Report on Brominated Flame-retardants in Mediterranean countries

Regional Activity Centre for Cleaner Production (CP/RAC)
Mediterranean Action Plan

Regional Activity Centre
for Cleaner Production

UNEP

MAP

STOCKHOLM
CONVENTION

GOBIERNO
DE ESPAÑA

MINISTERIO
DE MEDIO AMBIENTE
Y MEDIO RURAL Y MARINO

Generalitat de Catalunya
Government of Catalonia
**Department of the Environment
and Housing**

If there is any study point which can be improved or if there is any inaccuracy, please let us know.

The CP/RAC, based in Barcelona-Spain, was established in 1996. Its mission is to promote mechanisms leading to sustainable consumption and production patterns and sound chemicals management in Mediterranean countries. The CP/RAC activities are financed by the Spanish Government once they have been submitted and approved by the Contracting Parties to the Barcelona Convention and by the Bilateral Monitoring Commission made up of representatives from the Spanish and Catalan Governments.

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Index

1. Introduction

The Regional Activity Centre for Cleaner Production (CP/RAC) is one of the six Regional Activity Centres (RAC) of the Mediterranean Action Plan (MAP) for the Convention for the Protection of the Mediterranean Sea against Pollution (Barcelona Convention). The mission of the centre is “To promote mechanism leading to sustainable patterns of production and consumption and sound chemical management in the Mediterranean”.

During the third Conference of the Parties of the Stockholm Convention held in Dakar in 2007, the Government of Spain presented the candidature of CP/RAC as Regional Centre for Stockholm Convention to the Secretariat. Following this presentation, the CP/RAC was given the status of Nominated Centre for the Stockholm Convention in February 2008. In the decision taken by the fourth COP, held in Geneva in May 2009, the CP/RAC was finally endorsed as Regional Centre for capacity building and transfer of technology under the Stockholm Convention.

In this context, one of the activities the CP/RAC plans to conduct is a report on Brominated Flame-Retardants (BFRs) in Mediterranean countries. The aim of this activity is to gather all the information available in the Mediterranean countries concerning the production and consumption of BFRs, identifying the economic sectors that are potential users of BFRs, potential for use, products containing BFRs and the occupations or circumstances that could lead to exposure to these substances.

2. Status and trends on the use of BFRs

Synthetic polymers have largely replaced the use of wood, glass, and metal materials in our homes, offices, automobiles, public transport, and other public areas. These synthetic materials are often petroleum-based plastics that easily ignite and spread flames quickly (Janssen, 2005). In order to meet fire prevention standards, and to reduce the incidence of fire, flame-retardants have been added to consumer products for several decades in an effort to reduce fire-related injury and property damage. However, it is important to remark that products with BFRs are less prone to burn, but they are still flammable.

The idea of reducing occurrence of fire with chemical agents dates back to 450 BC, when the Egyptians used alum to reduce the flammability of wood. Later, about 200 BC, the Romans used a mixture of alum and vinegar to reduce the combustibility of wood (Hindersinn, 1990, on Alaee, 2003).

Today, there are more than 175 different types of flame-retardants, which are generally divided into classes that include the halogenated organic (usually brominated or chlorinated), phosphorus-containing, nitrogen-containing, and inorganic flame-retardants. The brominated flame-retardants (BFRs) are currently the largest market group because of their low cost and high performance efficiency (Birnbaum, *et. al.*, 2004).

Brominated flame-retardants are a chemically diverse group of substances. BRFs as a class include aromatic diphenyl ethers, cyclic aliphatics, phenolic derivatives, aliphatics, phthalic anhydride derivatives and others. Their major common points are that they are used to flame retard items in commerce and that all contain bromine (OSPAR Commission, 2001).

They are used as components in a variety of polymers, such as polystyrene foams, high-impact polystyrene, and epoxy resins. These polymers are then used in a medley of consumer products, including computers, electronics and electrical equipment, televisions, textiles, foam furniture, insulating foams, and other building materials. In Table 1 is shown a more detailed information of BRFs usage, and the distribution of BFRs by commercial products type. Regarding the importance of BFR uses by sector, Figure 1 shows the distribution for year 2001. As it can be seen, electronics and electrical equipment is by far the biggest consumer of BFRs.

Table 1. Examples of major BFR products by chemical

Chemical name	Typical products
Pentabromodiphenyl ether (Penta-BDE, PBDE, or Penta)	Polyurethane foams: mattresses, seat cushions, other upholstered furniture and foam packaging. Also: carpet padding, imitation wood, paints, sound insulation panels, small electronic parts, fabric coatings, epoxy resins, conveyor belts
Octabromodiphenyl ether (Octa-BDE, OBDE, or Octa)	Acrylonitrile -butadiene - styrene (ABS) plastic: housings for fax machines, computers and other electronics. Also: automobile trim, telephone handsets, kitchen appliance casings, small electronics parts, audio/video equipment, remote control products
Decabromodiphenyl ether (Deca-BDE, DBDE or Deca)	High-impact polystyrene (HIPS) plastic: housings for televisions, computers, stereos and other small electronics. Also: mobile phones
	Various plastics: polycarbonates, polyester resins, polyamides, polyvinyl chloride, polypropylenes, terephthalates (PBT and PET), and rubber. Also: upholstery textiles (sofas, office chairs, backcoating), paints, rubber cables, lighting (panels, lamp sockets), smoke detectors, electrical equipment (connectors, wires, cables, fuses, housings, boxes, switches), stadium seats
Tetrabromobisphenol A (TBBPA)	Reactive flame retardant: epoxy and polycarbonate resins. Also: printed circuit boards in electronics (96%), office equipment housings
	Additive flame retardant: various plastics, paper and textiles. Also: housings of computers, monitors, TV, office equipment, adhesive coatings in paper and textiles
Hexabromocyclododecane (HBCD)	Various plastics: Polystyrene (EPS, XPS), HIPS, polypropylene. Also: textiles and carpet backing, television and computer housings, textiles in automobiles, building materials (insulation panels, construction blocks, thermal insulation, roofs), upholstered foam, latex binders

Source: Janssen, 2005

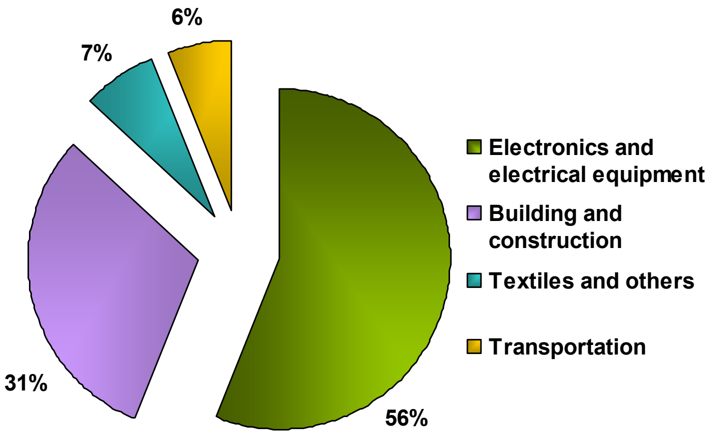

Figure 1. Brominated flame-retardants in consumer and commercial products. *(Source: BSEF, 2001)*

Flame-retardants can act in two ways: preventing ignition, or preventing the spread of a fire. First, the ignition susceptibility of a product lowers since the flame retardant increases de net heat capacity, i.e., the capacity of a body to store heat. Second, once the fire has already begun, these compounds can reduce the tendency of the fire to spread, by creating a non-combustible gaseous layer along the boundary of the fire (US EPA 2005).

In products without BFRs, combustion is propagated by a series of chemical reactions that occur in the gas phase, where oxygen combines with chemicals in the burning product. BFRs interrupt some of these reactions by introducing the volatilized halogens to react with the product in place of oxygen, slowing combustion.

Flame-retardants are categorized as either additive or reactive:

- Additive: they can be added to a manufactured product without bonding or reacting with the product. They are incorporated and dispersed evenly through the product but there is not chemical reaction between the product and the BFR. In general, additive flame-retardants react when heated and either (a) emit substances that displace the oxygen needed for a fire to burn, (b) form a protective coating on the surface of a flammable product, limiting access of the fire to fuel sources, or (c) do a combination of both. More precisely, BFRs act in the gas phase by releasing bromine-containing radicals. Examples of additive BFRs are the PBDEs and HBCDD.

- Reactive: they are chemically bound to polymer products either by incorporating them into the polymer backbone during the polymerization reaction or by grafting them onto it. This prevents possible leaching and/or volatilisation of the flame-retardant. In addition, they have no plasticising effect and do not affect the thermal stability of the polymer. They are mainly used in plastic fibres in which they can easily be incorporated, especially polyesters, epoxy resins, and polyurethanes (RIKZ, 2000). Therefore, reactive flame-retardants are typically already incorporated in the raw materials that are purchased and received by the final manufacturers. An example of reactive BFR is TBBPA.

Since the beginning of their commercial production in the 1960s, there have been more than 75 different commercially recognized BFRs. Some of these chemical classes include brominated bisphenols, diphenyl ethers, cyclododecanes, biphenyls, phenols, phenoxyethanes, and phthalic acid derivatives. The use of individual flame-retardants in products is dependent on the type of polymer, performance, durability, and aesthetics of the end product (Janssen, 2005). They exist in different chemical formulations and compositions, but they all contain at least a bromine atom as a common factor.

Bromine is a common naturally occurring element, and can be found in seawater, salt lakes, inland seas and in the earth's crust. It has many industrial applications such as water purification, agricultural pesticides, car batteries, pharmaceuticals, solvents and photography, although the largest worldwide use of bromine is in flame-retardants production (Janssen, 2005). The global demand for bromine use in flame-retardants has increased from 8% in year 1975 to 39% in year 2000, with an average 2% growth rate between 1990 and 2000 (Birnbaum, et. al., 2004). However, there are currently limited number of brines in the world with concentrations of bromine higher enough to make the process commercially viable. Some examples are located in US (producing 243.000 tons in year 2006 and the Dead Sea in Israel (179.000 tons in year 2006). China is the third largest bromine producer in the world, with 124.000 tons in 2006 (USGS, 2008). In EU, the bigger producer is UK, with 32.000 tons per year, and Japan produces 20.000 tons/year (Alaee, 2003). In year 2006, the total worldwide production of bromine was 643.000 tons (USGS, 2008).

With the exponential growth in sales of personal computers and other electronic equipment since the 1980s, the demand of BFRs grew substantially. According to the Bromine Science and Environmental Forum, over 90% of printed circuit boards contain BFRs (BSEF, 2000), and considering the increasing number of electronic equipment in every persons life, this is a good indicator of the necessity of BFRs in the World today. Figure 2 shows the evolution in the global demand of BFRs since 1992 to 2004.

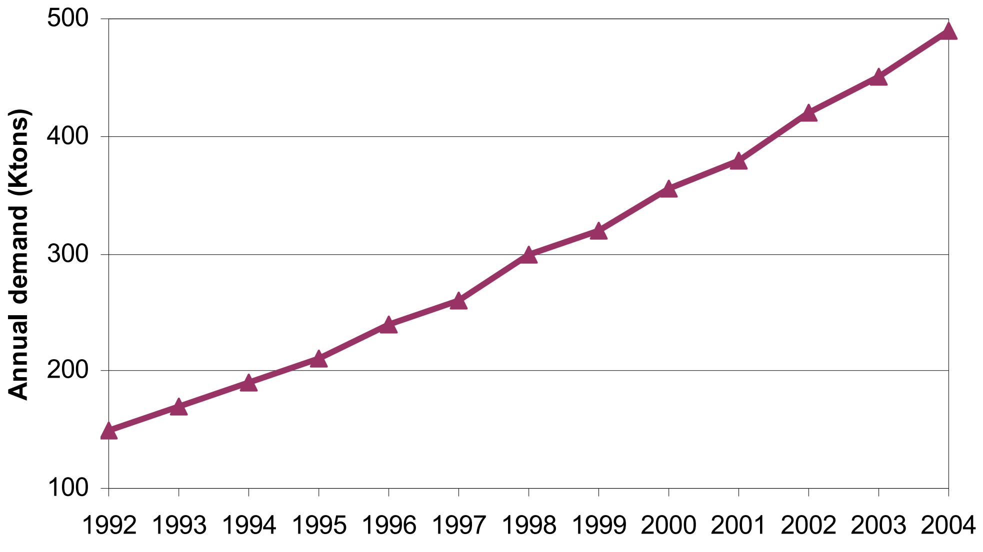

Figure 2: Evolution of global demand of BFRs. *(Source: RIKZ, 2000)*

Although flame-retardants can save lives and prevent property damages, there are increasing concerns about their environmental impacts and health effects. Some of them have already shown to be harmful to the environment or to humans and they are no longer produced. The most known case is the accidental contamination of animal feed with a commercial mixture of poly-brominated biphenyls (PBBs) in Michigan (United States) in the early 1970s, which resulted in loss of livestock and long-term impacts on the health of the local families. After this incident, North America suspended the production of this family of chemicals in 1979, and the last European manufacturer ceased production in year 2000 (Janssen, 2005).

