to supply of octabromodiphenyl ether in a non-powder form, the company producing the substance has indicated that any increased costs would be passed on and borne by companies that use octabromodiphenyl ether directly. Companies that already use the substance compounded with polymer and other additives would not experience any difference in the product purchased and thus it is expected that no price increase would be passed on to these companies. In general, it is likely that this measure could be introduced with no unacceptable costs borne by industry. One might expect that these costs could be at most the same as for R&D in utilising substitute flame retardants, as outlined in Section 7.2.3. The costs would, however, tend to be lower since only a small number of companies use octabromodiphenyl ether in a powder form (with a greater number using it in its compounded form).

7.5.4 Monitorability

The Chemical Agents Directive 98/24/EC places an obligation on employers to demonstrate that risks from hazardous chemical agents are eliminated or reduced to a minimum. In relation to the measures taken, such as the use of personal protective equipment or the utilisation of octabromodiphenyl ether in a non-powder form, the employer would be required to carry out monitoring in the workplace, particularly in relation to occupational exposure limit values. However, the employer need not undertake such monitoring if they can demonstrate compliance by other means of evaluation.

7.6 Controls on Spreading Sewage Sludge on Land

7.6.1 Effectiveness

Introducing controls on spreading sewage sludge on land would target the identified risk of secondary poisoning via the earthworm-based food chain (relating to the hexa congener). The level of octabromodiphenyl ether present in sewage sludge could be set such that the amount passing into the food chain would not present an unacceptable risk. This measure could, therefore, be effective in addressing the risks.
It would also target the area where the need for risk reduction is less certain (conclusion i) associated with secondary poisoning via the earthworm-based food chain for the commercial product as a whole. However, since there is no means of quantifying any such risk that may exist, it is not possible to state whether this risk could be reduced to an acceptable level.

7.6.2 Practicality

The means for implementing controls on the presence of certain substances in sewage sludge deposited on land is currently under development. Since controls are being introduced for a number of other organic substances, it should be relatively practicable to introduce similar limit values for octabromodiphenyl ether.

However, since these controls have yet to be introduced, the timescale for introducing any measures under the Sludge Directive is likely to be longer than for some other measures.

7.6.3 Economic Impact

It is possible to estimate the likely costs associated with introduction of controls under the Sludge Directive to some extent. For example, sludge that contained octabromodiphenyl ether at a concentration above the limit value set would need to be diverted to an alternative disposal route. If, for example, the sludge were incinerated instead of deposited on land, there would be an associated cost increase.

For example, if it is assumed that 2.5% of sludge in the EU is present at a concentration leading to an unacceptable risk, around 113,000 tpa of sludge could not be deposited on land due to the presence of octabromodiphenyl ether at an unacceptable level[45] (Table 7.3).

---

45 This is based on the estimate that 4,536 k tpa of sewage sludge will be re-used in the EU in 2005 (European Commission, 2001c).

The actual amount of sludge containing octabromodiphenyl ether at a concentration that would be unacceptable for spreading on land is unknown because the actual distribution of octabromodiphenyl ether in sewage sludge in the EU is unknown. However, these estimates provide an idea of the likely magnitude of such costs.

Table 7.3: Estimated Costs of Introducing Controls on Spreading Sludge on Land	
Percentage of sewage sludge with octa above limit value	2.5%
Amount of sewage sludge requiring diversion (thousand tpa)	113
Cost of diverting sludge containing octa (€m)	19.3
It is estimated that the costs of spreading sewage sludge is €135 per tonne and of landfilling or incinerating is €305 per tonne (after Anderson (2001)).	

There would be costs for the authorities in developing an appropriate limit value for octabromodiphenyl ether deposited on land and there would also be costs associated with monitoring for the substance. We have not been able to estimate these costs at this time.

7.6.4 Monitorability

Proposals for introducing controls on organic contaminants in sewage sludge that is spread on land are currently being developed. It can be expected that any future legislation on this issue will include suitable provisions for monitoring the success of the measure.

7.7 Economic Instruments

7.7.1 Overview

A number of possible economic instruments were discussed in Section 6, including the following:

- an emissions charge;
- product charges;
- tradeable permits; and
- legal liability-based systems.

These four types of instruments are discussed in the following sections as applied to the risks associated with octabromodiphenyl ether. This discussion assumes that it would be feasible to introduce these measures under the Marketing and Use Directive.

7.7.2 Emissions Charge

Effectiveness

Under an emissions charging regime, a tax would be levied on each unit of emissions of octabromodiphenyl ether from polymer processing facilities. Such a charge would have to apply to total losses to waste water and air and be levied on all plastic compounding and processing facilities using octabromodiphenyl ether. In order to minimise emissions to the environment, the charge would have to be set high enough to ensure that companies invested in adequate dust control measures and in measures ensuring that any volatile emissions produced during processing activities were captured. Given that emissions vary between compounders and processors, different emission charge rates would have to be set to provide each group of users with an adequate incentive to reduce emissions.

Owing to a lack of information on costs of adopting controls at the individual sites using octabromodiphenyl ether, it is not possible to calculate a minimum charge rate at this point in time. The rate would be calculated using detailed information on emissions per tonne for compounding and processing activities and on the costs for a given facility to adopt emissions control, where this would relate to measures protecting both workers and the environment.

In terms of the effectiveness of emissions charges in reducing the environmental and human health risks to acceptable levels, it is important to note that emissions charges provide no certainty in terms of the end outcome. They should act to provide an incentive to compounders and polymer producers to reduce emissions, but the companies may prefer to pay the charge than to respond by introducing further emission controls. As a result, they cannot guarantee that emissions will be reduced to acceptable levels.

Practicality

Under this type of scheme, individual companies would have to register their use of octabromodiphenyl ether on an annual basis and provide detailed monitoring records in order to validate emissions and associated charge payments. Regulators would need to set the charge rate, potentially at the facility level, develop collection procedures and undertake some form of auditing. Because there are only a small number of users, the requirements on regulators may not be overly onerous.

These systems would obviously only need to be developed only in those countries having users, although there may need to be some coherence across Member States on the actual charge levels in order to avoid activities shifting between countries.

Economic Impact

Because individual facilities would be allowed to decide the most cost-effective manner of responding to the emissions charge, this option should involve lower, or at least no greater, costs than those associated with direct regulation. Users could respond either by ceasing use of octabromodiphenyl ether, by reducing emissions or by paying the charge (or a combination of these).

Monitorability

As noted earlier, because compounding and processing do not fall under IPPC, the monitoring systems required at individual facilities may not exist to enable the charge to be enforced. This is a key constraint in this context and seriously limits the degree to which this option is feasible.

