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Formulation of proposals for measures to be taken to substitute environmentally relevant flame retardants in printed circuit boards, outer casings for IT and TV appliances and polyurethane insulation and one-component foams

Workshop reports

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Contents

Preface

This report gives an overview of three workshops which were held in May and June 2001 in Berlin following the submission of the Umweltbundesamt (Federal Environmental Agency) study "Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals“ (Umweltbundesamt Texte [Federal Environmental Agency publications] 25/01 – 27/01; Vol. I in English: Umweltbundesamt Texte 40/01). The objective of the workshops was to formulate and propose measures for substituting and decreasing environmentally relevant flame retardants. The debate is documented in its essential aspects, summarized and, in view of some new aspects, revised.

The measures proposed by the Federal Environmental Agency regarding printed circuit boards, outer casings of IT and TV appliances and polyurethane insulation and one component foams as revised following the workshop discussions are contained in the annex.

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1. Workshops on selected application areas of environmentally relevant flame retardants – general overview

The Federal Environmental Agency arranged, in May and June 2001, three workshops about "Measures proposed to substitute environmentally relevant flame retardants" regarding printed circuit boards, IT and TV exterior casings and also polyurethane insulation and one component foams.

Basis for the discussion were the study "Development of evaluation criteria to substitute environmentally relevant flame retardants" (Federal Environmetal Agency publications 25/01 – 27/01)[1] and the proposals for measures to be taken as formulated by that agency. Up for discussion were the state and trend of flame retardant equipment as well as possibilities of substituting and reducing flame retardants in the already mentioned areas of application and, finally, the measures to be adopted towards this end.

Purpose of the workshops was to take stock of and to evaluate the application of flame retardants and the applied flame retardants including substitutes recommended by the study and to debate the recommended measures developed by the Federal Environmental Agency with experts taken from the entire producer to user chain and to ear mark actual trends.

Reasons for selection/necessity for substitutes: Circuit boards, outer casings as well as PUR insulation and one component foams were selected from the various areas of application because the Federal Environmental Agency deems the substitution and reduced application of environmentally relevant flame retardants to be desirable in these areas. A discussion of the other fields of application examined in the study – vehicles on rails: Interior fittings and exterior parts of unsaturated polyester resins; textile applications: Upholstery composites for upholstered furniture and mattresses – was considered unnecessary. At present there is no need for action in these areas.

In *duroplastics for rail vehicles*[2] the haloginated flame retardants have been largely replaced in the 90's by the newly developed thermo stabile ATH.

In *upholstery composites and mattresses*[3] in the Federal Republic flame retardant equipment plays only a marginal part (institutional sector) and at present it does not

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[1] UBA FB 000171/1: "Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals". Vol. I: Results and summary overview. Authors A. Leisewitz, H. Kruse, E. Schramm, Umweltbundesamt Texte [Federal Environmental Agency publications] 25/01, Berlin 2001 (in German; in English: Umweltbundesamt Texte 40/01);
UBA FB 000171/2: "Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals". Vol. II: Flame-retardant finishings of selected products – applications-focused analysis: State of the art, trends, alternatives. Authors A. Leisewitz, W. Schwarz, Umweltbundesamt Texte [Federal Environmental Agency publications] 26/01, Berlin 2001 (in German);
UBA FB 000171/3: "Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals". Vol. III: Toxicological and ecotoxicological substance profiles of selected flame retardants. Authors H. Kruse, O. Paulsen, C. Schau, M. Wieben, U. Böhde, Umweltbundesamt Texte [Federal Environmental Agency publications] 27/01, Berlin 2001 (in German).
The study will henceforth be cited by volume number and page number; references are given to the German version of volumes I-III.

[2] See vol. I, pages 139-149 (summary interior fittings and exterior parts for rail vehicles);
vol. II, pages 1-35 (application related review) as well as the appertaining flame protecting agents' evaluation and substance profiles in vol. I and III.

seem that the suggestions repeatedly aired in individual member states of the European Community for fitting out upholstery furniture for private use would be put into practice. But, should this indeed take place, then this field will have to be reconsidered because environmentally relevant flame retardants would then be used on a larger scale which would be very problematic environmentally and for health reasons.

With *circuit boards*[4] and with *exterior casings for electrical and electronic appliances*[5] it is the halogenated (brominated) flame protection which calls for alternatives, both under the aspect of toxicity/ecotoxicity of the flame retardants in use and their decomposition products (particularly TBBA), and of the disposal of the second hand products. Because these are components of electrical and electronic appliances the discussion of substitutes has to consider the two draft directives of the European Parliament on electrical and electronic appliances (WEEE), and about limiting the usage of certain dangerous substances in electrical and electronic appliances (ROHS) adopted at the EU council meeting on June 7th, 2001.[6]

With *polyurethane insulation and one-component foams*[7] the halogenated flame protection (brominated-chlorinated polyols; TCPP) is to be viewed critically and preferably substituted because of the disposal and the traces of TCPP found in the environment.

Main points of discussion: The discussion of each of the areas of usage was orientated towards the problem complexes of "Trend of equipping with flame retardants", "Evaluation of the potential of alternatives", "Possibilities and prerequisites for a more far-reaching substitution and stronger decrease of flame retardants" as well as "Measures proposed". The recordings of the results were passed on to the workshop participants.

Division of the report into sections: The following summary of the workshop discussions in the sequence "Printed circuit boards", "Exterior casings", "PUR rigid foams" (sections 2-4) is arranged according to points emphasised in the workshops and gives the most important discussion results. In contrast to the result recordings, the names of those who participated in the discussions are not given wherever the contributions were consenting and not controversial. The sections are subdivided into the chapters

- State and trend of the flame-retardant finishings;

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[3] See vol. I pages 184-190 (Summary textile applications – cover fabrics for upholstered furniture and mattresses) and vol. II pages 281-317 (application related review) as well as the appertaining flame protecting agents' evaluation and substance profiles in vol. I and III.

[4] See vol. I, pages 164-173 (Summary duroplastic printed circuit boards); vol. II, pages 139-212 (application related review) as well as the appertaining flame protecting agents' evaluation and substance profiles in vol. I and III.

[5] See vol. I, pages 174-183 (Summary thermoplastic outer casings for IT and TV appliances); vol. II, pages 213-279 (application related review) as well as the appertaining flame protecting agents' evaluation and substance profiles in vol. I and III.

[6] Press statement 2355. Conference of the Environmental Council on June 7th, 2001. Both draft directives are subject to a second deliberation by the European Parliament (as per September 2001).

[7] See vol. I, pages 150-161 (Summary PUR insulation and one component foams); vol. II, pages 37-116 (application related review) as well as the appertaining flame protecting agents' evaluation and substance profiles in vol. I and III.

- individual questions in respect of the trend development and of the discussion of substitution with different accentuation in the various workshops;
- discussion of the measures proposed and of the material estimations they are based on; some of the latter were controversial;
- conclusions drawn in respect of the measures proposed based on the discussion results.

The *closing chapter*, in a summary fashion, deals with the question of which factors enhance or hinder the substitution and decreased use of environmentally relevant flame retardants.