Worldwide, there are currently three classes of BFRs produced in high volumes: polybrominated diphenyl ethers (PBDEs), tetrabromobisphenol A (TBBPA), and hexabromocyclododecane (HBCD). The total world demand for this family of chemicals in 2001 was 203.740 metric tons (BSEF, 2001), although there are important regional differences. As it can be seen in Table 2, two BFRs, TBBPA and Deca-BDE, accounted already in 2001 with 87% of the market demand, while HBCD represented 8% and two other commercial mixtures of PBDEs contributed with 6%. It should be specified that commercial formulations of PBDEs do not consist of a single compound but rather a mixture named for the predominant congener in the group.

Table 2: Brominated Flame-retardants Total Market Demand (metric tons, 2001)

	Europe	Americas	Asia	Other	Total
TBBPA	11.600	18.000	89.400	600	**119.600 (59%)**
Deca-BDE	7.600	24.500	23.000	1.050	**56.150 (28%)**
HBCD	9.500	2.800	3.900	500	**16.700 (8%)**
Penta-BDE	150	7.100	150	100	**7.500 (4%)**
Octa-BDE	610	1.500	1.500	180	**3.790 (2%)**
Total	**29.460 (14,5%)**	**53.900 (26,5%)**	**117.950 (57,9%)**	**2.430 (1,2%)**	

Source: BSEF, 2001.

Considering the distribution by region, Asia is by far the biggest consumer of BFRs, with almost 60% of the total demand, followed by the Americas and Europe. The differences are also remarkable regarding the type of BRF used in each region: Asia requires almost 75% of the total TBBPA existences while the Americas consume the biggest amount of Deca-BDE (44%).

The OSPAR Commission, in a report from 2001 (the same year as the one referred before from the BSFE), mentions that TBBPA and deca-BDE account with 50% of the total BFRs production worldwide. The remaining 50% is composed of a number of different brominated flame-retardants like octa-BDE and penta-BDE (OSPAR Commission, 2001).

Considering the information provided in Figure 2 and Table 2, and the previous paragraph, it is clear that the available data regarding the global production varies among sources. However, regardless of the differences in the available data, it its obvious that TBBPA and PBDEs (mainly deca-BDE, octa-BDE and penta-BDE) are the most used BFRs today, followed by HBCD. For that reason, this report will focus mainly in those three families and their most used congeners, although references to other families will be also made due to their importance in the past.

3. International framework

3.1 Legal framework

An adequate legal framework is the main tool in the management of emissions and production of chemicals into the environment. Through regulations, appropriate management and control measures are specified, in order to reduce the possible harmful effects to the human health and to the natural ecosystems.

Regarding the brominated flame-retardants, there is very little specific normative, although some of the compounds are mentioned in the international and regional legal agreements.

This section is a compilation of the available information regarding the international legal status of the BFRs. It will be analyzed at international and European level. A more profound analysis of the situation in the Mediterranean countries will be made later in this report.

3.1.1 International

3.1.1.1 North Sea Conference

Seas at Risk is the European association of non-governmental environmental organisations working to protect and restore to health the marine environment of the European seas and the wider North East Atlantic. The North Sea Conference process was the initial focus of this association, and still is one of their main activities. The most recent meeting was in Gothenburg in 2006 and focused on fisheries and shipping, two of the principle threats to the environment of the North Sea. Despite the fact that its members are European NGOs, it has been included in this section because their decisions and agreements have an international scope.

At the beginning Seas At Risk was working only from the outside (in London in 1987 and The Hague in 1990), but they became a formal “Observer” organisation for the Copenhagen inter-ministerial meeting in 1993. In this capacity went on to play a part at inter-ministerial North Sea Conference meetings in Esbjerg in 1995, Bergen in 1997 & 2002 and Gothenburg in 2006.

The Ministers of Environment decided at the North Sea Conference of 1995 through the Esbjerg Declaration, to **start action to replace the brominated flame-retardants by less harmful products** (RIKZ, 2000).

3.1.1.2 OSPAR Commission

The OSPAR Commission for the Protection of the Marine Environment of the North East Atlantic is responsible for managing work undertaken as a consequence of the 1992 OSPAR Convention. The Commission is formed by the governments of 15 Contracting Parties and the European Commission.

The OSPAR Commission's principle objective is the reduction and elimination of marine pollution, but they work on the protection of marine species & habitats too. The Commission has strategies on the protection and conservation of marine biodiversity and ecosystems, eutrophication, hazardous substances, the offshore oil & gas industry, and radioactive substances, as well as a strategy on marine environmental monitoring and assessment.

OSPAR Commission's work is organised under six strategies, applying the ecosystem approach to deliver on the Ministerial Declarations and Statements made at the adoption of the Convention and at subsequent Ministerial meetings of the OSPAR Commission. For each strategy, a programme of work is designed and implemented annually.

The brominated flame-retardants have been taken into consideration by the Commission since 1990, through the studies on diffuse emissions (DIFFCHEM). In 1994, Sweden recommended the OSPAR Commission to out phase penta-BDE and deca-BDE, which was not supported by the member states. After several proposals, **in 1999, the BFRs were included in the list of high concern substances**.

The OSPARs Commission Co-ordinated Environmental Monitoring Programme (CEMP) is currently focussed on monitoring the concentrations and effects of selected contaminants in the marine environment such as the brominated flame-retardants in biota and sediment, among others. (OSPAR Commission, 2009)

3.1.1.3 United Nations' Stockholm Convention on Persistent Organic Pollutants

In section 4 of this report, the toxicological properties of BFRs will be analyzed in detail. According to their chemical properties, some of the BFRs have been proved to be persistent and bioaccumulative.

The United Nations' Stockholm Convention on Persistent Organic Pollutants (POPs) is a global treaty to protect human health and the environment from chemicals that remain intact in the environment for long periods, which have become widely distributed geographically and accumulate in the fatty tissue of humans and wildlife.

Chemicals included in the Annexes A or B of the Stockholm Convention, are subjected to elimination or restriction respectively by the signatory Parties. Annex C of the Convention's text is related to unintentional emissions of chemicals (mainly dioxins and furans).

Any party may submit a proposal to de Secretariat for listing a new chemical in the Annexes of the Convention. This proposal is submitted to the POPs Review Committee (POPRC), and if the relevant criteria are fulfilled, the Secretariat invites all Parties and observers to provide technical information, with which the POPRC develops a Risk Profile. If on behalf of that document the POPRC decides that the proposal shall proceed, the Secretariat invites all Parties and observers to provide technical comments and socio-economic information for the POPRC to develop a Risk Management Evaluation. After this process, the Conference of the Parties decides whether to list the chemical in the annexes and specifies its related control measures.

During the last decades, recommendations regarding brominated flame-retardants have been made by different members to the Stockholm Convention. Table 3 shows the status of the BFRs that have been proposed to the Secretariat for listing in the Convention's annexes that where under evaluation before the fourth meeting of Conference of the Parties (COP4) held in May 2009.

Table 3: Summary of BFRs status under the Stockholm Convention

Chemical	Proposing Party	Year	Status
Hexabromobiphenyl **(HBB)**	European Community	2005	Risk management evaluation finished.
Hexabromocyclododecane **(HBCDD)**	Norway	2008	Proposal made to the POPRC.
Octabromodiphenyl ether **(Octa-BDE)**	European Community	2006	Risk management evaluation finished.
Pentabromodiphenyl ether **(Penta-BDE)**	Norway	2005	Risk management evaluation finished.

In the COP4, **Annex A of the Convention has been amended with the inclusion of the following BFRs** (UNEP, 2009)**:**

- **HBB:** has been included with no exemptions for production or use.
- **Tetra-BDE, penta-BDE, hexa-BDE, hepta-BD:** have been included with a specific exemption for using articles containing them for recycling, or the use and disposal of articles manufactured from recycled materials that contain those compounds, provided some specific conditions described in part IV of Annex A.

According to this, each Party shall prohibit and take the legal and administrative measures necessary to eliminate the production, use, export and import of HBB, and shall establish control measures to assure that only the uses allowed by the exemptions occur in their territory.

Considering the actual demand of BFRs worldwide, described in Table 2, only one of the most used BFRs, that is, penta-BDE, has been included in the amendment of the Stockholm Convention's Annex, and the HBCDD is under review by the POPRC. However, as it will be explained later in this report, the commercial octa-BDE contains in its composition up to 60% of hexa- and hepta-BDE, so the inclusion of these two substances implies, *de facto*, the inclusion of octa-BDE.

Parties shall update their National Implementation Plans according to the amendment of Annex A of the Conference's text, incorporating the new chemicals onto their national regulation. According to paragraph 3(c) of Article 22 of the Convention, amendments to the annexes shall enter into force on the expiry of one year from the date of the communication by the depositary. As a result, in this case, the amendments shall enter into force on 26 August 2010 for all Parties that have not submitted a notification stating that are unable to accept the amendment of the annexes. Thus, Parties shall take the appropriate measures to comply with the modifications of the Stockholm Convention prior to that date.

Those new chemicals included in the annexes of the Convention will have to be included in the Global Monitoring Plan, in order to evaluate stockpiles from all regions and identify changes in levels over time or provide information on their regional and global environmental transport. However, how this will be done, and the timeframes for including those chemicals in the monitoring plans remains to be determined.

3.1.1.4 Rotterdam Convention (PIC)

The Rotterdam Convention entered into force on 24 February 2004, with the following objectives:

- to promote shared responsibility and cooperative efforts among Parties in the international trade of certain hazardous chemicals in order to protect human health and the environment from potential harm;
- to contribute to the environmentally sound use of those hazardous chemicals, by facilitating information exchange about their characteristics, by providing for a national decision-making process on their import and export and by disseminating these decisions to Parties.

The Convention creates legally binding obligations for the implementation of the Prior Informed Consent (PIC) procedure. It covers pesticides and industrial chemicals that have been banned or severely restricted for health or environmental reasons. There are currently 39 chemicals listed in Annex III of the Convention, and therefore subject to the PIC procedure.

In the family of flame-retardants, Polybrominated Biphenyls (PBBs) is the only BFR included in Annex III, since 1993. That means that any country Party that plans to export PBB for use within its territory has to inform the importing Party that such export will take place before the shipment, and it can only be carried out if the importing Party gives explicit permission to the exporting country.

3.1.1.5 Organisation for Economic Cooperation and Development (OECD)

The OECD is one of the international institutions with more initiatives regarding the brominated flame-retardants. In 1991, their Risk Reduction Programme carried out an investigation about these compounds. In 1994, they published a monographic in the environmental and commercial life cycle of BFRs (mainly about substances added to synthetic fibres and plastics). After that, OECD Member countries and the manufacturers of these substances held discussions on possible actions that could further reduce risks. In 1995, OECD Member countries agreed to oversee a voluntary industry commitment (VIC) by the global manufacturers of brominated flame-retardants to take certain risk management actions. In parallel to this work, OECD conducted an investigation of the waste management practices in Member countries with respect to products containing BFRs.

The OECD's Hazard/Risk Information Sheets for five Brominated Flame Retardants were updated in 2008, according to the information provided by member states and multinational organisations. This document is a summary description of the legal status on penta-BDE, octa-BDE, deca-BDE, HBCDD and TBBPA in different countries and/or regions. An individual analysis by chemical is made in section 3.2 of this report, compiling the most recent information available.