7.7.3 Product Charges

There are three possible types of product charge that could be used as a means of reducing the risks associated with the use of octabromodiphenyl ether as a flame retardant. The first of these is to levy a charge on all consumer goods containing octabromodiphenyl ether. The aim of such a measure would be to shift consumer demand away from goods containing octabromodiphenyl ether to electrical and electronic goods relying on a substitute flame retardant by creating a significant enough price differential. The second approach is to place the product charge on the use of octabromodiphenyl ether as an input to the production of ABS. The aim here is to increase the price of octabromodiphenyl ether relative to the substitutes so that it no longer becomes attractive as an input to production. The third approach is to place the charge on the presence of the two congeners of penta and hexa within the commercial product. Thus, the mechanisms through which the different charges would act are significantly different, with this having implications for how the charges would have to be set and their likely effectiveness in risk management terms.

Effectiveness

In order to create a sufficient price differential to stimulate changes in consumer purchasing, a product charge on electrical goods would need to be high enough to make it a market differentiating factor. In other words, the increase in price for goods containing octabromodiphenyl ether would have to outweigh other factors affecting the demand for individual products, such as quality, features, appearance, durability, etc. This is a major drawback to the use of a product charge in this case, as the types of electrical goods in which these flame retardants are used can be expected to vary considerably across these different factors. Thus, establishing a charge rate for the presence of octabromodiphenyl ether may be extremely difficult. As a result, there would be little certainty as to the degree to which a given charge rate would deliver the desired reductions in health and environmental risks.

In contrast, a product charge placed on the use of octabromodiphenyl ether as in input to ABS used in electrical equipment may provide greater certainty of outcome. In this case, the charge could be set either at a rate that is high enough to drive all users to move away from the use of octabromodiphenyl ether in the short-term or one that is aimed at providing a longer-term incentive. The first approach would involve setting a charge on octabromodiphenyl ether as an input equivalent to the cost of switching to use of the alternative flame retardants, where this includes not only any additional per unit costs associated with adoption of the substitutes but also of reformulation and of changing processing methods. Based on the costs presented above in Section 5, a input charge of between 10 and 30%[46] may be required under the first approach, with a lower rate being adopted if the aim is instead to enable industry to respond in the longer term.

The degree to which environmental and health risks are reduced will depend on the rate at which the input-based product charge is set. The higher rate will be more likely to reduce use of octabromodiphenyl ether to zero, while the lower rate may only result in only a partial reduction in use in the short-term at least. The lower rate, however, may be all that is required to stimulate further movement by industry away from these flame retardants. Neither form of charge could be guaranteed to lead to a cessation in the use of octabromodiphenyl ether, though, with the potential for on-going environmental and health risks.

The final possible form of product charge is placing a charge on the level of the penta and hexa congeners contained within the octabromodiphenyl ether product. This type of charge would allow continued use of the flame retardants but provide further (and ongoing) encouragement to the producers to reduce the levels of these congeners, which are key drivers for precautionary risk management. In this case, the rates at which the charges were set would need to be determined carefully. They would probably be set at a level below the rate which would shift users away from octabromodiphenyl ether in the short-term, but would need to be high enough to penalise use so that producers act swiftly to reduce the levels of the two congeners in the commercial product (for example, to ensure that they achieve the reductions within the 2 year period quoted in Section 6.5).

This latter type of charge would probably have a dual effect of providing an incentive to some users to move away from octabromodiphenyl ether, thus reducing emissions to some extent. Other may bear the additional costs of using octabromodiphenyl ether in the short-term, while producers refined the commercial product. If the producers were unable to refine the product, the effect of the on-going charge on the two congeners would likely be one of shifting users away in the longer-term.

Practicality

A consumer-focused charge placed on electrical goods containing octabromodiphenyl ethers is not considered to be practical given the difficulties associated with charge setting.

Both of the latter types of input charges should be fairly easy to implement in administrative terms and to monitor given that there is only one supplier of octabromodiphenyl ether to the EU. Thus, the system would be based on the importer (in the case that this is not the producer) providing details upon import as to the quantities and/or the composition of the commercial products. A legal duty would need to be established requiring importers to make such a declaration prior to marketing/use, with the charges then levied at point of import.

46 Based on the increased costs associated with adopting 1,2 bis(pentabromophenyl) ethane as a direct substitute or of moving to alternative polymer plus flame retardant combinations such as TPP or RDP.

It is unclear how acceptable the use of these types of input-based product charges would be to non-industry stakeholders given the uncertainty surrounding the risks to the environment and human health. It could be argued that they would not be precautionary enough in that they do not ensure that the risks are reduced to zero. On the other hand, such charges may be more acceptable to industry as they enable continued use albeit at a penalty.

Economic Impact

As with emission charges, the introduction of a product charge would provide flexibility to compounders and processors in their response. They could pay the charge for as long as it was financially attractive to do so, or cease using octabromodiphenyl ether. This flexibility should make the use of a product charge more cost-effective from the point of view of users and the producer. Because these options would place a burden in charge setting, collection and monitoring, they would not be less resource intensive for regulators than the introduction of marketing and use restrictions.

Monitorability

As noted above, systems would need to be put in place at point of import for recording quantities and/or their composition. However, this type of approach would rely on declarations by importers as it could be difficult for Customs authorities to monitor imports otherwise. The potential for charge evasion will exist unless the producers were also willing to provide records of sales for cross-validation purposes.

7.7.4 Tradeable Permits

Effectiveness

Tradeable permit systems are generally thought of in terms of trading in emissions to the environment. Given the concerns surrounding the use of octabromodiphenyl ether, it is considered that such trading in emissions would not be acceptable. An alternative form of trading then could be in the use of octabromodiphenyl ether as an input to production. In contrast to the charge-based approaches discussed above, this would involve setting a ceiling on the quantity of the commercial product that could be consumed within the EU. Permits would then be auctioned to prospective users to the highest bidders. The proceeds from the auction could be used to fund administration of the system including monitoring activities.

This type of approach would allow the level of octabromodiphenyl ether being consumed within the EU to be fixed, avoiding the potential for the use of octabromodiphenyl ether to increase in the future. It would therefore provide certainty as to the levels being used. Furthermore, there is no reason why restrictions could not be placed on those potential buyers entering the auction market, such as requirements on emissions control and worker safety measures. Restrictions could also be placed on the life of a permit, for example, limiting is validity for a period of two or three years prior to review of the system.

As on-going use of octabromodiphenyl ether would be permitted under this type of approach, it would not provide for a precautionary reduction to zero in the use of these flame retardants.

Practicality

The key issue concerning the practicality of a permit trading based approach is that it assumes that regulators would be willing (and able) to establish an allowable level of usage. This may not be the case (and may not be acceptable to non-industry stakeholders), although it would provide a means of ensuring that some level of risk reduction was achieved while the producers of octabromodiphenyl ether either carried out further testing or refined the commercial product to reduce concentrations of the penta and hexa congeners. If the results of further testing confirmed the conclusion i) risks as requiring risk reduction, or efforts to refine the commercial product failed, then marketing and use restrictions could come into force. Alternatively, the auctioning of octabromodiphenyl ether up to a capped amount could continue on a periodic basis, with trading of permits allowed within a fixed period of validity.