The *annex* documents a number of appendixes: Two written statements handed in later about the estimation of PBDE, TBBA and TCPP (EBFRIP 2001 and Elastogran 2001), comments about these statements by the revisers of the study and by a producer of flame retardants (Kruse 2001, Leisewitz 2001 a and b; Schill + Seilacher 2001) and, finally, the proposed measures as revised by the Federal Environmental Agency after the workshop discussions.

2. Workshop Printed circuit boards

Reports and discussions at the centre of the workshops dealt with

- the state of development and introduction of halogen-free flame protected printed circuit boards (base material and complete circuit boards, unassembled) and discussion of the "general conditions";

- questions pertaining to usage, state of knowledge and evaluation of flame protecting substances in printed circuit boards and demands made on "halogen-free electronics" as well as recycling;

- the problem of "adapted" or excessive flame protectionand the influence it has on halogen substitution;

- problems connected with measures proposed by the Federal Environmental Agency including questions related to substance evaluation.

2.1 State of development and introduction of halogen-free flame retarded duroplastic circuit boards

Trend: The development of halogen-free laminates and prepregs for circuit boards flame resistant by means of phosphorous and nitrogen compounds has been carried out in Germany for just over 10 years. The materials have become cheaper. The base material developed in Germany and Europe is on par quality-wise with the competing products of Japanese and other Asian producers. The Asian producers, however, pursue a more aggressive marketing strategy with "green electronics". The resins they have developed are primarily used for their own products and are not generally available on the international market.

Alternatives on the basis of halogen-free flame resistance are being developed for all types of circuit boards (including multilayer ones). They are not yet, however, available for all areas of application. Standard FR4 material (epoxy resin glass fabric, approx. 90% of demand; this material alone was discussed in detail) can be supplied halogen-free flame resistant if of a lower glass transition temperature (Tg value) of 135 – 150, whilst according to experts this is not yet possible for higher Tg material (170 – 190). The demands made on the material show a strong trend towards a higher Tg. In the EU the material with Tg 150/160 has a 40% share; in the US only Tg 170 is in demand and this will likely set the trend.

Development examples: Reports were made about a recently completed introductory project of a halogen-free flame protected FR4 circuit board with a low halogen solder resist for the telecommunications sector/landline telephone (a joint project of the base material producer Nelco-Dielektra/Cologne and the printed circuit board producer Vogt-electronic Fuba GmbH/Gittelde as suppliers of the Siemens group; see Krüger/Bach 2001; PARK nelco 2001). The development began in May 1999 and ended with the internal Vogt-Fuba release in December 2000. The circuit board producer had demanded compatibility of the new material with the installed production lines in order to avoid refitting costs. The overall material costs were not to be any higher. Here the flame protection stems from the reactive insertion of a phosphorous compound into an epoxy resin hardened with dicyandiamide in the usual concentration (Hellmig 2001).

Enhancing and hindering factors: From the viewpoint of base material producers to-day it is not so much technical considerations or constraints but marketing considerations propelling the development of halogen-free printed circuit boards. In their opinion bringing forward the time limits in the WEEE and ROHS[8] should accelerate the introduction process. On the other hand, at present, there is not yet a relevant market for halogen-free flame protected printed circuit boards. An acceptance problem, having to do with technical aspects, doubts as to the long term reliability of the new material and costs, is considered the hampering factor.

Technical aspects: Development work is still necessary for high Tg standard material. Comparative studies on halogenated and halogen-free flame retardant laminates carried out by BSEF/APME[9] showed that the properties of both materials are very similar. A weakness in halogen-free flame retardant materials could be water absorption (see vol. II, pages 177, 179) which requires additional drying during processing, influences the storage stability of prepregs and complicates passing the "pressure cooker test" (10 sec at 288 °C). Here practical application experience is still required over longer periods. As a comparison: The halogenated standard material, which the alternatives have to compete with, has been through a thirty year optimizing process. In detail, there are also technical problems in the processibility of the alternative material (e.g. drilling, solder bath sensitivity). However, the practice examples reported in the workshop demonstrate that these problems can be overcome. Sony, for example, at present uses three new halogen-free laminates, amongst others in cam-coders and notebooks which, in comparison with the traditional standard material, have a slightly higher water content Sony intends to change over completely to halogen-free material by March 2006. (According to a company statement the postponement of this time limit announced for 2003 is due to problems on the suppliers' level.) Numerous products already meet this standard. On the whole, it is expected that the wider application of halogen-free material and long-term experience will lead to better products of a quality higher than that of to-day's standard material with halogenated flame protection.

Cost factor: The cost factor is likely to be the most important drag-shoe in introducing halogen-free laminates. Higher costs arise in the production of flame retardants because the phosphorus chemistry is dearer in comparison to the bromine chemistry, also in the processing due to additional drying because of water absorption and because of changes necessary in the processing process (f. i. in the drilling of the circuit boards). Sony's halogen-free laminates are 20 – 30 % more expensive. With the greater series production and increasing experience, economy of scale is expected or has been reported – similar to when halogen-free cables were introduced. The phosphorous-ATH flame protected laminate for printed circuit

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[8] The European Parliament had proposed advancing the time limit from 2008 to 2006; at the council meeting on 7th June, 2001 this time limit was changed to 2007. See European Council, press statement 2355. Conference of the Environmental Council on 7th June, 2001. The council also decided that, in consideration of the principle of precaution, the list of prohibited substances of the ROHS is to be reviewed two years after entry into force in the light of new scientific discoveries (the proposal of the European Parliament contained a fixed date: Review on or before the 31st December, 2003).

[9] BSEF: Bromine Science and Environmental Forum, Brussels (joint venture of the bromine industry); APME: Association of Plastic Manufacturers in Europe, Brussels.

boards, which were installed in the London Underground is, according to the manufacturer, in aggregate no more expensive than standard FR4 on the basis of TBBA (see vol. II, page 179, statements by Toshiba and Martinswerke).

2.2 Flame retardants utilized, halogen substitution, recycling – specific questions

Definition of "halogen-free": From the end-user's (electronic industry) viewpoint "green electronics" means the development of completely halogen-free appliances. It is therefore considered inadequate just to take into account single components, in this case laminate or the printed circuit boards. The Siemens AG proposes, as definition for "halogen-free" for printed circuit boards and solder resist, a maximum halogen content of < 0,18 weight percent.[10]

Level of information about toxicology/ecotoxicology of substitutes: The actual level of knowledge or information about the TBBA alternatives differs widely amongst the individual products and manufacturers. It was basically confirmed that with standard FR4 material, at present, a combination of reactive phosphorus and nitrogen (the latter to be introduced through the hardener) must be applied in order to obtain UL94-V0 classification. This is because phosphorus alone is hardly able to achieve all FR4 parameters. Besides, thermally stabilized ATH can serve as flame retardant component in combination with phosphorus (as in the London Underground).