3.1.1.6 Protocol on Strategic Environmental Assessment (Kiev Protocol)

The Kiev Protocol was adopted by an extraordinary meeting of the Parties to the Convention on Environmental Impact Assessment in a Transboundary Context, held on 21 May 2003.

The Protocol, once in force, will require its Parties to evaluate the environmental consequences of their official draft plans and programmes prior to their approval. Strategic environmental assessment (SEA) is a key tool for sustainable development, since it is undertaken much earlier in the decision-making process than project environmental impact assessment. The Protocol also provides for extensive public participation in government decision-making in numerous development sectors.

Under the Kiev Protocol, not yet ratified, PBDEs would be subject to notification for emissions to water and land respectively exceeding 1kg/year per plant. BSEF takes the view that reporting requirements are important for the understanding and tracking of levels of emissions into the environment. However, according to the BSEF, this threshold of 1kg per industrial plant per year may be discriminating against brominated flame-retardants in comparison to other limits set for other chemical substances.

3.1.1.7 Convention on Long-range Transboundary Air Pollution (CLRTAP)

The history of the Convention on Long-range Transboundary Air Pollution (CLRTAP) starts back in the 1960s, when scientists demonstrated the interrelationship between sulphur emissions in continental Europe and the acidification of Scandinavian lakes. After the 1972 United Nations Conference on the Human Environment in Stockholm, several studies confirmed the hypothesis that air pollutants could travel thousands of kilometres before deposition. This implied that cooperation at the international level was necessary to solve problems originated by these pollutants.

In response to these problems, a High-level Meeting within the Framework of the ECE on the Protection of the Environment was held at ministerial level in November 1979 in Geneva. It resulted in the signature of the Convention on Long-range Transboundary Air Pollution by 34 Governments and the European Community (EC). The Convention was the first international legally binding instrument to deal with problems of air pollution on a broad regional basis.

The Convention entered into force in 1983, and it has been extended by eight specific protocols. One of these protocols is the Protocol on Persistent Organic Pollutants from 1998, signed by 29 Parties, which entered into force on 23 October 2003. The ultimate objective is to eliminate any discharges, emissions and losses of POPs. **The Protocol bans the production and use of some products, and among them, hexabromobiphenyl,** which is listed in Annex A. The provisions of the Protocol oblige Parties (currently 25) to **phase out all production and uses of hexabromobiphenyl**.

3.1.1.8 Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal (Basel Convention)

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal aims to protect human health and the environment against the adverse effects of the generation, management, transboundary movement and disposal of hazardous and other wastes. The Basel Convention was adopted in 1989 and entered into force on May 5, 1992.

The Basel Convention regulates the transboundary movements of hazardous and other waste by applying the "Prior Informed Consent" (shipments without consent are illegal). Shipments to and from non-Parties are illegal unless there is a special agreement. Each Party is required to introduce appropriate national or domestic legislation to prevent and punish illegal traffic in hazardous and other wastes. Illegal traffic is criminal.

Furthermore, the Convention obliges its Parties to ensure that hazardous and other wastes are managed and disposed of in an environmentally sound manner (ESM). To this end, Parties are expected to minimize the quantities that are moved across borders, to treat and dispose of wastes as close as possible to their place of generation and to prevent or minimize the generation of wastes at source. Strong controls have to be applied from the moment of generation of a hazardous waste to its storage, transport, treatment, reuse, recycling, recovery and final disposal.

Regarding to brominated flame-retardants, **PBBs are included in Annex I of the Convention's text as "waste streams to be controlled"**, meaning that signatory Parties are subjected to all the requirements of the Convention when shipping wastes containing this substance.

In addition, list A of **Annex VIII of the Convention designates as hazardous all wastes containing polybrominated biphenyl (PBB), or any other polybrominated analogues of these compounds, at a concentration level of 50 mg/kg or more**, according to Article 1, paragraph 1(a).

3.1.1.9 Strategic Approach to International Chemicals Management (SAICM))

The Strategic Approach to International Chemicals Management (SAICM) was adopted by the International Conference on Chemicals Management (ICCM) on 6 February 2006 in Dubai (United Arab Emirates); SAICM is a policy framework to foster the sound management of chemicals.

SAICM was developed by a multi-stakeholder and multi-sectorial Preparatory Committee and supports the achievement of the goal agreed at the 2002 Johannesburg World Summit on Sustainable Development of ensuring that, by the year 2020, chemicals are produced and used in ways that minimize significant adverse impacts on the environment and human health.

SAICM comprises three basic texts: the **Dubai Declaration** (expresses the commitment of ministers, heads of delegation and representatives of civil society and the private sector to the SAICM); the **Global Strategic Policy** (sets out the scope of SAICM, the needs to be addressed and the objectives for risk reduction, knowledge and information, governance, capacity building and technical cooperation and illegal international traffic); and the **Global Action Plan** (proposes work areas and activities for implementing the Strategic Approach grouped under themes such as risk reduction, knowledge and information, governance, capacity-building and technical cooperation, and illegal international traffic).

SAICM is a voluntary agreement, thus its texts do not include actual actions to be taken related to actual chemicals. However, there are several documents related to the emerging issues that should be taken into account for the development of new policies on chemicals. The SAICM Global Strategic Policy states in paragraphs 24 and 25, functions and agenda of the International Conference on Chemicals Management (ICCM). As an outcome of the second session of the ICCM held in Geneva, Switzerland, in 11-15 May 2009 (ICCM2), the Resolution II/4 on emerging policy issues, recognizes that **"near end-of-life and end-of-life electrical and electronic products are a growing concern as a result of dumping in developing countries, which results in the illegal transboundary movement of their hazardous constituents such as heavy metals and brominated flame retardants"** (SAICM/ICCM.2/15, 2009). The Conference invites the participating organizations of the Inter-Organization Programme for the Sound Management of Chemicals, and the secretariats of the Basel and Stockholm Conventions to organize a workshop to consider issues in relation to electrical and electronic products based on a life-cycle approach.

3.1.2 European

3.1.2.1 REACH

The European Community Regulation EC 1907/2006, on chemicals and their safe use, deals with the Registration, Evaluation, Authorisation and Restriction of Chemical substances (REACH). The new law entered into force on 1 June 2007.

The REACH aims to improve the protection of human health and the environment through the better and earlier identification of the intrinsic properties of chemical substances, while enhancing innovative capability and competitiveness of EU chemicals industry (European Commission, 2009)

Under this new regulation, manufacturers, importers and users need to be aware that chemicals falling within the REACH requirements must be registered before being produced, imported, or placed on the market within the EU.

Chemicals listed in the European Inventory of Existing Commercial Chemical Substances (EINECS) are defined as “phase-in” according to REACH, and were placed on the market in the European Community prior to September 1981. Those chemicals are considered as “existent” and have to be registered under REACH, as long as chemicals produced within the member states, but not placed on the market in the 15 years before REACH comes into force.

BFRs that can be found in EINECS list are Deca-BDE, HBCD, TBBPA and therefore these compounds have to be registered. According to the European Brominated Flame Retardant Industry Panel (EBFRIP), all three substances are currently under the pre-registration phase under REACH.

3.1.2.2 RoHS Directive

The Directive 2002/95/EC, on the restriction of the use of certain hazardous substances in electrical and electronic equipment, commonly known as the Restriction of Hazardous Substances Directive (RoHS), was adopted in February 2003 by the European Union, and took effect on July 1st, 2006, being required its enforcement in each member state.

The directive restricts the use of six hazardous substances in the production of electronic and electrical equipment over a certain concentration by weight of homogeneous material.

Among the substances affected by the RoHS Directive, in addition to lead, mercury, cadmium and hexavalent chromium, are included two BFRs: polybrominated biphenyls (PBB) and polybrominated diphenyl ether (PBDE). In the annex of the directive it is also mentioned that the Commission shall evaluate the applications for deca-BDE as a matter of priority in order to establish as soon as possible whether it should be included in the restrictions.

The European Commission is currently reviewing the RoHS Directive, and the European Parliament and the Council of the European Union is expected to consider the proposal in 2009-2010. **In the proposal for modification submitted in December 2008[1], deca-BDE has been released from the ban, according to the impact assessment carried out. However, the same document draws attention to another BFR, hexabromocyclododecane (HBCD), including it among the substances to be considered for prohibition if an unacceptable risk to human health or the environment arises from its use.**

3.1.2.3 WEEE Directive

The Waste Electrical and Electronic Equipment (WEEE) Directive (2002/96/EC) came into force in February 2003, setting a deadline for the transpose into national law by August 2004.

The WEEE Directive aims to prevent WEEE and, where this is not possible, to recycle and recover it, to reduce its disposal and to reduce the negative environmental impacts of WEEE through an environmentally sound electrical and electronic waste management.

It requires Member States to ensure that collection and treatment schemes are set up and to set minimum collection targets to increase separate collection making producers responsible for the financing of the WEEE management. The Directive, thus, enables market mechanisms and financial incentives in favour of efficient collection, treatment and “design for recycling”.

The Directive sets out collection requirements and a minimum collection target of 4 kg per inhabitant per year for WEEE from private households. In line with the so-called waste hierarchy, preference is given to re-using whole appliances of collected WEEE. In addition, the directive provides minimum combined targets for re-using components and recycling and minimum recovery targets.

The directive is based on producer responsibility and the polluter pays principle as enshrined in the Treaty. The producers of equipment used by private households are responsible for providing financing for the collection, treatment, recovery and environmentally sound disposal of WEEE deposited at collection facilities. Producers of equipment used by others than private households are financially responsible for the costs of collection, treatment, recovery and environmentally sound disposal (European Commission, 2008).

Annex II of the directive **requires the removal of plastics containing brominated flame-retardants and printed circuit boards from electrical and electronic equipment prior to recovery and recycling**.

The directive is currently under review, and the European Parliament and the Council of the European Union will consider the proposal in October 2009, although no changes related to BFRs are expected.

3.1.2.4 Water Framework Directive (WFD)

The Water Framework Directive (2000/60/EC), entered into force in December 2000. It establishes a legal framework to protect and restore clean water across Europe, and ensure its long-term, sustainable use. The directive creates a new approach based on river basins, and it sets specific deadlines for Member States to protect aquatic ecosystems. It addresses inland surface waters, transitional waters, coastal waters, and groundwater.

The directive identifies 33 chemicals as priority substances, and among them, 13 are categorized as *priority hazardous substances* due to their persistence, bioaccumulation and toxicity. **Octa-BDE and deca-BDE are listed as substances to be monitored, and penta-BDE is listed as priority hazardous substance, meaning that emissions to the aquatic environment shall cease before 2020**.

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[1] COM(2008) 809 final

3.2 International legal status of BFRs

This section includes a description of the international legal status of the most commonly used BFRs. The information is presented by chemical, providing a description of the allowance of usage in different regions and/or countries.

3.2.1 TBBPA

Tetrabromobisphenol-A is mainly worldwide used as reactive flame-retardant in printed circuit boards or laminates. It is also used as an additive flame-retardant in ABS plastic housings (BSEF, 2009).

In the **United States**, the Environmental Protection Agency is running a programme called "Design for the Environment" that includes the Printed Circuit Boards Flame Retardancy Partnership, with the purpose of achieving a better understanding of the environmental health and safety aspects of commercially available flame-retardants. The partnership plans to assess alternatives focusing on environmental and human health considerations through a life-cycle methodology (US EPA, 2009). A draft report has been recently published establishing the toxicological hazard for TBBPA, including disposal and recycling practices. TBBPA is not currently restricted under any legislation in the US.

In the **European Union**, TBBPA has undergone an 8 years Risk Assessment for the Environment and Human Health, whose conclusions where published in June 2008. The assessment, and the Risk Reduction Strategy, did not foresee any regulatory restriction for TBBPA. It concludes that this flame-retardant presents no risk to human health, and no risk to the environment when used as reactive component. However, an environmental risk was detected when used as additive in one production plant in Europe, and was addressed requiring emissions reduction measures.

TBBPA is not restricted by the RoHS Directive, not even in the text for the revision released on December 2008, despite the proposal for inclusion made by countries like Germany, Sweden or Norway on several occasions.