Economic Impact

As with the charging based systems, users of octabromodiphenyl ether would be free to determine whether they should respond to the instrument by ceasing use of these flame retardants or by remaining in the market. In this case, they would have to establish their willingness to pay for the use of octabromodiphenyl ether in order to determine their maximum auction price.

It is unclear from the information provided by industry the degree to which different users can adopt different responses and thus that the willingness to pay to continue using octabromodiphenyl ether is likely to vary across users. Only if such variations exist is trading likely to occur. Theoretically, those facilities that find they could adopt substitutes at a lower cost than the market value of the permits will seek to do so and either not enter the auction or later trade their permits in the market. This should lead to an economically efficient solution in terms of the overall costs achieving the necessary reductions in the use of octabromodiphenyl ether.

Monitorability

If trading of permits was allowed, systems would be required to register and monitor any trades to ensure that there were adequate worker safety and environmental controls in place in the facilities buying up permits.

7.7.5 Legal Liability-Based Systems

The main form of legal-liability system applicable to risk management of octabromodiphenyl ether is that of a performance bond. These bonds could be used to reinforce the voluntary commitments made by industry to reduce the concentrations of the penta (and would have to be extended to the hexa) congener in octabromodiphenyl ether to acceptable levels. Industry would be required to deposit the bond amount into a holding account for an agreed period. Should it fail to meet its voluntary commitment within the allowed time period, the deposit would be forfeited as a penalty.

Although this type of approach may be appropriate in some risk management contexts, given the concerns surrounding octabromodiphenyl ether, it is unlikely that it would be acceptable to regulators or non-industry stakeholders. It provides no degree of certainty with regard to risk reduction and could be interpreted as putting commercial interests before environment and worker safety. However, this type of instrument could be support other measures that did not involve a total cessation in the marketing and use of octabromodiphenyl ether, providing further incentive for industry to adhere to its voluntary commitments.

7.8 Overall Analysis of Possible Further Measures

Table 7.4 provides a summary of the likely effectiveness of the various risk reduction measures in addressing the different environmental, worker safety and public health risks. As will be recalled from Section 2, the conclusion (iii) risks relate to polymer processing activities, with these activities also giving rise to conclusion (i) findings with regard to secondary poisoning and man via the environment more generally. Furthermore, the use and disposal of products containing octabromodiphenyl ether gives rise to conclusion (i) findings for both man via the environment and secondary poisoning.

Table 7.4: Summary of Risks Addressed by Possible Risk Reduction Measures

Measure	**Environment**		**Human Health**		**Health & Environment**
	Secondary poisoning – conc. (iii) for polymer processing	Secondary poisoning and debromination – conc. (i) for polymer processing	Worker Safety – conc. (iii) for polymer processing	Man exposed via the environment – conc. (i) for polymer processing	Man via the environment, sec. poisoning, debromination – conc. (i) all stages
M&U restrictions	+++	+++	+++	+++	+++
Reduced emissions from polymer processing	++	+	++	+	0
Reducing concentrations of lower congeners	++	0	0	+	+
Worker protection	++	+	++	+	+
Sludge Directive	++	+	0	++	+
Emissions Charge	+ ?	+ ?	0	+ ?	0
Product Charge	+ ?	+ ?	0	+ ?	0
Tradeable Permits	++	+	++	+	0
Performance Bond	0	0	0	0	0

Notes: 0 = no effect over the baseline
+ = possibly reduces risk but outcome not to 'safe' level
++ = possibly reduces risk to an acceptable level but depends on threshold set
+++ = risks reduced to an acceptable level

In relation to the worker protection measures, it should be noted that the supply of octabromodiphenyl ether in a non-powder form should allow the areas where there has been a definite need for risk reduction measures to be addressed. Since these both arise through the potential for dust generation, elimination (or a significant reduction) of such dust should eliminate the need for further risk reduction measures.

The only risk reduction measure that would ensure that the risks across all of the end-points were reduced to acceptable levels is marketing and use restrictions baning future use of octabromodiphenyl ether in flame retardants. Additionally, if octabromodiphenyl ether were classified as a priority hazardous substance under the Water Framework Directive, measures would be introduced to ensure a cessation or phasing-out of discharges, emissions and losses (also addressing both the areas where there is a defined need for risk reduction and those where the need is less clear).

Worker protection measures, requirements for reduced emission levels and emissions trading all appear to have the potential to address the conclusion (iii) risks but may not provide for adequate protection with regard to the conclusion (i) end-points. Reducing concentrations of the lower congeners on its own, only provides for minimal protection, while the sludge directive fails to address the worker safety risks (although these may be addressed through measures already taking place or through a revision to classification and labelling). The various charging based approaches are more uncertain in outcome and thus it is unclear the extent to which they would address the risks. Performance bonds are unlikely to deliver any significant reductions in risk on their own, although they may be a valuable supporting instrument in tandem with others of the economic instruments.

Tables 7.5a and 7.5b provide a summary of the above analysis of possible risk reduction measures against the four key decision criteria.

Table 7.5a: Summary of Advantages and Drawbacks

	Ban on Marketing and Use	Reduce Environmental Emissions	Reduce Conc. of Lower Congeners
Effectiveness	Would reduce all risks for human health and the environment and would address areas where need for risk reduction is uncertain (conclusion i) and that where a definite need has been identified (conclusion iii). Suitable substitutes appear to be available.	Control as a PS could reduce conclusion (iii) risks to acceptable level. If octa classified as a PHS, all environmental risks could be addressed (since cessation of all discharges, emissions and losses would be required). Timeframe potentially over 20 years for cessation of discharges, emissions and losses.	Could address conc. (iii) risks for earthworm-based food chain if reduced by percentage said to be possible by supplier (however, risk assessment conclusions may change). Would not address human health risks or areas where conclusion (i) has been reached.
Practicality	Procedures well established in the EU. Controlling imports of finished products could be more problematic.	Procedures for implementing measures will be developed under the WFD.	Technically feasible for the supplier to reduce concentration from <12% to <8%.
Monitorability	Monitoring success amongst EU companies should be straightforward. Again, imports in articles are harder to monitor.	Procedures for monitoring success assumed to be developed under the WFD.	Relatively simple to monitor since only one supplier.
Economic Impact	**Suppliers**: Loss of sales of around €1.6m directly and €3.2m relating to master batch and finished products. However, would be offset by increase in sales of alternatives. **Compounders/master batchers/polymer processors**: Possible costs of substitution estimated at around €7.5 million over five years for cost of substitute and R&D. Could also be one-off costs for mould replacement (e.g. up to €5 million as an indicative estimate). Possible increase in product price of 0.19% to 0.30% if passed on to **consumers**. **Regulators**: Costs of developing legislation and ensuring compliance.	**Suppliers**: No direct costs expected since not produced in the EU. **Compounders/master batchers/polymer processors**: Costs of implementing measures uncertain (but will tend to be less than for M&U restrictions). Costs will be greater if classified as a PHS. **Regulators**: No additional costs since measures will already be developed.	**Suppliers**: Could reduce concentration in a cost-effective manner. **Compounders/master batchers/polymer processors**: Some costs associated with need for process modification but not thought to be prohibitive. **Regulators**: Costs associated with ensuring compliance.
Balance of Advantages and Drawbacks	Provides most effective means of addressing both conclusion (i) and conclusion (iii) risks/potential risks. However, cost implications may be disproportionate if only conclusion (iii) risks are to be addressed, given the lower cost effectiveness compared to some other measures.	Only addresses risks for the environment for conclusion (iii). Would not address the risks in a timely fashion.	Provides a cost-effective means of addressing risks for hexa congener via earthworm-based food chain but uncertain whether reduction in concentration possible would reduce risks to acceptable level (since risk assessment conclusions subject to change).