During the workshop it was critizised that (often) no listing e.g. according to TOSCA (US Toxic Substances Control Act of 1976) is available with the base materials used by Asian manufacturers. Materials developed in Europe or Germany (f. i. "Struktol" of Schill + Seilacher) are listed, but here too one has to state that the level of knowledge or information of the TBBA alternatives is lower in comparison to that of the relatively well analysed (and at present undergoing the risk assessment as per 793/93/EG) TBBA. This constitutes a problem often arising in substitution processes where such knowledge deficits must be eliminated as thoroughly as possible. But the extent of the toxicological/ecotoxicological research should also be proportionate to the assumed risk potential of the substance analysed (see section 2.4).

Electronic scrap and flame retardants: With regard to PBDE discoveries in (disassembled) circuit boards (see vol. II, pages 173 f.) it was found that the FR4 material dominant in quantity was hitherto always equipped with TBBA and that PBDE was not used in paper laminates either. It was, therefore, maintained that such discoveries must be impurities which do not stem from the laminate but possibly from the component parts.

Questions connected with recycling: The workshop discussion did not produce any basically new facts about the disposal schemes and substance flow data assembled in the study (see vol. II, pages 196 – 202: Wet chemical reconditioning; metal recovery in copper smelting works; material utilization of granulates; incineration/depositing). It was pointed out that secondary copper smelters cannot process printed circuit board scrap because of insufficient flue gas purification (dioxin/furan emissions). A complete separation of halogen flame retardant and non-halogenated printed circuit boards is unlikely to be possible in the future.

[10] Siemens give the actual halogen content as being > 8 weight percent bromine and 0,2 weight percent chlorine in laminate and prepregs and approx. 4 weight percent chlorine and bromine in solder stop lacquer (Zeininger 2001).

Design alternatives: Besides material substitution, material or design alternatives to the existing duroplastic printed circuit board are being developed which allow for dispensing with environmentally relevant flame retardants and recycling (material reuse) (see vol. II, pages 192 – 195). This line of substitution was not discussed further by the workshop, but it's importance was highlighted. The continuation of the development work up until now carried out within the frame work of the BMBF project "green TV set" and currently concentrating on the development of halogen-free printed circuit boards made of foamed thermoplastics (see Öko-Institut 2001) is worth mentioning here.

2.3 Adjusted flame protection

Current situation: World wide printed circuit boards are almost entirely equipped with a flame retardance in line with UL94-V0 (Underwriter's Laboratories) (for details see vol. II, pages 157/158 with a commentary of the combustion classes V0 and V1). For a long time it has been pointed out that in wide fields this is technically unjustified and represents an exaggerated flame protection. The NEMA (National Electronics Manufacturers Association, USA) norm, which is the standard on the world market, demands for FR4 at least V1, not V0. In the workshop it was affirmed that the insistence on V0 is technically unnecessary for a large part of printed circuit boards, e. g. those for portable electronic appliances. But this recognition is opposed by so-called market requirements and safety demands by clients.

Halogen substitution and V0/V1 standard: If the insistence on V0 were given up in favour e.g. of V1, the necessary content of flame retarding agents would diminish both in halogenated and halogen-free flame protection. This would facilitate halogen substitution inasmuch as the technical parameters required of the printed circuit boards can more easily be warranted in the case of a lesser addition of reactive phosphorus than in the case of FR4-V0 material. Also, higher glass transition temperatures, which are becoming more important on the market, could be attained more easily if the phosphorus content were lower. Taking everything into account the material costs would also be lower.

Obstructing elements: However, as the discussion has shown, the decision for V0 or V1 is not so much technically, but primarily market determined. At Siemens, with a predominantly industrial clientele, the requirements of the US market (V0 compulsory; practice of claiming for damages by fire) as well as the discussion forced by, among others, the "US fire marshals"[11] of external fire sources of electronic products exert a strong influence. It was reported that, despite the readiness of important car manufacturers such as BMW, the change-over from V0 to V1 contemplated by a working committee of the German motorcar industry was foiled by arguing that the US market wouldn't accept it. With other motorcar components (e.g. car seats) regionally specific equipment with different flame retardants is quite common.

Contradictory trends: The barriers named against changing from V0 to V1 where V0 is not necessary were: The dominance of the certifying Underwriter's Laboratories and of the US market, psychological factors (the sales promoting argument of

[11] See vol. II, page 222.

"greater safety"), logistical problems in case of dual stock piling of both V0 and V1 material coupled with the great number of printed circuit board specifications, the fact that buyers have hitherto been "spoiled" with V0 ("additional safety") at low cost.

This absurd situation calls for a solution at EU level. The Federal Environmental Agency will strive for this. Environmental associations (in this case: BUND) go further by demanding that the issue not be limited to the alternative V0-V1, but to take into consideration even lower classifications (V2), depending on the technical requirements. One should also consider that V0 touches on only one aspect (self-extinguishing) and that more attention should be paid to the all-inclusive safety aspect encompassing other secondary phenomena of fires (such as flue gas density and flue gas toxicity).

The motorcar industry should be generally interested in halogen-free products because of the scrapping of old cars and does, indeed, stress this interest. In spite of this discussion, participants rather saw a current move back to halogenated flame retardants. The disposal of old motorcars could then prove to be a "technical propelling force" for changing over to halogen-free printed circuit boards and V1 when a halogen-free design of all motorcar components is possible ("complete solution"). The change intended in the long term of motorcar mains from 12 to 42 volt (see Schlott 2001) does not present a problem (Isola AG 2001).

2.4 Measures proposed by the Federal Environmental Agency

Proposal summary: The action plans proposed by the Federal Environmental Agency for printed circuit boards called, in the draft, for prohibiting PBDE and PBB because of occasionally still occurring discoveries in scrap products (see in this context the discussion under 2.2). The study recommends the substitution of TBBA (reactive) and considers an accelerated development of alternatives (halogen-free flame retardant printed circuit boards) as necessary (installation of a working committee of the manufacturing industry to this end; review of the allocation guide lines of the "Blue Angel"; improved information in technical instruction leaflets). In addition, it proposes giving up universal V0 listing in favour of a flame retarding equipment tuned to the technical requirements (UL94-V1 instead of V0). At the same time the proposals call for more extensive research into the substitutes and disclosure of their properties.

Main points of discussion: In the controversial discussion of these proposals the focus was on the following aspects:

- Evaluation of the substances employed and of their substitutes;
- relationship between national and international regulations;
- working committee for the promotion of halogen substitutes;
- possibilities for and limits of labelling;
- adapted flame protection.