The WEEE Directive requires that plastics containing TBBPA and printed circuit boards bigger than 10cm^2 receive a separate treatment from other collected waste from electronic and electric equipment. According to BSEF, removal of plastics containing BFRs has no added environmental or health protection benefits.

In June 2005, certain chemicals where declared as Priority Existing Chemicals in **Australia**, being TBBPA among them. As a consequence from that this substance is currently being assessed for its potential effects on human health and the environment by the National Industrial Chemicals Notification and Assessment Scheme. Information on quantities and uses is being currently compiled from importers and producers (OECD, 2008).

In year 2007, **Norway** made a proposal to restrict the use of 18 chemicals, included the flame retardant TBBPA. This proposal received a general opposition, since it was considered to act ahead the EU risk assessment conclusions. In light of this reaction, the proposal list was reduced to 10 substances, and TBBPA was withdrawn from the list.

The use of TBBPA in **Asia** is not under any regulatory restriction. For instance, in Korea and China has not been included in the so-called Korea-RoHS (Act on the Recycling of Electrical and Electronic Equipment and Vehicles) or in the China-RoHS (Management Methods for Controlling Pollution Caused by Electronic Information Products Regulation).

3.2.2 Deca-BDE

The flame-retardant deca-BDE in the **United States** is available for all uses, and there are no legal restrictions. In the past four years, different attempts to restrict its use have failed to pass. There are, though, limited restrictions in the states of Maine and Washington, which allow the most common uses of deca-BDE, prohibiting only certain potential uses (BSEF, 2009[2]). The Toxic Substances Control Act excludes deca-BDE from its scope, although different studies are being carrying out to evaluate the risks associated to the use of this substance under the Voluntary Children's Chemical Evaluation Program (VCCEP), sponsored by industries. In the programme's update, released in February 2008, it is stated that much of the numerous studies carried out since 2002, regarding the potential health or environmental effects of deca-BDE, are flawed with design, methodology, statistical, data quality and analytical problems. This report affirms that regardless the discussion of deca-BDE absorption or metabolism, the substance produces little, if any, effects (VCCEP, 2008).

Individual States in the US have taken action on PBDEs, mainly for penta and octa-BDE. For instance, Washington prohibits deca-BDE in mattresses as of January 2008, and intends to prohibit its use in upholstered furniture and TV/computer plastic housing in January 2011, if a feasible alternative is found (OECD, 2008).

Deca-BDE in the **European Union** was exempted from the RoHS Directive in October 2005, based on the risk assessment finalised in 2004. However, this decision was revoked by the European Court of Justice in April 2008, after the legal procedures initiated in 2006 by the European Parliament and Denmark. Therefore, since July 2008 deca-BDE can no longer be used in electric and electronic equipment, but is allowed for use in all other applications (BSEF, 2009[2]).

The 10 years EU risk assessment concluded in 2008 that there was no need for risk reduction measures related to deca-BDE, although further studies are necessary in the form of a monitoring programme, a bio-monitoring programme, and a neurotoxicity study.

In **Australia**, deca-BDE is also included in the list of chemicals declared as Priority Existing Chemicals, so it is currently being assessed for its potential effects on human health and the environment by the National Industrial Chemicals Notification and Assessment Scheme (OECD, 2008).

In **Canada**, deca-BDE is listed as a toxic under the Canadian Environmental Protection Act 1999, and it prohibits the manufacture of this product in the country. However, there are no restrictions in its usage (BSEF, 2009[2]).

From April 1, 2008, **Norway** introduced a ban on the manufacture, import, export sell and use of deca-BDE as a substance, in preparations and in products, such as cellular rubber, textiles and upholstery (for quantities greater than 0.1 % by product weight). The use of this substance in electric and electronic equipment has been banned in the country since July 2006, including the prohibition of usage in plastics (SFT, 2008).

Despite the fact that the Commission allows the use of deca-BDE for all uses but electric and electronic equipment, **Sweden** introduced a partial ban in January 2007. It included textiles, furniture and some cables, and exempted electronic equipment, for which the European Commission started an infringement procedure against Sweden (EBFRIP, 2009). In 2008, the Swedish government repealed the national ban for using deca-BDE in textiles and furniture, since it was considered that regulation on this subject should be carried out from an EU level (KEMI, 2009). A study by the Swedish Chemical Agency presented in April 2009, concludes that the suspicions about persistence, bioaccumulation and developmental toxicity for deca-BDE have been strengthened, so the Agency will remain active in the continuing EU assessment of this substance. However, due to a reduction in its usage, a reduction of exposure to humans and the environment is expected, so no further immediate actions are proposed (KEMI, 2009[2]).

In **Asia**, the use of deca-BDE is not under any regulatory restrictions. The Chinese and Korean RoHS equivalent regulations have exempted this BFR from the list or restricted substances for electric and electronic equipment. In Japan, yearly reports of produced, imported and used volumes of deca-BDE have to be reported to the governmental control agency, together with the releases to the environment (BSEF, 2009[2]).

3.2.3 HBCD

A toxicological study by national Academy of Sciences in the **United States** concluded that HBCD was one of the flame-retardants that could be used in upholstered furniture. The US EPA is carrying out an assessment of this substance that should be finalised in 2012.

In the **European Union**, HBCD has undergone a 12 years risk assessment to evaluate the hazards of this substance to the environment and human health. This study was concluded in May 2008, and it identified no risk for consumers, or even for workers, if standard industrial hygiene measures are applied. However, it was proved to have persistent, bioaccumulative and toxic properties. It is for this reason that producers and users are implementing voluntary programmes to control and reduce missions to the environment (BSEF, 2009[3]).

HBCD has been included in the list of very high concern substances under the REACH regulation, and it has been recommended for being subject to Authorisation. The European Chemicals Agency is currently preparing the final list of substances that will require this procedure.

In **Canada**, a risk assessment of HBCD is ongoing and a final draft is expected to be published in 2009 (BSEF, 2009[3]).

In **Japan**, HBCD is considered not biodegradable and highly bioaccumulative and it is classified as class 1 monitoring substance by the Chemical Substance Control Law, which means the obligation to report manufactured, imported and used amounts annually. Ministry of the Environment of Japan conducted measurement of HBCD in air, water, sediment and aqueous biota in 2003 (OECD, 2008; BSEF, 2009[3]).

3.2.4 Penta-BDE and Octa-BDE

In the **United States**, penta and octa-BDE were subjected to a risk assessment under the Voluntary Children's Chemical Evaluation Program with the conclusion that further data is needed for a complete risk assessment. The only US manufacturer these two substances voluntarily phased out the production at the end of 2004, after which EPA promulgated a regulation that requires potential producers or manufacturers to get EPA approval prior to resume the production, for any use, of penta-BDE and octa-BDE. In addition to the federal regulation, individual States have also take action on this subject, prohibiting the manufacturing, processing, or distributing in commerce of a product, or a flamer-retardant part of a product containing more than 0.1% of these chemicals (OECD, 2008).

The **European Union** carried out a risk assessment of penta and octa-BDE, and in view of the environmental risks identified, decided to ban, from August 2004, commercialisation and use of these substances in the EU with concentrations higher than 0.1% (24th amendment to the Marketing and Use Directive 76/769/ECC).

Australia is carrying out a full risk assessment of penta and octa-BDE, but based on an interim risk assessment of similar congeners, decided to ban the import and/or manufacture of these chemicals from March 2007. These chemicals or mixtures containing the chemicals cannot be imported or manufactured in Australia without prior notification to the National Industrial Chemicals Notification and Assessment Scheme. The only exceptions are products imported or manufactured as a laboratory standard for analytical determination.

After the human health and ecological screening risk assessment on PBDEs, **Canada** added penta and octa-BDE to the List of Toxic Substances. The manufacture of these two substances is prohibited in the country, but not the use, sale, offer for sale and import.

3.2.5 PBB

Polybrominated biphenyls have been widely used around the world, being one of the first fire-retardants commercially distributed. Among the many compounds belonging to this family, hexabromobiphenyl (HBB) has been the most commonly used for many years.

Today, HBB usage is forbidden in most of the countries through international agreements regarding chemicals management and use, but due to its importance in the past, it is necessary to make some special remarks about it.

In the **United States**, the sole producer of HBB stopped its production in 1975. However, it continued producing other PBBs (octa- and decabromobiphenyl) until 1979, and the re-initiation of manufacture of any PBB in the US would require approval from the EPA (UNEP, 2007).

The production of PBB in **European Union** continued until year 2000. In the Atochem's factory located in France, decabromobiphenyl was produced until this year, and according to one author, with the closure of decaBB production in France, the PBB production in the world has ceased (Darnerud, 2003).

In summary, according to the information available, **production and use of hexabromobiphenyl has ceased in most, if not all, countries**. However, it is possible that hexabromobiphenyl is still being produced in some developing countries or in countries with economies in transition (UNEP, 2007).

4. State of the art on toxicological properties

The main objective of this report is to analyze the situation in BFRs related issues on the Mediterranean, and it is considered outside of the study's scope to give a deep description on the toxicological properties of these chemical compounds. However, it is considered important to fully understand the issue to outline them with general facts.

4.1 TBBPA

TBBPA is a white (colourless), crystalline powder, containing 59% bromine. The melting point is approximately 180°C and the boiling point, 316°C. Vapour pressure is much less than 1 mmHg at 20°C. TBBPA has a low solubility in water (0.72mg/L), but is very soluble in methanol and acetone. The n-octanol/water partition coefficient (log Pow) is 4.5 (WHO, 1995; Birnbaum, et. al., 2004).

The chemical structure of the TBBPA is shown in Figure 3.

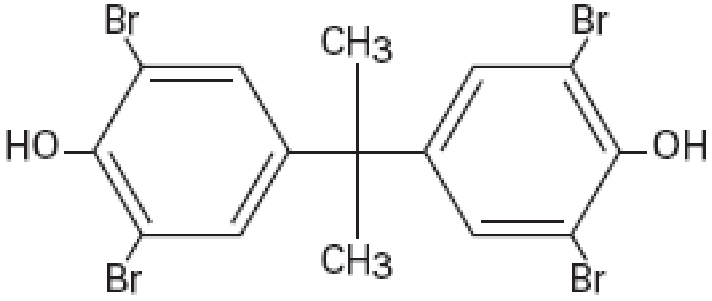

Figure 3: Chemical structure of a TBBPA molecule (*Source: Janssen, 2005)*

Measurable quantities of TBBPA have been found by different studies in the air near production sites, in soil and sediments. Regarding the presence of this compound in biota, limited data has been found, what seems to be a consequence from its relatively low half-life in air, water and sediment. Thus, the compound presents little potential for bioaccumulation. However, detectable TBBPA serum levels from computer technicians were measure in year 2002 (Birnbaum, *et. al.,* 2004; Janssen, 2005).

Studies on biodegradation rates have been conducted both in aerobic and anaerobic conditions in several environmental media, with an average result of 2 months. Depending on soil type, temperature, humidity, and the composition of the soil, approximately 40-90% of TBBPA remained in the soils after 56-64 days. TBBPA has also shown to be sensible to light, resulting in a photodegradation half-life in water that ranges from 7 to 80 days, depending on the season. The half-life of TBBPA in fish is lower than 1 day, and in oysters, lower than 5 days (WHO, 1995).

Regarding the toxicity, TBBPA is absorbed form the gastrointestinal tract and accumulated in fatty tissues, but does not appear to cause immediate symptoms from acute toxicity at average doses (Janssen, 2005). Rodent studies have indicated that TBBPA is not acutely toxic, because of the high LD_{50}[2] in rats and mice, and the same result was found with variable dietary levels. No mutagenic evidence was found in studies carried out on bacteria, although no carcinogenicity or long-term toxicity studies have been reported (WHO, 1995).

Most of the adverse effects of TBBPA have been found *in vitro*. Some of the most recent concerns are based on the potential endocrine disruptor properties of this compound, since it has a very similar structure to bisphenol A, which is a known weak environmental estrogen. Positive results have been found *in vitro* (Birnbaum, *et. al.,* 2004), but not enough studies *in vivo* have been carried out to affirm this toxic effect of TBBPA, and, therefore, more studies are needed to determine if low-dose exposures have estrogenic activities in humans or other species (Jansen, 2005).