Table 7.5b: Summary of Advantages and Drawbacks (Worker Protection, Sludge Directive, Input-Based Product Charge and Tradeable Permits)				
	Worker Protection	**Sludge Directive**	**Input-Based Product Charge**	**Tradeable Permits**
Effectiveness	Measures introduced through revised classification and labelling could reduce conclusion (iii) risks for health to an acceptable level. Supply of octa in a non-powder form could reduce all conclusion (iii) risks for health and the environment to an acceptable level. Would not directly address conclusion (i) risks.	Would target risk of secondary poisoning for hexa congener - conclusion (iii) (but level of any limit value unknown at present). Could reduce secondary poisoning for conclusion (i) via the earthworm-based food chain but not to an 'acceptable' level.	Effectiveness will depend on rate at which charge is set; cannot be guaranteed to deliver risk reduction. Will address risks associated with use of octa in polymer processing, but will not necessarily address worker safety or conclusion (i) risks; although some reductions may take place owing to lower levels of usage.	Would place a restriction on the amount of octa that could be used and be linked to emission control and worker safety requirements. The latter would reduce the conclusion (iii) risks to an acceptable level. Provides for some certainty compared to other economic instruments. Would not directly address the conclusion (i) risks.
Practicality	Various worker protection measures are already in place for implementation under the Chemical Agents Directive. Supplier could relatively easily supply octa in a non-powder form.	Means for implementing currently being developed. Timetable for implementation unknown at present.	Should be relatively easy to implement and monitor given low number of users. Would require establishment of a duty to declare imports.	Assumes regulators able to establish an 'acceptable' level of usage. Also requires that a system for monitoring trading is put in place and that trades are approved by regulators. Number of companies involved may mean that no trading takes place.
Monitorability	Systems for monitoring are in place under the CAD.	Expect that future legislation will contain provisions for monitoring.	Systems required to monitor imports, with some potential for charge evasion. Systems for charge collection also required.	Systems required to register and monitor trades, and to ensure that any emissions/worker safety controls are in place.

Table 7.5b: Summary of Advantages and Drawbacks (Worker Protection, Sludge Directive, Input-Based Product Charge and Tradeable Permits)				
	Worker Protection	**Sludge Directive**	**Input-Based Product Charge**	**Tradeable Permits**
Economic Impact	**Suppliers**: Costs of producing octa in a non-powder form. **Compounders/master batchers**: Costs of utilising octa in granular form not expected to be prohibitive (can be used in existing equipment). **Polymer processors**: No additional costs imposed. **Regulators**: Costs associated with monitoring compliance.	**Suppliers, compounders and polymer processors**: No additional costs expected. **Regulators**: Difficult to estimate costs due to uncertainty regarding limit value set and distribution of octa in EU sludge. Indicative costs of diversion from spreading on land to incineration or landfill are around €19m to €130m per year.	**Suppliers:** Main costs would be from any lost sales and from need to report imports. **Polymer Processors**: Would bear either costs of the charge or the costs of moving to a substitute FR. If paying charge, then would further costs in making an import declaration. **Regulators:** Would need to monitor and validate imports and establish system for charge collection.	**Suppliers:** If ceiling on use is set below current levels then this would affect sales of octa. Otherwise no impact. **Polymer Processors:** Would be costs of ensuring adequate emissions control and any transaction costs associated with trading. Costs should be lower than under M&U restrictions. **Regulators:** Costs of approving trades and monitoring usage.
Balance of Advantages and Drawbacks	Measures adopted under the CAD should address conclusion (iii) risks for health cost effectively. Supply in a non-powder form would address all conclusion (iii) risks without prohibitive cost.	Would address only conclusion (iii) risks for environment (hexa congener). Costs for authorities in diverting sludge may be significant and more than marketing and use restrictions.	On balance, this option should achieve some reductions in risks at lower cost than M&U restrictions.	If linked to emission controls should ensure that conclusion (iii) findings addressed and provide for ceilings on usage with regard to conclusion (i) findings.

8. PROPOSED RISK REDUCTION STRATEGY

8.1 Overview

8.1.1 Areas where a Need for Risk Reduction has been Identified

As discussed in Section 2, the risk assessments have concluded that there is a need for risk reduction (conclusion iii) for two areas. Firstly, in relation to human health, there is a need for risk reduction measures to address risks arising from inhalation and dermal exposure to octabromodiphenyl ether as a dust in the workplace. Whilst worker protection measures are likely to be in place already, it cannot be confirmed that these are universally applied.

Secondly, there is a risk for secondary poisoning via the earthworm-based food chain (for the hexabromodiphenyl ether congener), related primarily to the settling out of dust during the mixing stages of polymer processing and subsequent washing down of floors and equipment to waste water. This leads to the deposition of octabromodiphenyl ether on soil through sewage sludge into which the substance is partitioned.

8.1.2 Areas where there is a Possible Need for Precautionary Action

There are several areas where a need for further information and/or testing has been identified, applying to both human health and environmental risks. For these areas, it has been concluded that there is a possible need for precautionary action and that consideration should be given at a policy level to the need to investigate risk management options now in the absence of adequate scientific knowledge. Key concerns for the environment are the suitability of the current risk assessment approach for secondary poisoning and the possible debromination of octabromodiphenyl ether in the environment.

For human health, there are concerns regarding the presence of octabromodiphenyl ether (and lower congeners in particular) in breast milk and subsequent breast feeding and also for prolonged exposure. This also relates to humans exposed to the substance via the environment, from all life-cycle stages including in-service use and disposal of products.

Therefore, the steering group for this project considered two possible risk reduction strategies for addressing the risks, based upon the Stage 3 report. The first possible strategy is that which represents the best balance of advantages and drawbacks in addressing the areas where conclusion (iii) has been reached and the second represents the best balance where conclusion (i) has also been reached.

8.2 Possible Strategies Considered

8.2.1 Strategy to Address Risks where Definite Need for Reduction Identified

Based upon the analysis in Section 7, there is a number of options that could address the risks to human health and the environment. Of these, the option providing the best balance of advantages and drawbacks for reducing the conclusion (iii) risks appears to be for octabromodiphenyl ether to be supplied in a non-powder form. This would significantly reduce the generation of dust during polymer processing and, therefore, should reduce both risks to human health and to the environment.

It is understood that the supplier of octabromodiphenyl ether to the EU market could work with their customers to provide the substance in this form and that this could be done without incurring disproportionate costs.