Evaluation of substances employed and of substitutes: As regards PBDE, the producers of brominated flame retardants pointed out that Penta is expected to be forbidden as from 2003 (as a consequence of the EU scrap material directive[12]), whilst Deca is not classified toxic/ecotoxic in the current risk assessment (1st priority list of 25th May, 1994). They said that production of PBB has stopped. Therefore, the assumptions named by the Federal Environmental Agency as justification for banning measures do not apply in the case of Deca and PBB. The representatives of the Federal Environmental Agency recommended waiting for the risk assessment. It was also pointed out that, according to the ROHS draft directive, PBDE and PBB are to be substituted in electronic and electrical appliances as of the 1st of January, 2007.[13]

As to TBBA (now also in the risk assessment, 4th priority list of 25th October, 2000), it was maintained in the workshop that the test value last submitted for water solubility of TBBA is clearly lower than the one taken as a basis for the assessment of the Federal Environmental Agency study (see vol. I, pages 83-87) and for the justification of the measures proposed. It was argued that, as the NOAEL values are way above this water solubility value of TBBA, the indications given about the toxicity must also be re-evaluated. For this reason the producers assume that TBBA need not be classified environmentally dangerous (N) and "very poisonous for water organisms". From their point of view essential prerequisites for recommendations to substitute thus fall by the wayside. Furthermore, in the written statement by EBFRIP the occurrence of TBBA in mother's milk is doubted. (see EBFRIP 2001, appendix 1 to this report)

Critical examination of the objections[14]: The EBFRIP suggestion cannot be followed to classify DecaBDE, which was more thoroughly tested in the frame work of the study, and TBBA as toxicologically harmless. Regarding Deca, the well founded indications of carcinogenicity are relevant to toxicological assessment (vol. I, page 81; vol. III, pages 18-20) and do not permit classifying Deca as "non-toxic". As regards TBBA water solubility it is, in view of the wide spread of the available water solubility research data (see vol. III, page 49, IUCLID data 1995 and BSEF 2000), illegitimate under aspects of precaution to rely on the lowest value by far. For an evaluation under aspects of precaution, the worst case value of the IUCLID set of data must be taken. (To date the IUCLID data are the basis also for the TBBA classification.) Also, upon enquiry, information was given at the workshop on printed circuit boards that until now no reclassification of TBBA has taken place. The importance of the discovery of TBBA in mother's milk must definitely be stressed despite the fact that the discovery is still under reserve (see vol. III, page 62), especially as TBBA traces were also found in fish (see Kruse 2001 and Leisewitz 2001a, appendixes III – V of this report.)

Comparability substitutes/TBBA: The producers of brominated flame retardants and brominated flame retardant resins also raised the question whether the substitutes are more compatible under toxicological/ecotoxicological aspects than reactive TBBA. They maintained that the alternatives need to have been tested as thoroughly as the substances to be substituted before decisions can be made.

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12 Meanwhile both the risk assessment of PentaBDE (2nd priority list of 27th September, 2005) (see EUJRC 2001) and a proposal by the EU Commission to ban Penta as of July 1st, 2003 (EU document 501PC0012 of 21st May, 2001) have come to hand.

13 Changed by the European Council in it's meeting on 7th June, 2001 from 2006 to 2007; see FN 8.

14 As Dr. Kruse, the responsible specialist, due to illness could not take part in the workshop, this point was not discussed in detail, but dealt with in written statements (Kruse 2001; Leisewitz 2001a).

From the Federal Environmental Agency's point of view it is important that the comparison of substitutes with substances to be substituted produces certainty in the assessment of their ecological relevance. For this reason a "comparable level of knowledge" should be aspired to. Therefore, the Federal Environmental Agency considers it necessary that further research into the substitution products, both as regards the pure substances and the flame retardant products, is conducted and that the companies participating in the product chain lay open the relevant data (measures proposed, sub-paragraph B2). But this cannot mean that substitutes showing no indication of relevant risks must be subjected to tests which without any reason encumber or hinder their development. (For instance, expensive carcinogenicity tests are necessary when, and only when, pertinent suspicious indications exist.) Schill + Seilacher in a statement (Annex VI) point out that a number of risk assessments can only be made on the basis of experiences gained from application but not yet available for substitutes.

The announcement by one flame retardant and resin manufacturer (Schill + Seilacher) that more extensive substance tests are carried out with their substitution products, inclusive of a carcinogenicity study, is to be welcomed.

Relationship between national and international regulations: Impending EU regulations (risk assessments for PBDE and TBBA) were put forward as an argument against the effectiveness of national regulations such as those proposed by the Federal Environmental Agency. It was also argued that imports containing problematic substances in practice cannot be suppressed, not even with an EU regulation. In answer to this the Federal Ministry of the Environment pointed out that control problems cannot be used as an argument against necessary legislation; the Ministry continued that, should an EU regulation came into effect, the home industry is called upon to inform about problematic imports. In addition, it was stressed that despite EU regulative competence there is also room for action at the national level.[15] This applies also to the demand for more extensive tests with problematic end of life products. Substance tests at EU level are conducted within narrow formalized tracks (EC "end of life products" directive 793/93/EC, OECD tests) and may lead to legally binding regulations. But the dynamic animation of substance evaluation, necessary under aspects of a precautionary environmental protection, requires more extensive material tests and evaluations on the national level (such as those done within the framework of this study) without limitation to the politically binding criteria fixed at the EU level (see vol. I, pages 90 f.).

Working committee for advancing halogen substitutes: This kind of working committee, if considered useful, should encompass the entire chain of manufacturers. ZVEI represents the printed circuit board manufacturers and the base material producers but not the raw material (resin) producers at the chain's front end. Also, the objection was raised that this is only a national body, in contrast to which a

[15] The limitations, which substance regulations at the national level are subjected to by the increasingly powerful EU communal law, was a problem reoccurringly tabled in the debate of measures proposed at all workshops. As a rule the industry representatives, by pointing to impending regulation at the European level and the freedom of trade, saw hardly any possibility for independent action in Germany; the public administration sees wider room for action. Here a concrete weighing of pro and contra is necessary in each individual case. Amongst other considerations it is important which article of the EC treaty the regulations in question are founded on. With directives based on article 95 of the EC treaty (internal market – assimilation of standards) there is hardly any possibility for more ambitious national legislation; this is different with directives such as the WEEE based on article 157.1 of the EC treaty (protection of the environment, minimal standards) (see section 5.4).

supranational co-operation, aiming for the inclusion of the international manufacturers and sub-contractors of electrical and electronic appliances and for a common standard at the international level, was considered more useful. In view of globalisation this was thought to be the more promising approach. Agreements would at least have to cover the European level.

Possibilities for and limits of labelling: Regarding sub-paragraph B3 of the measures proposed by the Federal Environmental Agency (review of the award guidelines for the "Blue Angel") the laminate manufacturers pleaded for awarding the "Blue Angel" also to products with halogenated flame protection whenever this protection is unobjectionable under environmental aspects. BUND demanded the labelling of halogen-free printed circuit boards in order to facilitate the separation of halogen-free from halogen containing electronic scrap in the disposal. The labelling in practice to-day on safety data leaflets and on the circuit board itself (UL labelling) was pointed out. But it's transparency for end-users and those engaged in disposal is questionable.

Adapted flame protection: The non-technical general conditions militate against an easing of the V0 standard in favour of, for instance, V1 where this is objectively called for. It was concluded, therefore, to check whether measures exceeding mere recommendations are possible.

2.5 Conclusion: Revised proposals for measures to be taken regarding printed circuit boards

Taking into account the workshop discussion, the revised proposals of the Federal Environmental Agency for measures to be adopted regarding printed circuit boards (see annex VII to this report) contain the following points:

A) Legislative regulations

A1: With printed circuit boards there is no need to use PBDE and PBB. In view of reported occasional discoveries of PBDE in printed circuit boards, the Federal Environmental Agency considers it necessary to forbid PBDE and PBB because of the critical environmental properties of these substances (persistence, toxicity, ecotoxicity). The proposal to ban PBDE and PBB contained in the ROHS (Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the restriction of the use of certain hazardous substances in electrical and electronic equipment) is being supported.