Regarding the routes of exposure to human, no dietary studies on TBBPA have been carried out, but traces of this substance were found by various studies in indoor dust samples, and, although the sources of the dust were not identified, they are suppose to be treated carpet fibres, furniture, wiring, computer and other electronics. It should be remarked than this studies show concentrations of TBBPA in indoor dust 1 to 3 orders of magnitude (i.e. 10 to 1000 times) lower than those found from other BFRs, such as PBDEs (Janssen, 2005).

According to the conclusions by the World Health Organisation, risk for the general population from exposure to products made of flame-retardant incorporating polymers, is considered to be insignificant. There is, thought, a risk of occupational exposure during packaging or mixing operations, that can be controlled using respiratory protection or local ventilation. Regarding the environmental fate, a relatively high bioconcentration factor seems to be balanced by rapid excretion and the compound has not been normally found in environmental biological samples. However, the World Health Organisation recommends minimizing the environmental exposure to TBBPA by treating appropriately effluents and emissions in industries using this compound, and through an environmentally sound management of wastes (WHO, 1995).

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[2] Dose lethal to 50%.

4.2 Deca-BDE

There are three polybrominated diphenyl ether flame-retardants available commercially, referred to as penta-, octa- and decabromodifphenyl ether, but each of them is a mixture of several BDEs with varying degrees of bromination (European Communities, 2002). The typical composition for commercial products would be around 97% deca-BDE and 0.3 to 3% of other BDEs, such as nonabromodiphenyl ether and small amounts of octa-BDE and penta-BDE (WHO, 1994; Birnbaum, *et. al.,* 2004).

Deca-BDE is a fine, white to off-white crystalline powder, with a melting point of around 300ºC, with a non-appreciable boiling point, and a vapour pressure of 4.63×10^{-6} Pa at 21ºC. It has a very low water solubility (20-30 µg/L) and a solubility in organic solvents that ranges from 0.05% to 0.87%, i.e. a limited solubility. The log Kow was determined as 6.3 at 25ºC (WHO, 1994).

The chemical structure of the deca-BDE is shown in Figure 4.

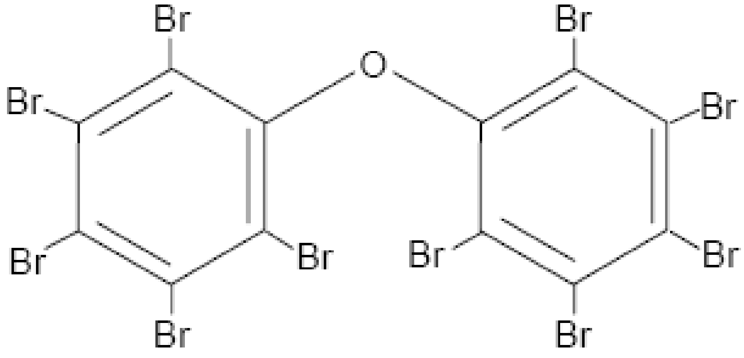

Figure 4: Chemical structure of a deca-BDE molecule (*Source: European Communities, 2002)*

PBDEs are reported to be more stable, although several studies have demonstrated that when dissolved in organic solvents, debromination occurs in presence of UV light, and deca-BDE breaks down to lower brominated congeners (nona- to hexa-BDE) with a half-life lower than 15 minutes. Half-life in sand, sediments and soil is 15, 100 and 200 hours respectively. The debromination reaction rate depends on the number of bromine atoms, being slower for higher brominated congeners (Birnbaum, *et. al.,* 2004).

Regarding the exposure pathways, one study reported a dietary intake of PBDEs in food stuffs from Spain of 97 ng/day, being most of the exposure from the lower brominated congeners (tetra- and penta-BDE), coming mainly from oils, fats, fish, shellfish, meat and eggs (*ibid*.).

Toxicological studies are limited, but in general, the lower brominated mixtures are more toxic than the higher congeners, so deca-BDE is essentially non-toxic for invertebrates. Despite the low toxicity risk of this substance to surface-water organisms and top predators, there are concerns for wastewater, sediment and soil organisms. In vertebrates, studies on deca-BDE toxicity have been conducted in rats and mice, and only very high doses of daily intake resulted in neoplastic nodules in the liver in both male and female rats (*ibid*.). In animal studies all of the commercial PBDE products have shown to affect to some extent the endocrine function, disrupting thyroid hormone balance, although the potency of deca-BDE appears much lower than the rest of congeners (Janssen, 2005; Birnbaum, *et. al.,* 2004).

The main sources of deca-BDE to the environment have been found to originate in the production facilities, in the polymers production sites and service life and disposal, in textiles compounding, application and washing, and in textiles final disposal. Regarding the quantities, releases to landfill/incineration are the biggest contributor, followed by industrial areas and soils, surface water, wastewater and air as dust or vapour.

As a conclusion, according to the Risk Assessment carried out by the EU, the risk of exposure via surface water is low, and exposure of organisms via sediment is thought to be much more relevant. No risk was identified for sewage treatment processes or the terrestrial compartment, and no adverse effects are expected on the atmosphere from the production and use of deca-BDE. However, the available information reveals that further investigation and toxicity testing is necessary, especially in top predators (such as birds, and birds' eggs) and mammals, or in the degradation rate under environmentally relevant condition over a prolonged period of time. Regarding human health, "there is at present no need for further information and/or testing and no need for further reduction measures beyond those which are being applied already" (European Communities, 2002).

4.3 HBCD

The molecular structure of HBCD is more complicated than the one from other BFRs, and can present different diastereomers known as α-, β- and γ-HBCD, with a very complex stereochemistry, still under evaluation. It is a white odourless solid, with a melting point that ranges from 172-184 ºC to 201-205 ºC, depending on the crystallisation status. The boiling point is situated at 190 ºC, and the vapour pressure is 6.3×10^{-5} Pa at 21 ºC. Solubility in water is low (66 µg/L), and therefore is expected to accumulate in sediments.

Solubility in organic solvents ranges from 33.9% in dimethyl formamide to 0.01 in isopentane. The Log Kow was determined to 5.6 at 25 ºC (Birnbaum, *et. al.,* 2004; Janssen, 2005)

The chemical structure of HBCD can be seen in Figure 5.

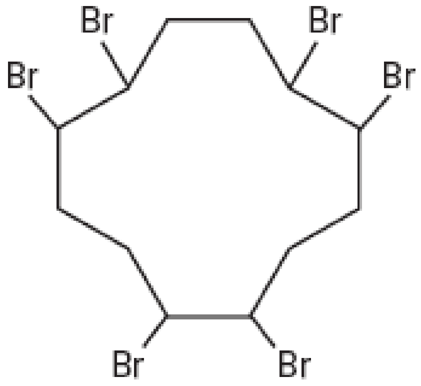

Figure 5: Chemical structure of a HBCD molecule (*Source: Janssen, 2005)*

There are studies showing the strong propensity of HBCD to bioaccumulate, demonstrated by a bioconcentration factor of approximately 18,100 in aquatic animals. It is also persistent, with a half-life of 3 days in air and 2-25 days in water. In European wildlife studies, HBCD has been found in fish, birds and mammals, with relatively high concentrations.

The ecotoxicity of HBCD has been studied in very limited occasions. In algae, the concentration effective in 50% (EC_{50}) values range from 9.3 µg/L to 0.37mg/L, which indicates a potential for high toxicity. However, these values are greater than the water solubility of the compound, meaning than episodes of aquatic organisms intoxication are rare to occur. Studies in rainbow trout have found an LC_{50} of 2.5 µg/L, while studies in daphnia have demonstrated a life-cycle no-observable-effect concentration of 3.1 µg/L. Studies regarding dietary intakes are contradictory, and range from 13 mg/kg/day as lowest-observable-adverse-effect to 1,000 mg/kg/day as no-observable-adverse-effect, depending on the source. However, a decrease in T_4 hormone levels has been reported at 100 mg/kg/day, what could be an indicator of endocrine disruptions.

HBCD has shown not to be mutagenic in studies carried out in yeast and *Salmonella*. Studies performed in year 2002 with neonatal mice led to spontaneous changes of behaviour, learning and memory defects. In fact, HBCD's potential to cause neurobehavioral alterations have been shown in *in vitro* studies too. Regarding studies carried out in people, there is very limited information, and available reports show contradictory data regarding dermal sensitization effects after exposure to fabrics treated with this substance (Birnbaum, *et. al.,* 2004).

The Risk Assessment report for HBCD concludes that no need for further information and/or testing is needed to develop new risk reduction measures, beyond those that are being already applied, to most of the environmental compartments or exposure routes, but makes a special mention to take into account the measures that are already being applied. The only concern is the secondary poisoning of predators, because of the bioaccumulation effect that would result in unpredictable long-term effects, difficult to predict (Swedish Chemicals Agency, 2008).

4.4 Penta-BDE

The available commercially penta-BDE is not a pure substance, but a mixture of congeners, mainly tentra-, penta- and hexa-BDE. The name denotes only the main component of the mixture, although it is not possible to give an actual composition of the mixture, since it varies between manufacturers (European Communities, 2001; Birnbaum, *et. al.,* 2004).

Penta-BDE is a viscous liquid at 20 ºC, with a melting point of -7 to -3 ºC, and a boiling point above 200 ºC. The vapour pressure is low, $< 10^{-7}$ mmHg, and the solubility in water is negligible. It is, however, very soluble in organic solvents, with an n-octanol/water partition greater than 6 (European Communities, 2001; Birnbaum, *et. al.,* 2004).

The molecular structure of the chemical is shown in Figure 6.

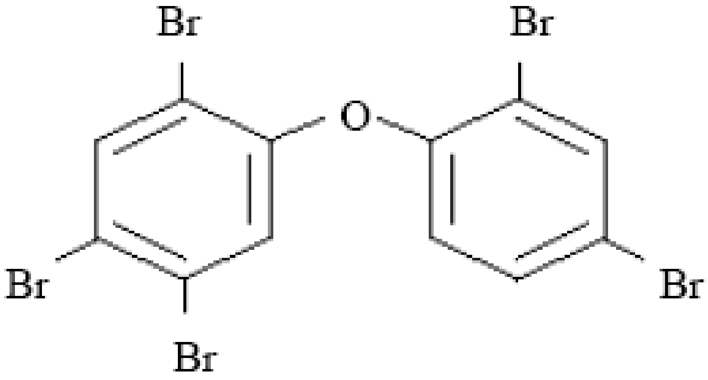

Figure 6: Chemical structure of a penta-BDE molecule (*Source: European Communities, 2001)*

This chemical is likely to be persistent and bioaccumulative, with a bioconcentration factor of over 10,000 found in carp. A high concern on the penta-BDE waste management has been originated, since pyrolysis studies showed that between 700-800 ºC, furans and dioxins are formed in presence of oxygen. In reductive atmosphere, polybromobenzenes, polybromophenols and furans were formed.

Penta-BDE has been found in biota, sediment and sewage sludge samples in different regions of the World, with values ranging from approximately 28 µg/kg dry weight in Japanese estuaries and rivers, up to 1,200 µg/kg in certain sediment samples of Swedish rivers. The half-life of the penta-BDE has only been investigated in the perirenal fat in rats, with an average between 25 and 47 days, depending on the sex of the animal and the type of isomer determined.

Regarding the uptake from oral, pulmonary and dermal sources, data is very limited, but by analogy with other persistent organic pollutants, it is likely that relative absorption may decrease at high concentrations. There is also a relationship between the degree of bromination and the level of absorption: penta-BDE is more likely to be absorbed than its higher brominated congeners (WHO, 1994).

Exposure to humans occurs mainly to workers, during the manufacture of polyurethane foams. Although the number of workers could not be established through industry contacts, due to the extensive use of flame-retardants polyurethane foams, the amount of exposed workers is estimated to be of several thousands. Consumers' exposure is considered negligible, since they are not directly in contact with polyurethane foams. However, there is exposure to the general population through environmental routes, such as food intake (being fish the major contributor), drinking water, air, etc. The combined occupational-environmental exposure is estimated in 2.068 mg/kg/day (European Communities, 2001)

The risk assessment report carried out by the European Union in year 2001 concludes that further information is needed in several aspects, such as occupational, environmental, and combined exposure, or exposure to infants through breast and cow milk. However, penta-BDE is no longer produced, although there are probably in the market articles containing this substance. Considering that penta-BDE will disappear from the market when those articles reach their end of life, the main stress should be made in the sound environmental management of wastes containing penta-BDE, while new research efforts should be made in currently produced BFRs.