This option would reduce the risks to an acceptable level without there being costs incurred to the same level as would be experienced under marketing and use restrictions (a ban). The outcome is more certain than reduction of environmental emissions through measures adopted under the Water Framework Directive or through reducing the concentration of lower brominated congeners (and these two measures do not directly target the human health risks[47]). Other worker protection measures that may be adopted as a result of a revised classification and labelling would not be certain of addressing the environmental risks (for example, if companies decided to use personal protective equipment, with losses to the environment not reduced). Likewise, introducing restrictions on spreading sewage sludge on land where the concentration of octabromodiphenyl ether is above a certain limit would only address the environmental risks and could result in significant costs.

In order to partially address the areas where the need for risk reduction is less clear (where conclusion (i) has been reached), the above measure could be combined with an economic instrument in the form of an input-based product charge. This would encourage companies to move away from use of octabromodiphenyl ether where it is financially viable to do so.

8.2.2 Strategy to Address Risks where Possible Need for Precautionary Action

In relation to the areas where there exists considerable uncertainty regarding the need for risk reduction, the only means by which the risks could be reduced to an ‘acceptable’ level would be to ensure that no emissions of the substance to the environment occur and that no human exposure takes place[48].

---

[47] Although the former is expected to take into account humans exposed via the environment in the procedure for setting quality standards for Priority Substances (formal proposals are expected in autumn 2003).

[48] Since it has not been possible for the risk assessment to reach a quantitative estimate of the risk, it is not possible to provide an estimate of the degree to which emissions would need to be reduced in order to remove the concern.

There are only two measures that would ensure that the environmental risks associated with octabromodiphenyl ether are reduced accordingly. A ban through marketing and use restrictions would prevent any environmental emissions from occurring as a result of the substance no longer being used in the EU. Alternatively, if octabromodiphenyl ether were to be classified as a priority hazardous substance under the Water Framework Directive, a cessation or phase-out of discharges, emissions and losses would be required, thus reducing the risks to an acceptable level (since there could effectively be no entry into the environment).

However, measures under the WFD would not necessarily address all of the human health issues and could potentially take over 20 years to address all of the concerns[49].

Therefore, the only measure that could address all of the areas where a potential need for precautionary action has been identified would be a ban through marketing and use restrictions (given that it is not possible to identify an 'acceptable' level of risk for these concerns). The potential costs to EU industry of this strategy have been estimated at around €7.5 to €12 million over five years. If these increased costs were passed on to the consumer, the percentage increase in the average price of products would be between 0.19% and 0.30%, based on an estimated 3 million products on the market per year.

8.3 Recommended Risk Reduction Strategy

The results of this report will be taken into account by the UK and French Competent Authorities in recommending Community-level measures to reduce the risks associated with octabromodiphenyl ether.

In deciding upon the option to take forward, it has been necessary to take into account the strategy that represents the best balance of advantages and drawbacks for reducing the risks where a definite need for risk reduction has been identified (for secondary poisoning related to the hexabromodiphenyl ether congener and for worker protection). Additionally, it has been necessary to take into account the strategy that best deals with the areas where the need for risk reduction is less certain.

To address the first concern (conclusion iii areas), there are measures that could be implemented that potentially provide a better balance of advantages and drawbacks than a ban, especially given that the cost implications of such a restriction are not insignificant. However, in order to address all of the risks and potential risks (conclusion iii and conclusion i areas), it was decided by the steering group that a ban through marketing and use restrictions represents the best balance of advantages and drawbacks overall. Industry, however, did not agree that a ban on the substance was justified on the basis of the conclusion (i) areas.

---

49 Under the WFD, the timetable for cessation of discharges, emissions and losses is within 20 years of the adoption of measures. However, Member States should aim for compliance with quality standards for all Priority Substances (including octabromodiphenyl ether), which would partially address the environmental concerns and some of the human health concerns.

It is therefore recommended by the majority of the Steering Group that the marketing and use of octabromodiphenyl ether be banned under Directive 76/769/EEC.

9. REFERENCES

Akzo Nobel (2001a): *IUCLID Data Set for Phosphoryl Chloride, Polymer with Resorcinol Phenyl Ester*, Akzo Nobel Functional Chemicals, New York, 26 October 2001, submitted under the US EPA's HPV Challenge Programme, downloaded from **US EPA** internet site (www.epa.gov).

Akzo Nobel (1998): *Technical Data Sheet for Fyrolflex RDP*, Azko Nobel Functional Chemicals Inc. 1 November 1998 (downloaded from www.akzonobel.com).

Albemarle (2001a): **Material Safety Data Sheet for 1,2-bis(pentabromophenyl) ethane (Saytex 8101)**, Albemarle Europe SPRL, 9 April 2001.

Albemarle (2001b): **Toxicology Summary for Saytex 8010 Flame Retardant**, Albemarle Corporation, 21 June 2001.

Albemarle (2000a): **Material Safety Data Sheet for Brominated Polystyrene (Saytex HP-7010)**, Albemarle Europe SPRL, 8 June 2000.

Anderson (2001): *Revision of Directive 86/278/EEC Cost Benefit Analysis*, Anderson Environmental Risk Consulting, presentation at conference on Sewage Sludge Directive, Brussels, 30/31 October 2001

APME (2001): **Plastics - A Material of Innovation for the Electrical and Electronic Industry**, Association of Plastics Manufacturers in Europe, Brussels.

Australian Government (2001): **Polybrominated Flame Retardants (PBFRs) - Priority Existing Chemical Assessment Report No 20**, Australian National Industrial Chemicals Notification and Assessment Scheme, June 2001

Benjamin/Clarke Associates (1997): **The Life Safety Benefits of Brominated Flame Retardants in the United States**, prepared for Brominated Flame Retardant Industry Panel, Chemical Manufacturers Association, April 1997.

BRE (1998): Use Category Document - Plastics Additives, revised draft for discussion, June 1998, Building Research Establishment, Watford.

BSEF (2000): **An Introduction to Brominated Flame Retardants**, Bromine Science and Environmental Forum, Brussels, 19 October 2000.

CEU (2001a): **Common position adopted by the Council on 6 December 2001 with a view to the adoption of a Directive of the European Parliament and of the Council amending for the 24th time Council Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations (pentabromodiphenyl ether)**, Inter-institutional File 2001/0018 (COD), Brussels, 6 December 2001.

CFSTF (1997): *Safe as Houses*, report by the **Community Fire Safety Task Force** downloaded from the DTLR Internet Site (www.safety.dtlr.gov.uk/fire/fepd/pdf/sah.pdf).

Croner (1999): **Croner's Substances Hazardous to the Environment**, Croner Publications Limited, Surrey.

Danish EPA (2000a): **Brominated Flame Retardants - Toxicity and Ecotoxicity**, Environmental Project No 568 2000, report for the Danish Environmental Protection Agency by the Danish Toxicology Centre, DHI Water and Environment and the Centre for Integrated Environment and Toxicology.