A2: The Federal Environmental Agency, on the basis of what is presently known about the substitution problems with printed circuit boards, does not, at this point in time, consider legislative regulations exceeding A1 (banning of substances) advisable, but supports measures to reduce the deficit in knowledge and more far-reaching recommendations based on article 6 of the ROHS emanating from wider knowledge (for example, the environmental committee of the EU Parliament in the above draft directive proposes a renewed review of the necessity for substitution in respect of other halogenated flame protecting agents for the year 2003 (§ 6).)

B) Further measures proposed

B1: The Federal Environmental Agency recommends the inauguration of a working committee, for instance within ZVEI or within another suitable body of the industrial branch in question, for the development and introduction of halogen-free flame protected circuit boards. This committee is to include every-one participating in the product chain and especially the raw material producers.

B2: With regard to halogen-free flame protected circuit boards, the Federal Environmental Agency believes more thorough research into the substitution products (toxicological/ecotoxicological properties of the pure substances and flame protected products) and disclosure of data by the enterprises engaged in the product chain to be necessary.

B3: The Federal Environmental Agency undertakes to review the allocation guidelines for the "Blue Angel" with a view to printed circuit board flame protection optimised under environmental (disposal) and health aspects. In this undertaking halogen-free solutions are to be given special consideration.

B4: Where-ever it is not yet the case, the Federal Environmental Agency recommends a generally understandable presentation of the flame retardants in the technical instruction leaflets. For easier, practical distinction of flame retardant equipment, for example when disposing of it, a suitable colour labelling of halogen-free printed circuit boards should be introduced ("blue circuit boards").

B5: It is recommended to equip appliances operated at low currant and where the printed circuit boards are subject only to low thermal charges, with an adjusted halogen-free flame retardant (UL94-V1 instead of V0).

B6: It is in the disposal of printed circuit boards where the danger of setting free hazardous substances lies. Even the forming of dioxin and furan is potentially possible as, under certain temperatures and the catalytic effect of the copper, the bromide compounds in the material can form dioxin or furan.

The Federal Environmental Agency suggests testing the mass fluxes and emissions containing hazardous substances in the main recycling procedures for printed circuit boards.

3. Workshop Exterior casings for IT and TV appliances

In this workshop the following questions were in the centre of the discussion:

- Technical trends presently and in future of importance for equipping casing materials with flame protecting agents and for guaranteeing fire safety;
- general conditions such as fire safety discussion, marketing, labelling, costs;
- disposal and recycling;
- problems in connection with measures proposed by the Federal Environmental Agency including questions concerning substance evaluation.

3.1 Trend setting factors in flame protection for exterior casings: Technical development

Dependence on synthetic material: As known, the application of flame retardants depends on synthetic materials (see vol. II, pages 223-237). Exterior casings are produced of plastics on the basis of polyolefin. In contrast to small parts, mineral-based flame retardants cannot be employed in exterior casings because with them, on account of the great quantities required, the mechanical stress (drop tests) and other constructive demands as well as weight limits cannot be mastered.

Miniaturising: The trend to miniaturise applies both to the complete appliances and to the individual construction elements. The resulting reduction of distances inside the appliances complicates constructive solutions to the fire safety requirements where-ever the solutions depend on the observance of minimum distances and require space. Abandonning picture screen valves in favour of plasma screens in TV appliances was given as an example. This causes the loss of a lot of "stowage" space inside the appliance and may also result in higher temperatures in the appliance.

Energy intake, power loss: TV appliances with plasma screens have a very much higher energy consumption than valve screen sets and, therefore, require a stronger flame retardant equipment. On the other hand, these are expensive appliances produced for a small market segment. The transition to LCD (liquid crystal display) flat screens, which have approx. 50 % less energy intake than traditional monitors, demonstrates the existence of adverse trends. The energy intake also falls drastically when using fluorescent diodes (LED) for optical indications. Here, it is easier to fulfil the fire safety requirements because of lower voltage and lower currents taken in and subsequently also lower power loss. In the future, the share of appliances with LCD screens in monitors will increase significantly (market share estimates of 15 – 20 % were given).

3.2 General conditions (fire safety discussion, marketing, labelling, costs)

Fire safety discussion and flame protection of TV appliances: In Europe TV sets made for the European market are, in general, not equipped with flame retardants in the outer casings; manufacturers usually guarantee fire safety by constructive measures (see vol. II, page 236). Partly, however, a flame retardant equipment as per UL94-V0 is being reintroduced. Sony, for example, since the year 2000, employs again material equipped with flame retardants in the outer casings (flame retardants on the basis of phosphorus) and this goes for other manufacturers in the Far East as well. Triggering factor is the discussion intensified, amongst other causes, by relevant studies (see vol. II, pp. 250/251) of exterior ignition sources as a cause of TV fires. The Federal Environmental Agency and some industry representatives (Original Equipment Manufacturers = OEM) have stressed that the videos and TV spots on TV fires do not stand up to scientific scrutiny and only serve to influence the market in a suggestive manner. The connections between the frequency of TV fires and flame retardant equipment of the casings, reported in the publications available on the subject, are inconclusive. But as European consumer associations take these scenarios seriously, manufacturers such as Sony find it compelling to react. It is for this reason that the flame retardants based on phosphorus acid are gaining a certain weight. (In the application of ABS, in Europe exterior casings of monitors equipped with flame protection as per UL94-V0 are, as a norm, made in PC/ABS equipped with phosphorus organic flame protection, but in Asia in ABS with brominated flame protection.) In addition, there is obviously a tendency amongst TV appliances manufacturers for reasons of cost not to produce any longer specifically by sales regions, but to serve international markets with uniform products. This leads to the fire protection standards of the US market (UL94-V0) gaining in weight.

Labelling: Important manufacturers of TV and IT appliances are pressing for combining, for the triad markets, the norms which, from a customer safety point of view, are the most important and severe, and to include in this measure the use of environmental labels with world-wide recognition as a marketing instrument. As seen by the OEM, fire protection, for the reasons already stated, has great importance in this "norm combination". Whilst the "Blue Angel" is only designed for a national sales market – Germany – , the TCO labelling is gaining world-wide status. TCO (Tjänstemannens Centralorganisation, Sweden) is interested in this because it is financed by the label. As TCO excludes halogenated flame retardants (see vol. II, page 246), this development supports the application of halogen-free phosphorus organic flame retardants.