4.5 Octa-BDE

The commercial octa-BDE label designs a mixture containing other similar substances, mainly penta- to deca-BDE congeners. The actual composition of the substance varies among manufactures, and it is normally confidential. However, in physico-chemical tests over the years, average amounts of 43% hepta-BDE, 33% octa-BDE, 10% hexa-BDE and 10% nona-BDE were found, being the rest up to 100% traces of penta- and deca-BDE (European Communities, 2003).

Octa-BDE is an off-white powder or flaked material, has a wide melting point range, depending on the composition of the mixture, that varies from 70 to 257 ºC, and a very high boiling point (the substance presents a 2% decomposition at 330 ºC and 40% at 395 ºC). The vapour pressure has been estimated in 6.59×10^{-6} Pa at 21 ºC. It has a measured solubility of 0.5 µg/L in water, and in organic solvents ranges from 2 g/L in ethanol to 250 g/L in styrene. The octanol-water partition coefficient (log Kow) is 6.29 at 25 ºC (European Communities, 2003; WHO, 1994).

The molecular structure of the chemical is shown in Figure 7.

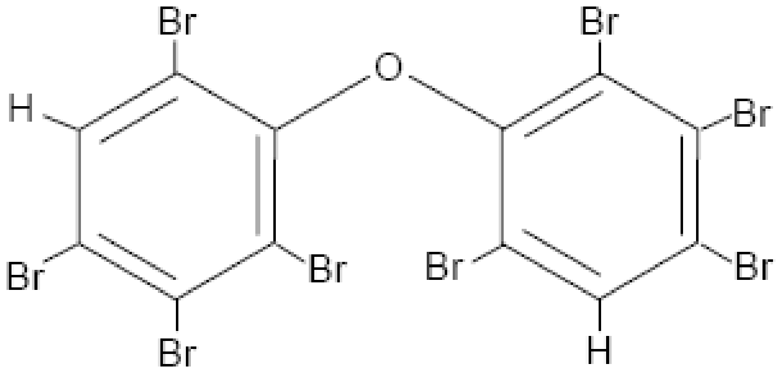

Figure 7: Chemical structure of an octa-BDE molecule (*Source: European Communities, 2003)*

Available data on octa-BDE's persistence is not complete, but there are evidences that it degrades to lower brominated PBDEs under certain conditions (Janssen, 2005). No aerobic biodegradation of this substance has been observed, but several studies confirm degradation under anaerobic conditions in sewage sludge. The predicted atmospheric half-life ranges from 30 to 160 days. However, octa-BDE in the atmosphere is strongly absorbed to suspending particles and removed via wet and/or dry deposition The bioconcentration factor from water has been studied in carps, with values found fewer than 9.5 (UNEP, 2007). The bioaccumulation factor from oral exposure in fresh water fish has been reported to be between 1 and 3 for hexa- and hepta-BDE (two of the substances included in the commercial octa-BDE mixture). Food-web biomagnification has not been observed for octa-BDE, but it has been demonstrated for hexa- and hepta-BDE. Absorption by oral or inhalation route has been demonstrated with an accumulation in the liver, the adipose tissue and the lung. A dermal abortion of 4.5% is estimated in animals, but no data is available in humans. There is no information on the rate of elimination or on bioaccumulation in humans, but due to the high lipophilic characteristics of octa-BDE, is expected to accumulate in the adipose tissue (European Communities, 2003). In summary, the presence of octa-BDE in biota is well documented, but its potential for bioaccumulation is lower than expected from their Kow partition coefficient. This fact could be justified by a reduced availability or slow metabolism (UNEP, 2007).

Potential exposure of this substance to animals and humans is reported to occur from various sources. Measurable concentrations in the atmosphere have been found in the United States, Sweden, Korea, India and other locations worldwide, with concentrations that range from 0.2 to 8.3 pg/m^3. In water, levels of octa-BDE have not been reported, but lower brominated congeners were found. Concentrations raging from 0.44 to 3030 µg/kg in sediments were found in UK in 1999, and several studies show similar results in other countries. Different amounts of octa-BDE have been also found in soil, waste effluents and biosolids (UNEP, 2007).

Actual exposure has been reported to occur to workers, being the main routes the inhalation of dust (roughly 5 mg octa-BDE/m^3) and skin contact (calculated in 0.54mg octa-BDE/kg/day). The highest exposure levels are supposed to occur while handling the dry substance during manufacture and compounding. A sound risk assessment for consumers has not been carried out, but according to scattered pieces of evidence, is likely to be negligible (European Communities, 2003).

Toxicity studies are limited, although an increase of the liver and thyroid glandule, together with a decrease in thyroid hormone levels has been observed in animal tests with oral and inhalation exposure (Janssen, 2005). Mutagenicity studies in *Salmonella sp.* did not show positive results. Regarding possible carcinogenicity effects, chronic studies in animals are not available, but the potential of this substance can be anticipated by subchronic studies (*ibid.*).

There are several studies showing that under certain combustion or pyrolysis conditions, octa-BDE can form brominated dibenzofurans and brominated dibenzo-*p*-dioxins. Thus, the release of these substances from incineration of plastics containing octa-BDE and during accidental fires is of high concern from an environmental and health safety point of view. The complete destruction of octa-BDE and any possible breakdown products occurs at temperatures of 800 ºC and above for a minimum of 2 seconds (*ibid.*).

In conclusion, the estimation of the potential hazard of commercial octa-BDE is of high difficulty, since the composition varies among commercial brands. There are ecotoxicological and toxicological studies without observed effects even at unrealistically high concentrations. However, these results should be considered with care, since they might suffer design flaws. The reason for this statement is that there is scientifically proved evidence that hepta- and hexa-BDE (major components of the commercial octa-BDE) are likely to lead to significant adverse human health and environmental effects (UNEP, 2007).

5. Alternatives to currently used BFRs

Fire safety standards have become more restricting through the last decades. With the exponential growth in the use of electric and electronic equipments, and the increasing use of synthetic fabrics, large volumes of chemical flame-retardants have been added, to fulfil safety regulations. Because of the wide range of applications for those plastics and synthetic materials, BFRs end up in products that would not require their use, such as foam soles of athletic shoes, or joysticks for video games. The over-reliance on chemicals additives has led to a lack of efforts to design products that continue to meet fire standards without the addition of chemicals. Changes to product design and materials is a feasible road to decrease the use of flame-retardants. For those cases where the use of alternative material is not possible, there are already in the market safer and even more suitable alternatives to using halogenated flame-retardants (Janssen, 2005).

Some of these design improvements to avoid the use of chemicals in electronics could be the development of components that generate lower temperature, or trying to separate heat-generating components from high flammable, for instance, with metal barriers. The use of lower voltage components, or the substitution of plastics with less flammable materials such as metal, leather, glass, pre-ceramic polymers, Kevlar, or natural fibres, are other options to reduce the amount of BFRs needed worldwide (Janssen, 2005).

Regarding the available commercial alternatives, the Danish Environmental Protection Agency carried out a very detailed report published in year 2000, and already by that time, numerous alternatives were available.

Table 4. BFR alternatives

Name	CAS no.	Available Information
Triphenyl Phosphate	115-86-6	Low impact on health, but quite toxic in the environment.
Tricresyl Phosphate	1330-78-5	Low impact on health, but quite toxic in the environment.
Resorcinol bis(diphenylphosphate)	57583-54-7	Poor information, not possible to conclude the effect pattern.
Phosphonic acid (dimethyl ester)	20120-33-6	Very few data identified. Acutely toxic at 13 mg/kg bodyweight in rats and mutagenic effects reported. Lethal to fish at approximately 1 ml/l.
Aluminium Trihydroxide	21645-51-2	Limited toxic effects in mammals after exposure to high doses. Generally not toxic in the available tests, but the metal-ion Al can be acutely toxic in fish and crustaceans at <1-10 mg/l.

Name	CAS no.	Available Information
Magnesium Hydroxide	1309-42-8	Limited toxic effects in mammals after exposure to high doses. Generally not toxic in the available tests, but the metal-ion Mg can be acutely toxic in fish and crustaceans at 65 mg/l.
Ammonium Polyphosphates	68333-79-9	Information not available.
Red Phosphorus	7723-14-0	Conclusions are unclear. The yellow phosphorus is reported acutely toxic to humans (1mg/kg), but the red allotropic form is less toxic.
Zinc Borate	1332-07-6	Practically no data available. Based on comparison with sodium borate and boric acid, the possible effects in humans are irritation of skin, eyes and throat, and harm to the unborn child. In the environment, zinc-ion is very toxic to crustaceans.
Melamine	108-78-1	Seems to be only mildly toxic when ingested by animals. Cancer evidence was not shown. Melamine may be harmful to crustaceans, but the reviewed toxicity data show little aquatic toxicity. Bioaccumulation is low, and persistence exists under aerobic and anaerobic conditions.
Antimontrioxide	1309-64-4	In the EU is classified as “harmful (Xn)”, and must be labelled as risk-phrase R40. The substance is reported as teratogenic, and toxicity in crustaceans or fish is very low.
Quinidin carbonate	Not available	No data was identified for health or environmental properties. According to the toxicity of quinidine sulphate, this substance is supposed to be harmful to crustaceans, but not to fish.

Source: Miljøstyrelsen, 2000

Regarding those chemicals, for instance, a report from the German government determined that the flame retardants aluminium trihydroxide, ammonium polyphosphates and red phosphorus are less problematic in the environment than currently used BFRs (Leisewitz *et. al.*, 2001 in Janssen, 2005).

In a study carried out in the framework of searching alternatives to penta-BDE in foam manufacturing, triphenyl phosphate used as additive flame retardant, was reported to be the less harmful to humans and the environment, with low cancer hazard, skin sensitization and reproductive, developmental or neurological damage. Persistence and bioaccumulation in the environment was also low, although a high acute and chronic toxicity was suggested (US EPA, 2005).

The Chemical Review Committee of the Stockholm Convention, after its third meeting held in Geneva in November 2007, released a report with considerations on the draft risk management evaluation of penta-BDE. This document provides a list with different alternative chemicals to substitute penta-BDE as flame retardant, and some alternative materials that would reduce the need of this substance (UNEP, 2007b).

Single chemical substitution assessments have also been carried out. For instance, in year 2006 the Danish EPA assessed the feasibility of substitution of deca-BDE, and could not identify any application of this substance in electric and electronic equipments for which technically acceptable alternatives were not available in the market (Danish EPA, 2006). However, this is contradicted by the manufacturers of BFRs, which have specifically remarked the difficulties of substituting deca-BDE in various plastics, due to the lack of extensively tested alternatives that can provide good flame retardancy and good mechanical properties.

Despite this discussion between manufactures and scientific bodies, the fact is that due the raising concern about the safety for humans and the environment of BFRs, many manufacturers are voluntarily phasing out the use of these substances. Weather it is for marketing reasons or under the scope of Social Corporate Responsibility policies, producers of computers and electronics such as Apple, Ericsson. IBM, Intel, Motorola, Panasonic, Phillips and Sony are using alternatives to halogenated flame-retardants. Furniture companies like Ikea, Crate and Barrel and Eddie Bauer are requesting PBDE-free polyurethane foam from their suppliers. Companies as Great Lakes Chemical, the main producer of BFRs in United States, voluntarily agreed to end the production of penta- and octa-BDE. Furthermore, initiatives like the Voluntary Emissions Control Action Programme (VECAP), initiated by the manufacturer’s association Bromine Science and Environmental Forum (BSEF) have been born with the mission of increasing the understanding about BFRs, and emissions from BFR’s utilisation (Janssen, 2005).

6. Status of the BFRs in the Mediterranean region

In order to obtain the required information to elaborate this study, a questionnaire was developed and sent to the National Focal Points in Mediterranean countries. National Focal Points have been asked to distribute the questionnaire to competent government representatives in order to complete the different areas of information included in the questionnaire.