Danish EPA (1999): **Brominated Flame Retardants – Substance Flow Analysis and Assessment of Alternatives**, Danish Environmental Protection Agency.

DEFRA (2002): *Progress in Screening Chemicals that Meet Stakeholder Forum PBT Criteria*, Second Interim Report (Ref. CSF/02/28), seventh meeting of the Chemicals Stakeholder Forum, 12 March 2002, downloaded from **Department for Environment, Food and Rural Affairs** internet site (www.defra.gov.uk).

DETR (2000a): **Fire Statistics United Kingdom 1999**, report prepared by Watson L et al, Issue 20/00, Department for the Environment, Transport and the Regions (now DEFRA) 8 November 2000.

DTI (2001): *Small and Medium Enterprise (SME) Statistics for the UK 2000*, **Department of Trade and Industry Small Business Service**, downloaded from www.sbs.gov.uk.

EBFRIP (2002a): *TBBPA is not covered by the ban on FR-720 ordered by the Dutch Ministry*, statement of March 2002, **European Brominated Flame Retardants Industry Panel** internet site (www.ebfrip.org/statements/tbbpa.html).

Emsley AM, Lim L and Stevens GC (2002): *International Fire Statistics and the Potential Benefits of Fire Counter-measures*, University of Surrey Polymer Research Centre, paper presented at Flame Retardants 2002 conference, February 2002, London.

Environment Agency (2002a): **Risk Assessment of Octabromodiphenyl Ether - Overall Results of the Risk Assessment**, summary of revised risk assessment, Building Research Establishment, Watford for the Environment Agency for England and Wales.

Environment Agency (2002b): **Risk Assessment of 2,2',6,6'-Tetrabromo-4,4'-isopropylidene Diphenol (Tetrabromobisphenol A) - Environmental Draft of March 2002**, Building Research Establishment, Watford for the Environment Agency for England and Wales.

Environment Agency (2001a): **Risk Assessment of Diphenyl Ether, Octabromo Derivative (Octabromodiphenyl Ether)**, Updated Draft Report of November 2001, Building Research Establishment, Watford for the Environment Agency for England and Wales.

European Commission (2002): **Highlights from the 2001 Survey - Observatory of European SMEs 2002 No 1**, report for the European Commission by KPMG Special Services and EIMB Business and Policy Research.

Environment Agency (2001b): **Review of Environmental Hazards of Flame Retardants - A Non-Confidential Overview**, report for the National Centre for Ecotoxicology and Hazardous Substances (part of the Environment Agency for England and Wales), Peter Fisk Associates, July 2001.

European Commission (2001b): **Proposal for a Directive of the European Parliament and of the Council, amending for the 24th time Council Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations (pentabromodiphenyl ether)**, COM(2001) 12 final, Brussels, 15 January 2001.

European Commission (2001c): **Organic Contaminants in Sewage Sludge for Agricultural Use**, European Commission Joint Research Centre and UMEG Centre for Environmental Measurements, Environmental Inventories and Product Safety, 18 October 2001.

European Commission (2000a): **Working Document on Sludge - 3rd Draft**, ENV.E.3/LM, Brussels, 27 April 2000.

European Commission (2000b): **Proposal for a Directive of the European Parliament and of the Council on waste electrical and electronic equipment and Proposal for a Directive of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment**, COM(2000) 347 final, Brussels, 13 June 2000.

European Commission (1998): **Technical Guidance Document on Development of Risk Reduction Strategies**, Office for Official Publications of the European Communities, Luxembourg, January 1998.

European Parliament (2002a): **Draft Recommendation for Second Reading on the Council common position for adopting a European Parliament and Council directive amending for the 24th time Council Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations (pentabromodiphenyl ether) (12332/1/2001 – C5-0638/2001 – 2001/0018(COD))**, European Parliament Committee on the Environment, Public Health and Consumer Policy, 2001/0018(COD) (provisional), 30 January 2002

European Parliament (2001a): **Report on the proposal for a European Parliament and Council directive amending for the 24th time Council Directive 76/769/EEC relating to restrictions on the marketing and use of certain dangerous substances and preparations (pentabromodiphenyl ether)**, Document A5-0271/2001, 12 July 2001.

German UBA (2001a): **Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals**, Texte 40/01, Umweltbundesamt, Germany, June 2001.

German UBA (2001b): **Formulation of Proposals for Measures to be Taken to Substitute Environmentally Relevant Flame Retardants in Printed Circuit Boards, Outer Casings for IT and TV Appliances and Polyurethane Insulation and One-component Foams**, workshop reports, Öko-Recherche on behalf of the Umweltbundesamt, Germany, September 2001.

GLCC (2001a): **Industry Comments - Final Draft Risk Assessment - November 2001 - Octabromodiphenyl Ether**, Great Lakes Chemical Corporation, 29 November 2001.

GLCC (2001b): *Material Safety Data Sheet for Reofos RDP*, **Great Lakes Chemical Corporation**, 6 September 2001, (downloaded from www.greatlakeschem.com).

GLCC (2001c): *Material Safety Data Sheet for FF-680*, **Great Lakes Chemical Corporation**, 27 November 2001, (downloaded from www.greatlakeschem.com).

GLCC (2000a): *Material Safety Data Sheet for BA-59P (Tetrabromobisphenol A)*, European Version, **Great Lakes Chemical Corporation**, November 2000, (downloaded from www.greatlakeschem.com).

GLCC (n.d.): *Technical Information Data Sheet for FF-680*, **Great Lakes Chemical Corporation**, (downloaded from www.greatlakeschem.com).

HSDB (2002): *Hazardous Substances Databank - Information on 1,2-bis (tribromophenoxy) ethane*, a database of the **National Library of Medicine's** TOXNET system on 20 May 2002 (toxnet.nlm.nih.gov).

HSE (1997): **Dust - General Principles of Protection**, Guidance Note EH 44 (third edition), Health and Safety Executive Books.

IAL (1999): **The European Flame-retardants Chemicals Industry 1998**, IAL Consultants, London cited in Danish EPA (1999)

IUCLID (1994): **IUCLID Data Set for Diphenyl Ether, Octabromo Derivative**, International Uniform Chemical Information Database.

IUCLID (1995): **IUCLID Data Set for Tetrabromobisphenol A**, International Uniform Chemical Information Database.

IUCLID (1996): **IUCLID Data Set for Triphenyl Phosphate**, International Uniform Chemical Information Database.

Kemi (1999): **Phase-out of PBDEs and PBBs - Report on a Governmental Commission**, Swedish National Chemicals Inspectorate, 15 March 1999

Ministère de l' Emploi et de la Solidarité (2000): **Risk Assessment of Diphenyl Ether, Octabromo Derivative (Octabromodiphenyl Ether), CAS Number: 32536-52-0, EINECS Number: 251-087-9 & Human Health Assessment**, Final Draft, Paris, France, 29 August 2000.

OECD (1995): **Voluntary Commitment by the Major Global Producers of Selected Brominated Flame Retardants Covered under OECD's Risk Reduction Programme**, 30 June 1995.