Cost issue: A cost comparison between halogenated and halogen-free or constructively flame protected casings must not be limited to the costs of the flame retardants alone. Generally, phosphorus organic flame protection equipment is dearer than flame protection on the basis of halogen (bromine). But as phosphoric organica simultaneously act as softeners their application is also technically restricted. However, the costs depend primarily on the synthetic material chosen which, in turn, determines the flame retardant equipment. In PC/ABS the decisive variable is the proportion of PC to ABS. The system price for the complete compound inclusive of brominated or halogen-free flame retardant differs by, at the most, 10 %. The choice of synthetic material and flame retardant applied primarily depends on the price calculation of the finished product (appliance price). Higher priced appliances are manufactured with halogenated flame protection, cheap appliances with low value synthetic material and brominated flame retardants. (Polycarbonate is expensive, ABS medium priced, PC/ABS flame protected more expensive than HIPS. The latter is a cost attractive production material for terminals in the lower price segment). Constructive solutions of fire protection can theoretically be realized everywhere. But there is only a limited amount of truth in the general argument that constructive solutions are cheaper because flame retardants as special chemicals are, as a rule, more expensive than the synthetic material and, through higher material and labour costs, make the compound more expensive. Constructive solutions often require a significantly higher consumption of material. This may mean higher weight and transport costs. For this reason, general statements are impossible in this field and an analysis of each individual case and a systematic cost analysis is necessary for each product unit.

3.3 Disposal/recycling

Recycling practice: The narrow limits for recycling casing materials – the practice has been presented exhaustively in vol. II (pp. 252-261) – were, for the most part, confirmed during the workshop. Additional information given was regarding the legal regulations of the re-acceptance of end of life appliances (TV and other) in Japan and to examples of Japanese OEM (Ricoh, Fuji-Xerox) who intend to recycle ABS, made flame retardant with brominated epoxy, into production material (limited addition of recycled to primary material).

Identification of synthetic material: Sony has a recycling centre where end of life commodities are distinguished by types of synthetic material with the help of a synthetic material identification system via IR (Bruker Analytik, Karlsruhe) (see vol. II, pp. 258 ff.) The bromine industry pointed out the possibility of separating brominated from non-brominated synthetic material by means of RFA (x-ray fluorescence analysing). This could be of importance regarding the WEEE/ROHS. But the workshop was of the opinion that the costs of the necessary logistical arrangements (casing selection, transport etc.) must be calculated which can render such sorting systems expensive.[16]

3.4 Measures proposed by the Federal Environmental Agency

Proposal summary: The measures proposed by the Federal Environmental Agency called, in the case of outer casings for IT and TV appliances, for a ban of PBDE and PBB as well as of TBBA (additive). The agency maintained that EU-wide regulations should be aspired to, but independently thereof national regulations as well. Furthermore, the Federal Environmental Agency points to further-reaching measures on the EU level like the review, planned in the ROHS draft directive for the end of 2003, of the list of prohibited substances.[17] Parallel to these proposals for legal measures, the Federal Environmental Agency supported the promotion of constructive fire protection which contributes to a reduced application of chemicals

[16] For a while IBM has practised a synthetic material identification by flame retardant groups by means of medium infrared light, but gave this up again for cost reasons (the system was too slow) in favour of incineration (see vol. II, page 259, FN 47).

[17] Or two years after coming into force (see FN 8). Being based on article 95 of the EC treaty, it is obligatory to accept the ROHS, without any possibility of change, into national law.

and facilitates recycling and is thus also of advantage with regard to the WEEE. The halogen-free substitutes should, according to the Federal Environmental Agency, be more thoroughly toxicologically/ecotoxicologically tested or data, which the companies may possess, should be made available. The Federal Environmental Agency has announced a review of the rules for allocating the "Blue Angel" to IT and TV appliances.

Main points of discussion: As expected, here too the discussion about the proposed measures was controversial because of differing interests. The topics were

- evaluation of the substances employed;
- relationship between national and international regulations;
- other details.

Evaluation of the substances employed and of the substitutes: The same reservations as in the discussion at the printed circuit boards workshop (see section 2.4) were made by the producers of brominated flame retardants concerning PBDE and PBB, as well as TBBA additively instead of reactively employed in casing polymers. With additive TBBA, the industry also finds a "segment orientated" ban of it's use in IT and TV appliances problematic because TBBA is used in products other than exterior casings as well.

Critical examination of the objections:[18] It has already been exposed that the evaluation proposed by EBFRIP of DecaBDE as "non toxic" cannot be followed. The same applies to the evaluation of TBBA for which the existing classification as "environmentally dangerous" and "very poisonous for water organisms" and the discoveries meanwhile reported in fish and mother's milk are relevant for the classification and recommendation to substitute (see section 2.4 and EBFRIP 2001, Kruse 2001, Leisewitz 2001a in the annex).

Imports containing PBDE: As far as PBDE is concerned, an important manufacturer of plastics pointed out the voluntary disclaimer by the German chemical companies which are association members. He added, however, that it does not suffice, and continued that a ban on the European level would make sense because of the material imported into Germany and used by processing companies not bound by the voluntary agreement. The manufacturers of brominated flame retardants disagree and insist on a "differentiating approach" to PBDE still undergoing risk assessment.

Halogenated substances as substitutes? One manufacturer of halogenated flame retardants criticised that, amongst the substances to undergo further tests, only halogen-free flame retardants are mentioned. The Federal Environmental Agency gave a generally positive answer to the question of whether materials used in the manufacture of casings and equipped with toxicologically/ecotoxicologically harmless halogenated flame retardants can obtain a "Blue Angel". This, the agency said, is not the object of an "ideological" debate, but depends on real tests, and to this extent the adjective "halogen-free" can be dispensed with. But the explicit reference to halogen-free compounds is meant to underline the need for overcoming, as much as necessary, the information and knowledge deficits seen to exist with these compounds as potential substitutes.

[18] See FN 14.

Relationship between national and international regulations: The tension between national measures and far-reaching regulative competence at EU level also affects the measures proposed for flame protection of exterior casings. The Federal Environmental Agency stressed that these are proposals for national German measures which have to observe EU regulations; the proposal for a ban of additive TBBA could also have been entered into the ROHS draft. The industrial association of synthetic material manufacturers (VKE) recommends awaiting the risk assessments of PBDE and TBBA because national measures on a legal basis "hardly stand a chance". It was further argued that the WEEE draft directive (as per article 157 (1) EC treaty) permits further-reaching national measures, but that this is out of the question with regard to the ROHS draft directive based on article 95 EC treaty. In any case, in the medium term the risk assessment and the already mentioned revision clause (review of the list of affected substances) of the ROHS draft directive must be observed and can be regarded as a starting point for further-reaching measures. The Federal Environmental Agency also stressed that, in contrast to the tests of chemicals conducted at EU level really only for the purpose of substance substitution, at the national level the possibilities of constructive flame protection should be given more attention.

Other details: Industry suggested that the Federal Environmental Agency include in it's research the questions, controversially discussed and also raised in the workshop, of the fire safety philosophy (external/internal ignition sources). The agency confirmed the importance of these questions and promised to consider the suggestion.