From the 22 countries comprised within the scope of this study, only 7 National Focal Points have submitted the questionnaire related to the status of BFRs in their country: Croatia, Cyprus, Israel, Libya, Monaco, Serbia[3] and Syria. However, the information provided by these seven countries, is very limited.

In the next sections, the available information by country according to the questionnaires will be provided.

6.1 Legal and management framework

Information about the legal and management framework of the brominated flame-retardants in the Mediterranean Region was required to the Mediterranean Action Plan Focal Points.

It is considered essential to have a good regulatory framework under which is possible to develop actual measures to deal with a proper management strategy regarding BFRs.

The information gathered is presented in the next paragraphs, and Figure 8 provides a general overview of the existence of regulatory measures related to BFRs.

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[3] The scope of the study includes Serbia despite the fact that does not belong to the Mediterranean Action Plan, due to its specific interest in participating. Besides, the CP/RAC, as designated Regional Centre under the Stockholm Convention for capacity building and technology transfer, has the obligation to promote the knowledge transfer among Parties.

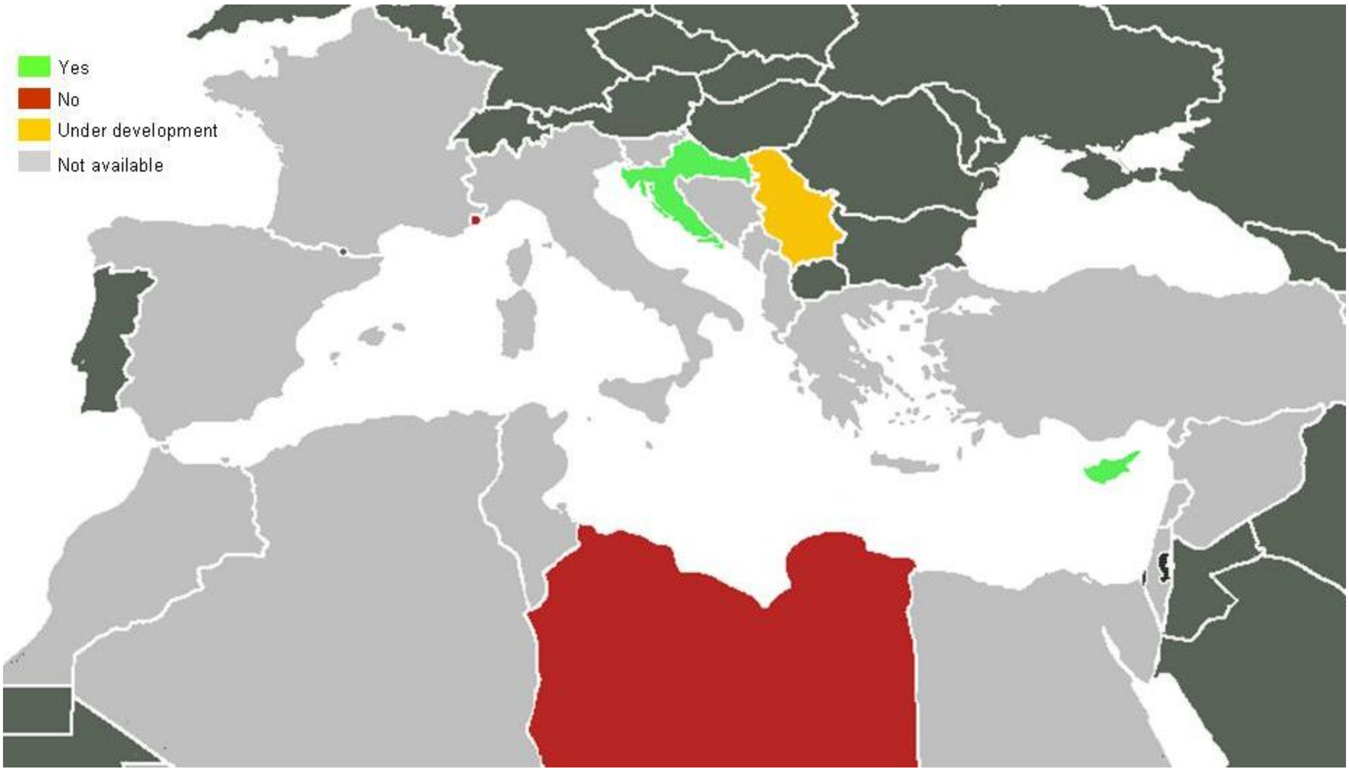

Figure 8: Legal measures on BFRs. *(Source: questionnaires from MAP Focal Points)*

6.1.1 Croatia

Croatia has taken administrative measures to restrict the use of BFRs. Specifically, the list of dangerous chemicals prohibited or restricted for use, published in the Official Gazette 17/06, states that PBBs (hexa, octa and decabromobiphenyl) may not be used in textile articles such as garments, undergarments and linen, intended to come into contact with the skin.

Regarding PBDEs, the same regulation restricts the use of penta and octa-BDE. These substances may not be placed on the market or used as a substance or as a constituent of substances or of preparations in concentrations higher than 0.1% by mass. On the other hand, it states that articles shall not be placed on the market if they, or flame-retarded parts thereof, contain these substances in concentrations higher than 0.1% by mass.

No regulation is mentioned regarding deca-BDE, TBBPA or HBCD.

6.1.2 Cyprus

Cyprus reports to have measures to restrict production, import, export and use of BFRs. HBB is legislated under Regulation 850/2004/EC on the European Parliament and of the Council on Persistent Organic Pollutants, from April 2004.

There is a specific country regulation on TDBPP[4], under the Dangerous Substances Regulations (P.I. 292/2002), related to the classification, packaging and labelling of dangerous substances and preparations. This chemical it shall not be used in textile articles, such as garments, undergarments and linen, intended to come into contact with the skin. TDBPP has not been subject of study in this report, since it is not one of the most commonly used BFRs. However, it is important to note that some countries are already taken legal measures on substances that could be possible alternatives to the ones currently used.

No information was provided on the existence of legal or administrative measures related to penta-BDE, octa-BDE, deca-BDE, TBBPA or HBCD, but since Cyprus belongs to the European Union, it can be assumed that the European Commission’s regulations apply in the country.

6.1.3 Israel

Israel did not provide information on the existence of legal or administrative measures to restrict the import, export, production and use of BFRs.

6.1.4 Libya

According to the questionnaire sent by Libya, there are no measures in the country to restrict the import, export, production and use of BFRs. The cause for this lack of regulation is the absence of an Action Plan related to Brominated Flame-retardants. For the same reason, strategies to identify and/or manage stockpiles, wastes or products containing BFRs do not exist in Libya.

6.1.5 Monaco

The Principality of Monaco reported not to have regulatory or administrative measures on the production, import, export or utilisation of BFRs, since this subject “does not apply in the country.”

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[4] Tris (2-3-dibromopropyl) phosphate

6.1.6 Serbia

Measures on the import, export, production and/or use of BFRs are not available in Serbia. However, this information was included in the questionnaire:

> *"In existing legislative there aren't' special measures to restrict the import, export, production and/or use of BFRs. New Law on Chemicals which is in Parliament and will be adopted soon prescribes basic obligations necessary for further prescription restriction related to BFRs in subsidiary legislation, as it is given in EU legislation (Annex XVII of Regulation 1907/2006/ EC - REACH). Also, new Law on waste management which is expected to be adopted soon is harmonized with Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment."*

Serbia reports not to have developed strategies to identify stockpiles, products and articles and wastes consisting of or containing BFRs. A new law on chemicals that will introduce restriction on BFRs is under development, together with a law transposing EU legislation on waste from electric and electronic equipment.

However, in order to improve the development of measures for these chemicals, they require guidance and assistance from other countries or supra-national organisations.

Regarding the existence of strategies for identifying sites contaminated by BFRs, there are not such measures in the country yet, but they will be developed together with the strategies for the identification of industrial contaminated sites and other contaminated sites.

6.1.7 Syria

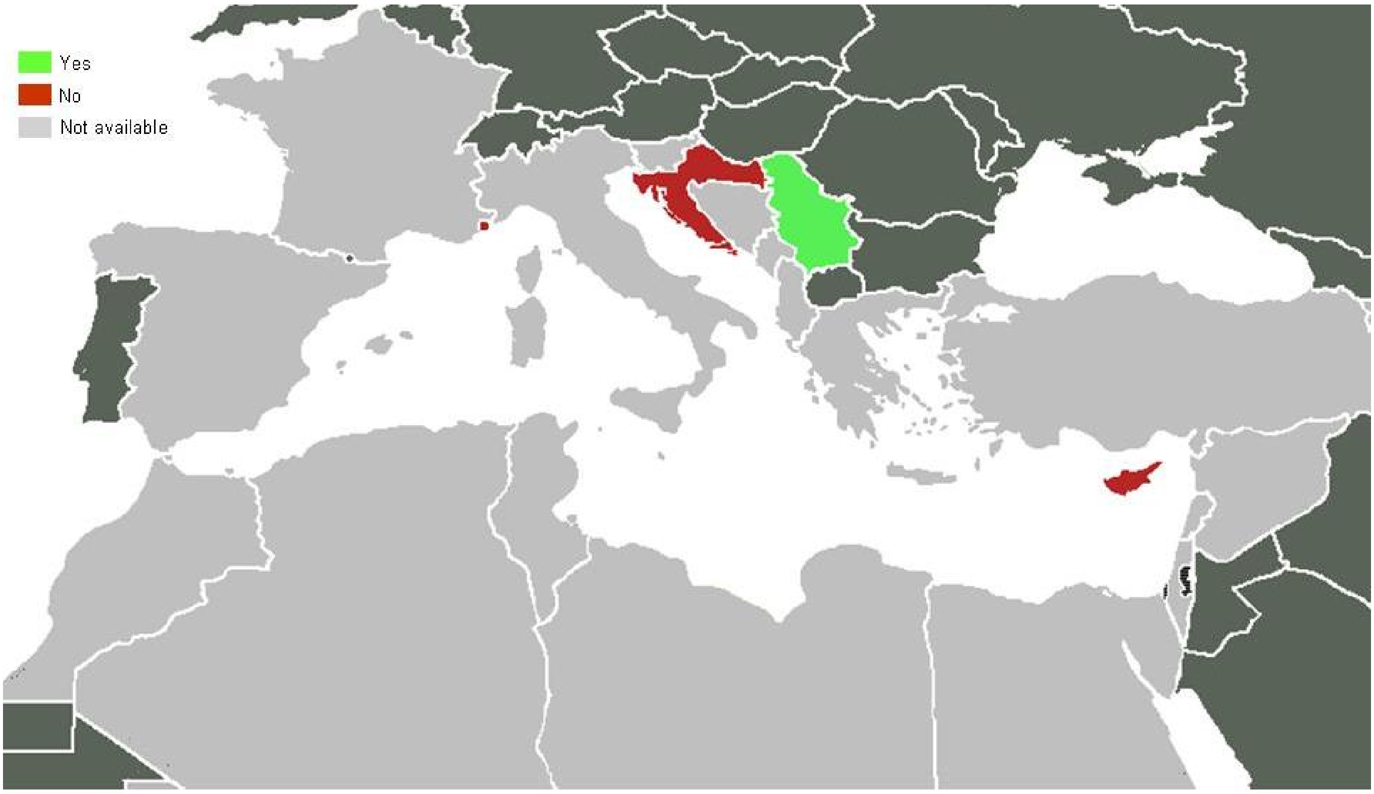
No information related the availability of legal or administrative measures to restrict the import, export, production and/or use of BFRs was provided by Syria.

6.2 Production, uses and stockpiles

In order to obtain a general knowledge about the BFRs status in the Mediterranean countries, it is essential to gather information on the production, uses and existent stockpiles in each country.

This section compiles the information gathered through the questionnaires sent to the MAP focal points, regarding the production, uses and stockpiles of brominated flame-retardants in the Mediterranean countries.

A general review on the information about production, uses and stockpiles of BFRs in the Mediterranean countries is outlined in Figure 9.



Remarks:

(1) Croatia and Cyprus have not produced BFRs, but no information was provided on import/export.

(2) Serbia has imported BFRs, but not produced or exported.