OECD (1994): **Risk Reduction Monograph No 3: Selected Brominated Flame Retardants - Background and National Experience with Reducing Risk, OECD Environment Monograph Series No. 102**, Organisation for Economic Co-operation and Development, Paris, 1994.

OSPAR (2000a): **OSPAR List of Chemicals for Priority Action (Up-date 2000)**, Reference Number 2000-10, Meeting of the OSPAR Commission, 26-30 June 2000, Copenhagen.

SP (1999): *Report for the Fire Testing of Computer Monitors*, report ref. 99 R31151, SP Swedish National Testing and Research Institute for the **National Association of State Fire Marshalls** (USA), 14 December 1999 (downloaded from www.firemarshals.org).

Stevens GC and Mann AH (1999): **Risks and Benefits in the Use of Flame Retardants in Consumer Products**, Polymer Research Centre, University of Surrey.

Stockholm Vatten (2001): *Brominated Flame Retardants in Sewage Sludge - The Swedish Experience*, Cajsa Wahlberg, Stockholm Watten, presentation at conference on Sewage Sludge Directive, Brussels, 30/31 October 2001.

Tavlet M and Santaoja M (1999): **Digest of a Technical Report by the IVF (Swedish Institute of Production Engineering Research) on Alternatives to Halogenated Flame Retardants in Electronic and Electrical Products**, Document TIS-TE/CC/99-08, November 1999.

Troitzch J (n.d.): **Fire Safety of TV Sets and PC Monitors**, prepared for European Brominated Flame Retardants Industry Panel and European Flame Retardants Association, Fire and Environment Protection Services, Wiesbaden Germany.

US EPA (2000): **Estimations Programs Interface for Windows (EPIWIN) Version 3.0**, United States Environmental Protection Agency.

VKE (1997): **Kunststoffindustrie bekräftigt Verzicht auf Polybromierte Diphenylether (PBDE)**, Verband Kunstofferzeugende Industrie E.V., 24/4/97.

WHO (1994): **Environmental Health Criteria 162 - Brominated Diphenyl Ethers**, International Programme on Chemical Safety (IPCS), World Health Organisation, Geneva, 1994.

WHO (1995): **Environmental Health Criteria 172 - Tetrabromobisphenol A and Derivatives**, International Programme on Chemical Safety (IPCS), World Health Organisation, Geneva, 1995.

WHO (1998): **Environmental Health Criteria 205 - Polybrominated Dibenzo-p-Dioxins and Dibenzofurans**, International Programme on Chemical Safety (IPCS), World Health Organisation, Geneva, 1998.

ANNEX 1

STEERING GROUP MEMBERS - DISTRIBUTION LIST

ANNEX 1: STEERING GROUP MEMBERS - DISTRIBUTION LIST

Steve Robertson	Environment Agency
Steve Dungey	Environment Agency
Adam Peters	Environment Agency
Nick Cartwright	Environment Agency
Dieter Drohmann	Great Lakes Chemical Corporation
John Biesemeier	Great Lakes Chemical Corporation
Bob Campbell	Great Lakes Chemical Corporation
Emilie Deriviere	Ministère de l'écologie et du développement durable, France
Martine Reynier	INRS, France
Claire Beausoleil	INRS, France
Sylvain Bintein	Ministère de l'écologie et du développement durable, France
François Deschamps	Syndicat des Producteurs de Matières Plastiques, France
Teresa Quinn	Health and Safety Executive
Tony Stafford	Department of Trade and Industry
Gwynne Lyons	WWF
Matthew Wilkinson	WWF
David Brooke	Building Research Establishment
Robin Fielder	Department of Health
Roger Tregunno	DEFRA (CB)
Brian Collins	DEFRA (CB)

ANNEX 2

LIST OF ORGANISATIONS CONTACTED

ANNEX 2: LIST OF ORGANISATIONS CONTACTED

Flame Retardants & Fire Safety

Albemarle Corporation
Alliance for Consumer Fire Safety In Europe (ACFSE)
** Brominated Flame Retardants Industry Panel (BFRIP, USA)
BFRS Co. Ltd
European Brominated Flame Retardants Industry Panel (EBFRIP)
** Great Lakes Chemical Corporation
** International Carbide Technology-INCA AB

Plastics Trade Associations & Companies

** Assn of Plastics Manufacturers in Europe (APME)
** British Plastics Federation
European Plastics Converters (EuPC)

Electrical/Electronic Trade Associations & Companies

AGORIA (CECED-Belgium)
AMDEA (CECED-UK)
ANFEL (CECED-Spain)
ANIE (CECED-Italy)
BEAMA (UK)
British Radio & Electronic Equipment Manufacturers Association
Business Equipment Association
Computer & Peripherals Equipment Association (COMPETA – UK)
EHA (CECED-Sweden)
Eurobit
European Commission of Domestic Equipment Manufacturers (CECED)
European Commission for Electrotechnical Standardisation (CENELEC)
British Electrotechnical Committee
European Display Industry Association (EDIA)
European Electronic Component Manufacturers Association (EECA)
European Federation of Electronic Retailers
EICTA
** European Institute of Printed Circuits (EIPC)
European Telecommunication Services Association (ETSA)
** Federation of the Electronics Industry (FEI - UK)
FEEI (CECED-Austria)
FEHA (CECED-Denmark)
GIFAM (CECED-France)
** International Electrotechnical Commission (IEC)
International Organisation for Standardisation (ISO)
International Telecommunication Union (ITU)
** Orgalime

The Printed Circuit Interconnection Federation (PCIF – UK)
Telecommunications Industry Association (TIA – UK)
VLEHAN (CECED-The Netherlands)
ZVEI (CECED-Germany)

European and National Governments

Department of Trade and Industry
EC, DG Environment - Ecolabel
Environment Agency for England and Wales
Health and Safety Executive
German Environment Ministry (Umweltbundesamt)
** Swedish National Testing & Research Institute

Others

Building Research Establishment
British Standards Inst (BSI)
Environmental Industries Commission
** Industrial Research & Development Corporation (IVF – Sweden)
LG Electronics Korea
Organisation for Economic Co-operation and Development
Spanish Institute of Statistics
University of Surrey

ANNEX 3

COMPARISON OF SELECTED SUBSTITUTES

Table A3.1: Data on Properties of Possible Substitutes for Octabromodiphenyl Ether