3.5 Conclusion: Revised proposals regarding materials for outer casings for IT and TV appliances

In considering the workshop discussion, the revised proposals of the Federal Environmental Agency for measures to be adopted regarding materials for outer casings for IT and TV appliances (see annex VII of this report) contain the following points:

A) Legal regulations

A1: PBDE and PBB, if (still) used in outer casings, can be substituted. Therefore there is no need for their use in outer casings. The Federal Environmental Agency considers a ban of PBDE and PBB necessary because of the critical environmental properties of these substances (persistence, toxicity, ecotoxicity) and here supports the corresponding proposals of the ROHS draft directive (Proposal for a DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the restriction of the use of certain hazardous substances in electrical and electronic equipment) for a ban of substances.

A2: The Federal Environmental Agency considers a ban of TBBA (additive) necessary for toxicological/ecotoxicological reasons. EU-wide regulations are to be aspired to. At present, TBBA is being risk assessed within the framework of the European material recycling programme. It is further suggested to introduce a substance ban for TBBA (additive) into the drafting of the ROHS directive with the aim of coming back to the substance ban of TBBA when the measures are revised. (The environmental committee of the European parliament, for example, proposes, for the above mentioned directive, a renewed revision in the year 2003 of the necessity to substitute other halogenated flame retardants [§ 6]).

A3: The Federal Environmental Agency does not, at present, consider any further legal regulations (restriction of substances) exceeding A1 and A2 necessary.

B) Further measures

B1: The Federal Environmental Agency considers, with a view to outer casings for IT and TV appliances, the constructive fire protection a sensible measure to minimize the use of chemicals and thereby ease the recycling of synthetic materials, which should be fully implemented within the frame of the fire safety regulations in force. This is true also in view of the requirements of the European WEEE (electronic scrap directive) and the ROHS.

B2: As to outer casings for IT and TV appliances, the Federal Environmental Agency considers it necessary that further research is conducted into the substitution products (toxicological/ecotoxicological properties of the pure substances and of the flame protected products) and that the enterprises participating in the product chain make the data they possess available.

B3: The Federal Environmental Agency will review the rules for allocating the "Blue Angel".

B4: In accordance with the regulations of the European electronic scrap directive (WEEE), the Federal Environmental Agency considers it necessary to support the recycling of the synthetic materials of casings except for those flame protected by means of PBDE. To this end, recycling companies are to separate casings and casing parts in the recycling process. Those parts should primarily be recycled into production material which are made of synthetic materials without flame retardants. In addition, processes for the detection of flame retardants (or their chemical systems) and for the separation of the synthetic material fractions so equipped are to be developed and implemented in order to enable safe reprocessing of flame protected synthetic materials. Recycled material should, above all, be used in the production of new casings.

4. Workshop Polyurethane insulation and one-component foams

During the workshop the following topics were discussed:

- Trend in foam formulation and flame retardant insulation in one-component foams, slabstock and continuous process foam as well as sandwich elements;

- behavioural patterns of TCPP in emissions and TCPP discoveries in interiors;

- disposal and waste incineration;

- problems connected to measures proposed by the Federal Environmental Agency including substance evaluation of TCPP.

4.1 Trend in foam formulation and flame retardant finishings

Quantitative significance of PUR foams: Insulation and one-component foams of polyurethane have, amongst the synthetic insulation materials, with about 6 % the smallest surface share in the insulation material market, but contain about two thirds of the flame retardants used in all synthetic insulation materials (see vol. II, page 40). When weighting their importance, primary product suppliers (system suppliers) and foam rubber manufacturers also give consideration to their share in the total value of the insulation material market. It is about 30 %. These are, therefore, relatively expensive products with a high economic significance.

Causes of the high flame retardant content: The higher level of flame retardant consumption in PUR in comparison to the other important synthetic insulating material, polystyrene (EPS)[19], is due to the fact that EPS, as a thermoplastic material, melts in front of the flame and therefore requires a lesser flame retardant equipment for passing the fire test, where-as PUR as a duroplastic material "stands up to the flame". The comparison, therefore, also raises the question of how realistic fire tests really are, because in a real fire with a large enough outer source of ignition, melting in front of the flame is without significance (see the Dusseldorf airport fire). In other words: It always remains to be considered that the properties of inflammability attributed to a material or polymer principally refer to it's behaviour in the respective test arrangement and cannot be viewed independently thereof (see Troitzsch 1990, pages 76 and following, about test problems).

4.1.1 One component foams

Flame retardant consumption on the increase: One-component foams have a share of approx. 21 % of PUR consumption, but about 36 % of flame retardant consumption in all PUR insulation and one-component foams (vol. II, page 86).

[19] See vol. II, pp. 105 ff. In PUR insulation foams (without one-component foams), the flame retardant content is approx. 10 weight percent; in polystyrene insulation foams it is about 2 weight percent (HBCD plus dicumylperoxide as synergetic agent). Calculated in kilos flame retardant/cubic metres, the content amounts to more than 4 kilos in PUR and approx. 0,3 kilos in polystyrene. The surface share of polystyrene amounts to more than 40 %.

Whilst the figures stated in the study for total quantity, formulations and applied flame retardants have been confirmed correct for the present time, in future, in connection with the introduction in Europe of a homogeneous classification of building materials (European building materials directive) and of new, corresponding test methods (SBI test, see vol. II, page 53), the consumption of flame retardants for one-component foams will further increase. This is because, according to information from the manufacturers, it will be impossible to attain the comparable European classifications E or F (the future rating will be stipulated in the state building codes) by retaining the presently prevailing foam formulation for B2 foams with halogenated flame retardant additives (TCPP). This is connected with a longer period of combustion in the appurtenant small burner test procedure. It is said that substituting HFC 134a/152a by combustible propane/butane/dimethylether as propellant also requires an increase of the flame retardant additives by about 20 – 25 % in the B2 foams. All in all, on the basis of the figures given in the study, an increase of about 30 % of the flame retardant content is expected. This takes into account that, at European level, countries which up until now have used B3 foam will change to B2 foam with a correspondingly higher flame retardant consumption.

Why the tests are problematic: The combustion test is conducted when the one-component foam is still fresh, i. e. still contains propellant. With ageing, the combustible propellant, as is well known, exudes gas. Therefore it is doubtful, as was noted by the Federal Environmental Agency, that the increase of the flame retardant content in reality leads to improved flame protection. The purpose of the increase is to pass the new test and attain the European classification. The PUR manufacturers don't see this any differently but point out the necessity to keep to the building law regulations all the more so because the insurers would advance claims of recourse if there is a fire.

TCPP substitution: Halogen-free flame protected one-component foam is formulated with DPK (diphenylcresylphosphate) or TEP (triethylphosphate) instead of TCPP. Such foam is, at present, about 15 – 20 % more expensive and subsequently not competitive on the hotly contested market for one-component foams. If general conditions do not change, a TCPP substitution is, therefore, not to be expected even though, from the manufacturers' point of view, there are no real technical problems for formulating halogen-free one-component foams.

Costs: The cost issue loses in severity because of scale effects when broadly changing to other flame retardants. The following calculation was made to demonstrate this: Halogen-free formulated B1 foam of which, at present, less than 100.000 cans are sold, is in such small batch sizes about 20 % dearer than halogenated flame retardant B1 foam. With a sales increase to 10 million cans, one would have to reckon with a price only 5 % higher. The scale effect would then clearly show.[20]

4.1.2 Block and slabstock foam

Flame retardant content and usage: The change-over from PUR to PIR foam has greatly progressed with block and slabstock foam with flexible covering layers (approx. 35 % of PUR insulation and one-component foam; see vol. II, pp. 58-64).