Figure 9: Production, import, export, uses and stockpiles *(Source: questionnaires from MAP Focal Points)*

6.2.1 Croatia

Croatia reports not to have produced any of the BFRs referred to in this study, but there is no data available on the import and export of these substances.

No measures to reduce or eliminate releases from stockpiles and wastes were notified, and strategies for identifying BFRs stockpiles, products, articles or waste containing BFRs do not exist. No information was provided on the existence of measures to manage product or waste stockpiles in a safe and environmentally sound manner

6.2.2 Cyprus

According to the questionnaire sent by Cyprus, no production of BFRs has occurred in the country. Information on the export and import was not provided.

6.2.3 Israel

No information was provided on the production or export of BFRs by Israel, but when asked if the country had imported these chemicals, they responded negatively, specifying that “brominated flame retardants are produced locally in sufficient quantity”.

6.2.4 Libya

Libya reported not to have information about the production, import and export of BFRs.

6.2.5 Monaco

Strategies to identify stockpiles, products, waste and contaminated sites with BFRs have not been developed in the country, since this subject does not apply in Monaco.

However, through the questionnaire, Monaco reported not to have produced, imported or exported BFRs

6.2.6 Serbia

Serbia reports not to have produced BFRs, and there is no information available on the export of such substances. Small quantities for laboratory purposes have been imported, but actual quantities are not known.

Regarding the historic and current uses of BFRs, Serbia reports not to have information on previous uses, but investigations on the area of fire fighting products showed that products placed on the market do not contain these compounds.

6.2.7 Syria

No information on the production, export or import of BFRs was provided by Syria in the questionnaire.

6.3 Related actions and main concerns

The existence of programmes or research activities related to BFRs is a good indicator of the general knowledge about these chemicals in the country.

It is also very important to know if activities on public information, awareness and education to the general population are being carried out. Despite the importance of an adequate legal framework, it is crucial to inform the people about risks and concerns of the utilisation of these chemicals.

Information on what the Mediterranean countries believe to be emerging issues or main concerns related to BFRs was also required, but very few comments have been made on this subject. A general review on the information about the existence of BFRs related programmes or research activities is outlined in Figure 10.

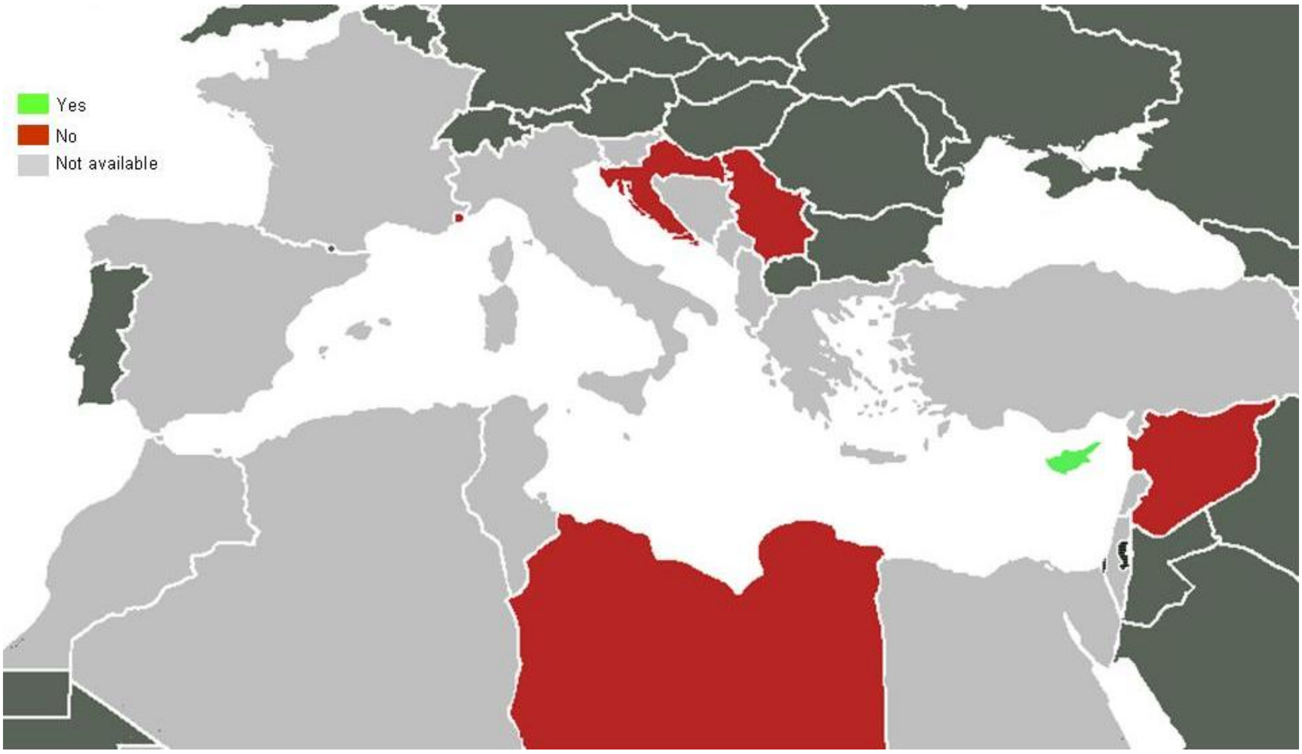


Figure 10: Programmes on research for alternatives, public information, awareness and education *(Source: questionnaires from MAP Focal Points)*

6.3.1 Croatia

Regarding possible studies carried out in the country related to human health and environmental impacts of the use of BFRs, research programmes to find alternatives to avoid the use of these chemicals or measures on public information, awareness and education, Croatia reports not to have developed any of them, since other priorities are identified, and there is a lack of financial or technical resources.

When asked about emerging issues related to BFRs, the main concern is the lack of a monitoring plan for identifying products and articles in use containing or contaminated with regulated brominated flame-retardants.

It is identified as a priority challenge to take measures on public information, awareness and education, referred to these chemicals.

6.3.2 Cyprus

Cyprus reports to have taken measures on public information, awareness and education about BFRs through the website of the Department of Labour Inspection. Information on HBB and TDBPP was published in the web, accessible to the general population.

No programmes on the effect on human and the environment, or research for alternatives to BFRs have been carried out in the country.

6.3.3 Israel

No information was provided by Israel about the studies carried out related to human health and environmental impacts of the use of BFRs, research programmes to find alternatives or public information, awareness and education.

6.3.4 Libya

Regarding the availability of programs to substitute BFRs, the country reports not to have such measures, due to the lack of an Action Plan.

Research on the subject of BFRs, such as studies, risk assessment and monitoring programmes have not been carried out in Libya, due to the lack of technical skills and lack of similar experiences.

Campaigns on public information, awareness and education of the general population have not been promoted in Libya.

6.3.5 Monaco

Since the subject of BFRs does not apply in the country, according to the questionnaire, there has been no promotion on the research BFRs' alternatives in Monaco, or in the development of studies, risk assessments or monitoring programmes on the issue.

6.3.6 Serbia

According to the questionnaire, there is no data on the substitution of brominated fire-retardants in the country, or about studies, risk assessments or monitoring programmes carried out in Serbia with the objective of identifying the effects on human health and the environment of BFRs.

Measures on public information, awareness and education about BFRs are not available in the country, and this is one of the main difficulties and barriers encountered by Serbia on this subject, together with the lack of an inventory of BFRs' stockpiles and waste stockpiles, or the lack of overall legislation related to these compounds.

Serbia considers as priority activities the adoption of a new regulatory framework harmonised with EU legislation, the development of an inventory of waste and stockpiles containing BFRs, and the implementation of measures to increase public awareness related to these compounds.

6.3.7 Syria

According to the questionnaire, Syria has not carried out measures on the research of alternatives to avoid the use of BFRs. Studies, risk assessment or monitoring programmes related to these chemicals have not been developed in the country, and neither have measures on public information, awareness and education of the general population about brominated flame-retardants.

7. Conclusions

A general overview on the legal status of the brominated flame-retardants in the Mediterranean Region reveals that European Mediterranean countries do have a proper legal framework according to international regulations on BFRs. However, according to the information gathered through the questionnaires, Mediterranean countries not belonging to the European Union seem to have much less developed strategies and knowledge about this subject or even a total lack of regulation.

Nevertheless, it must be remarked that this statement should not be taken as representative for all the non-European Mediterranean countries, since even among those who have submitted the questionnaire, the information is not always as complete as needed to make an accurate evaluation of the situation.

Among those Mediterranean countries not belonging to the EU-27, the general perception is that the European regulations are taken as a reference to develop the national laws, based mainly in the RoHS and WEEE Directives.

In addition to the information obtained through the questionnaires, a bibliographic research has been carried out during this report, in order to establish a general overview of the BFRs topic in the Mediterranean. The information found was scattered and incomplete, and it mainly referred to toxicological studies carried out in some of the Mediterranean countries, or to general regulations at the European level. For those non-European countries, little information was available. This fact, together with the low success of responses obtained on the particular subject of BFRs through the questionnaires, leads to believe that the general knowledge of this topic in most of the Mediterranean countries is limited.

Regarding the impact of BFRs on the environment and in human health, although toxicological and ecotoxicological studies have been carried out over the years, the assessment tackled through this report reveals the need of further information, mainly for those BFRs that have been used recently, as a replacement of the first substances used in the 1970's. The development of further studies should be promoted, focussing in the long term effects of the utilisation of BFRs in commonly used products by the general population, in order to asses the possible environmental and safety risks associated to their use.

The inclusion of BFRs in the international agreements regarding chemical management is essential. Due to the chemical properties of these substances (which favours their distribution around the World), and the globalized market prevailing at present, where products are manufactured and shipped thousands of kilometres away for the final user, local actions would not be sufficient to tackle the subject of BFRs. Progresses have been lately made on this direction with the amendment of the Stockholm Convention's annexes to include some BFRs during 2009, but further work should be done to ensure the environmental and human health safety of those chemicals still being used as fire retardants.

Alternatives to brominated flame-retardants have been available in the market for many years, and some manufacturers have already taken measures to reduce the use of halogenated compounds. Although up to date data about global demand of BFRs has not been found, the existent trend shows an increase in the use of these chemicals.

8. Proposals

The study reveals the need for further ecological and toxicological studies on the existent brominated flame-retardants, especially for those BFRs that have been used for shorter time. Political measures should be developed to address this issue, oriented to regulate a proper management of these chemicals, and to promote research programmes regarding the possible impacts of the current tendencies in the use of BFRs.

Some of the Mediterranean countries have reported to lack the technical capability or financial resources to invest in research programmes on the subject of BFRs, or to promote the awareness raising among the general population. According to this, there seems to be a need for capacity building and technology transfer activities to increase the perception of the importance of this subject in developing countries, with the support of those countries or regions where the issue has been managed for a longer time.

Those countries with the technical and financial capability to do it, should gather all possible information available on the uses, commerce and waste of BFRs, in order to establish future strategies on the subject.

In this context, knowledge transfer among countries is essential, and with the different Secretariats of the relevant Multilateral Environmental Agreements (MEAs), to share information about alternative to BFRs, studies or R&D projects that are being carried out.

The existence of mechanisms for communication with chemical-related MEAs should be promoted, ensuring the preparation and sending of proposals to include BFRs in the international regulation of chemicals.

Campaigns to promote the knowledge on the subject of BFRs should be made among the general population, both in developed and developing countries. The consumer, that is, the final users of the products containing BFRs, should have the capacity to choose among the available products in the market, and decide whether they want to avoid those with potentially dangerous chemicals. Such actions can induce changes on the market demand and could be a powerful tool to reduce the amount of BFRs placed in the environment. Changes in the demand can lead manufactures to invest in the development of products that does not need added chemical flame-retardants, or to look for safer alternatives.

In line with the previous paragraph, measures to promote the substitution of BFRs should be developed, since even the available alternatives seem to be harmful to the environment or to human health to some extent. The optimal solution would be achieved through changes in the design of the products to reduce the need of added chemicals for meeting fire safety standards.

Toxicological and ecotoxicological information is available on BFRs commonly used, but is limited in those that are replacing them through the voluntary measures implemented by some manufacturing companies. A very close tracking should be made about these substitutions, to try to avoid future issues with these chemicals that are starting to be used at present.

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