	TBBPA	Brominated Polystyrene	1,2-bis(tribromophenoxy) ethane
General Information			
CAS No	79-94-7	88497-56-7	37853-59-1
Suitable polymers	ABS, HIPS, PC, etc	PC, polyesters, polyamides	ABS, HIPS, PC
Usage (tpa)	40,000 in EU		Unknown
Cost	Around 1/2 price of octa	Slightly more than octa	Unknown
Physical Properties			
Molecular Weight	543.92	~ 80,000	687.6
% Br (if applicable)	58.8%	68.5%	69.7%
Melting point (degC)	181	180-195	223-238
Boiling Point (degC)	316	N/A	502 ***
Vapour pressure (Pa)	6.24E-6 (25 degC)	2.00E-05	3.20E-08
Partition coefficient (log Kow)	5.90		9.15 ***
Water solubility (mg/L)	4.16 at 25 degC; 0.065 at 21 degC	Insoluble	Insoluble
Degradation			
Photodegradation	t1/2 = 130h (photooxidation)		
Stability in water	No degradation assumed		
Bidegradation	Not readily biodegradable		Not readily biodegradable ***
Environmental Toxicity			
Fish short-term Toxicity (mg/L)	0.54 (96h LC50)		1,410 mg/L (96h TL50)
Fish long-term Toxicity (mg/L)	0.16 (NOEC)		
Invertebrate short-term Toxicity (mg/L)	0.96 (48h LC50)		
Invertebrate long-term Toxicity (mg/L)	<0.066 (NOEC)		
Algal Toxicity (mg/L)	>0.56 (72/96h NOEC and EC50s)		
Accumulation			
BCF	1,235 =L/kg (fish)		Up to 27.1 at 0.3ppm and 43.6 at 0.03ppm
Human Health Toxicity			
Acute toxicity (oral)	3,200 mg/kg (lowest, mouse)	>2000 mg/kg (rabbit)	LC50 >10,000 mg/kg
Acute toxicity (dermal)	> 2000 mg/kg (rabbit)	> 3000 mg/kg (rabbit)	LC50 > 2,000 mg/kg
Acute toxicity (other)			LC50 > 36.68 mg/L (inhal)
Skin irritation	Not irritating	Slight	Not irritating
Eye irritation	Not irritating	Slight - moderate	Not irritating
Sensitisation	Not sensitising	Inconclusive	
Repeated dose toxicity	"Very low". Lowest NOAEL > 100 mg/kg	NOAEL = 200 mg/kg (28d rat gavage) (liver effects)	In 90d (rat) NOEAL = 1% in feed (liver cell enlargement at 10%) (no effects in 21d inhal. or 28 day feeding)
Genetic (in vitro)	Negative (various tests)	Non mutagenic (salmonella)*	Negative (2 in vitro assays)
Genetic (in vivo)	Negative		
Reproductive toxicity	No signs	NOAEL = 150 mg/kg bw (maternal tox in rats)	
Developmental toxicity	No evidence of teratogenicity up to 3,000 mg/kg	NOAEL = 100 mg/kg/day (foetal development in rats)	No signs in teratology study
References	WHO (1995) UBA (2001a) GLCC (2000a) IUCLID (1996) Environment Agency (2002b)	Albemarle (2000a) Australian Government (2001)	GLCC (2001c) HSDB (2002)

N.A. = not applicable
n.d. = not determined
* Considered non-mutagenic in Australian Govt (2001) but contaminants in commercial product (monomers, solvents) may give positive in-vitro results
** BCF values have been queried by the Environment Agency for England and Wales (see main text)
*** According to EPIWIN v3.10 QSAR (US EPA, 2000)

Table A3.1: Data on Properties of Possible Substitutes for Octabromodiphenyl Ether

	1,2-bis (pentabromophenyl) ethane	Triphenyl Phosphate	Resourcinol bis(diphenylphosphate)
General Information			
CAS No	84852-53-9	115-86-6	125997-21-9, 57583-54-7
Suitable polymers	ABS, HIPS	PC/ABS, etc.	PC/ABS, HIPS
Usage (tpa)	2500 in EU		
Cost	1/3 more than octa	0 to 25% cheaper (but overall cost may be higher)	Overall cost expected to be high
Physical Properties			
Molecular Weight	971.2		
% Br (if applicable)	82.3%		
Melting point (degC)	345	49.5	13
Boiling Point (degC)	N/A	220	n.d.
Vapour pressure (Pa)	< 1E-4 at 20 degC	0.00003	<10 at 38 degC
Partition coefficient (log Kow)	3.2	4.62	n.d.
Water solubility (mg/L)	0.00072	0.75	<10
Degradation			
Photodegradation	n.d.	100% in 1 hour (0.1 mg/L w/ UV light)	n.d.
Stability in water	n.d.	t(1/2) 3d at pH 9; >28d at pH5	e.g. 17 day t1/2 at pH 7
Bidegradation	Not readily biodegradable	Readily biodegradable	Inherently biodegradable
Environmental Toxicity			
Fish short-term Toxicity (mg/L)	> 50 (48h) (over water solubility)	0.32 (96h LC50)	12.4 (96h LC50), 3.0 (96h NOEC)
Fish long-term Toxicity (mg/L)		0.0014 (90d NOEC)	
Invertebrate short-term Toxicity (mg/L)	n.d	1 (48h EC50)	0.76 (48h EC50) (Akzo), >48.6 (GLCC)
Invertebrate long-term Toxicity (mg/L)		0.136 (28d)	
Algal Toxicity (mg/L)	n.d	0.26 (4h EC50)	48.6 (NOEC) (Akzo), >121.6 EC(10) (GLCC)
Accumulation			
BCF	2.5 at 0.5 mg/L and 25-34 at 0.05mg/L **	271 (meas), 1800 (calc)	
Human Health Toxicity			
Acute toxicity (oral)	> 5000 mg/kg (rat)	1,300 mg/kg (mouse)	> 5000 mg/kg (rat)
Acute toxicity (dermal)	> 2000 mg/kg (rabbit)	LD0 = 7,900 mg/kg (rabbit)	>200 mg/kg (rat)
Acute toxicity (other)			>4.14 mg/L (inhal, rat)
Skin irritation	Not irritating	Not irritating	Not irritating
Eye irritation	Not irritating	Slightly irritating	Slightly irritating
Sensitisation			n.d.
Repeated dose toxicity	NOAEL = 1,000 mg/kg in 90 day rat subchronic test (1,250 mg/kg in 28d)	NOAEL = 161 mg/kg for 4 month in rats (diet)	NOAEL 0.1 mg/L (rat inhal), 5000 mg/kg (mouse, gavage)
Genetic (in vitro)	Negative in gene mutation and chromosome aberration tests	Negative (Several Ames tests)	Negative
Genetic (in vivo)		n.d.	
Reproductive toxicity	No evidence of effect in above 28/90d rep. dose studies or dev. toxicity studies	n.d.	NOAEL > 20,000 ppm
Developmental toxicity	Maternal and foetal NOEL of 1,250 mg/kg in rat and rabbit (no higher doses tested)	Not developmental toxicant based on 4 month dietary study in rats	NOAEL > 1000 mg/kg bw
References	Personal comm Albemarle (2001a)	IUCLID (1996)	Akzo Nobel (2001a) GLCC (2001b)

N.A. = not applicable
n.d. = not determined
* Considered non-mutagenic in Australian Govt (2001) but contaminants in commercial product (monomers, solvents) may give positive in-vitro results
** BCF values have been queried by the Environment Agency for England and Wales (see main text)
*** According to EPIWIN v3.10 QSAR (US EPA, 2000)