[20] B1 foam being a mere niche product, this calculation is of rather an illustrative character only.

Compared to the status given in the study – about 40 % PUR and 60 % PIR foam – , the PIR share has further increased. Because the change to pentane as propellant has already taken place here, one need not reckon with an increased need for flame retardants caused by the propellant.[21] Therefore, one can assume that also in future the formulations mentioned and the flame retardant contents (approx. 4 %) remain as they are. In contrast to the one-component foam, the SBI test and the European norm will generally not lead to any changes in the B2 foam as it is to-day. Class E will remain attainable with formulations similar to those indicated for to-day.

In PIR foam, TCPP and halogen-free phosphoric acid ester are used in a 1:1 proportion; brominated polyols are of no importance in PIR foam. The flame retardant content to-day is already considered to be minimal. For various reasons a complete abandonnement of halogenated compounds is considered counter-productive. It is argued that, first of all, synergetic effects between the flame retardants would then be lost so that, on balance, a higher flame retardant content would become necessary. Secondly, the softening effect of phosphoric acid ester must be kept in mind. The halogen content stemming from the flame retardant of pentane propelled PIR foam is confirmed to be approx. 1 % (see vol. II, page 63; in PUR foams, however, it is approx. 5 % of weight).

Ammonium polyphosphate: Ammonium polyphosphate is offered as a TCPP substitute. Here the discussion with producers and users of APP revealed that plenty of application experience is available in connection with soft and integral foams (APP consumption p.a. is more than 1.000 tons), but that the practical trials with rigid foam on double plate conveyors are still confronted with great problems. The problems especially concern the foam formulation ability of the polyurethane and increased wear and tear of the production lines (mixing heads) due to the abrasiveness of the solid matter. Solid substances also turn the foam brittle and lead to the loss of dimensional stability. It follows that block and slabstock foams equipped with APP as flame retardant can be produced in acceptable quality only as of a bulk density of approx. 40 kilos. The usual commercial material has a bulk density of 30 – 35 kilos (see vol. II, pp. 58 and 62) so that, if APP is applied, distinctly higher costs (and weights) would be incurred as a result of an increased bulk density. In practice, APP is, therefore, not taken into consideration in the entire industrial branch for block and slabstock foam. This also applies to other solid matter such as melamine. Melamine has a cell destructive effect. It can be employed in open cell soft foam, but not in rigid foam.

4.1.3 Sandwich elements

Trend: Of all the PUR insulation material, the sandwich sector consumes the highest flame retardant share (a little more than 40 % of the PUR and of the flame retardant consumption, i. e. no "over-proportional" share of the flame retardant consumption as with the one-component foam; see vol. II, page 86) so that here lies the greatest potential for substitution and reduction. The expectation still voiced only recently that,

[21] With the change-over to pentane as propellant in slabstock foam, inflammability of the foam has increased by approx. 5 %. For this reason, pentane propelled PUR foam has to be equipped with somewhat more flame retardant than when using the hitherto usual halogenated propellant. In the change-over to less inflammable PIR foam, the flame retardant content diminished beyond proportion so that the final result is a flame retardant reduction in pentane propelled PIR foam.

after the change-over in propellants from HFCKW to pentane, now a change-over from PUR to PIR foam in sandwich elements can take place (see vol. II, pp. 64-68), does not, at least at present, appear possible for technical reasons.

PUR/PIR change-over: Several sandwich manufacturers (companies preparing their own formulations as well as system clients) have reported on their intensive trials with pentane propelled PIR foam.

PIR foam is, as such, nothing new to sandwich manufacturers (see vol. II, page 66). A decisive variable in the sandwich production history is the choice of propellant. In the early eighties the change from CFC-11 propelled PUR to PIR foam took place with a corresponding alteration of the flame retardant formulation. In comparison to PUR foam, PIR foam is cheaper. The problems at first arising in regard to the bonding of the facing layer (detaching of the sheet metal) could, at the time, be solved. At the outset of the nineties, the use of CFC had to be reduced successively because of the damages it afflicted to the environment (destruction of the ozone layer) (PUR with reduced application of R-11) and as of the mid-nineties discontinued, at first in favour of HCFC propelled PUR and finally of pentane/PUR. HCFC propelled PIR foams were never developed because this propellant variable was regarded, from the outset, as an intermediate solution only. To-day, pentane propelled PUR for sandwich elements is considered a "stable system". Approx. 5 years ago, trials began to change over to PIR/pentane. For about 2 years experiments are being carried out with pentane propelled PIR foam. One producer reported on several large-scale trials on two double plate conveyors with several tons of material. Here, too, cost saving is the main objective.

Top layer adhesion: The main problem is still posed by the sheet metal adhesion. The top layer adhesion between sheet metal and foam is of great importance for the stability of buildings erected with sandwich elements such as cold storage buildings, warehouses etc., because here the sandwich elements not only have an insulating, but also a statical function to fulfil. In cold storage buildings, for instance, in the summer great differences in temperature between the interior (- 30°C) and the exterior coating (+70°C) and, therefore, strong tensions and temperature pulsations can occur which can lead to the exterior sheet metal cracking off or similar damages in case of insufficient sheet metal adhesion. Here, then, long term trials for testing the long-term stability are indispensable in the eyes of the manufacturers.

Other processing problems: In comparison with PUR foam, PIR foam requires higher foaming temperatures because of the PIR specific isocyanate cross-linking. If, subsequently, the sandwich manufacturers heat their conveyors designed for PUR foam up to about 60 – 70° C, this results in high and costly wear and tear. The users of the old double plate conveyors say that these lines cannot be adjusted. It was not clarified how many of the twelve presently installed double plate conveyors in Germany can be converted to produce sandwich elements, and how much this would cost.

Propellant issue: To sum up, the development of pentane propelled PIR foam for sandwich elements is, on the whole, judged with scepticism, other than where no statical stresses exist. One system supplier argued that a suitable PIR foam could be produced by changing over to HFKW as propellant because one could then expect adhesion to be better and embrittlement of the foam, as occurs in PIR foam in contrast to PUR foam, to be less than in pentane propelled PIR foam. But HFC as propellant would have the disadvantage of the green house effect and of bringing fluorine into the foam with undesirable consequences for fire by-products (flue gas density, hydrogen fluoride).

4.1.5 Trend summary

The following trend resulted from the three areas of utilization discussed (in-situ foam was not discussed further because here no relevant changes can be discerned):

- In one-component foam, the flame retardant content (TCPP), when keeping to the actual foam formulation, will clearly increase because of the European classification and new test conditions. Although halogen-free flame protected one-component foams can basically be formulated and supplied, their market introduction is, under prevailing conditions (= cost factor), too expensive. But in the long term and given large volume sales, a cost reduction is regarded probable.

- A further increase of PIR foam is noticeable in flexibly coated block and slabstock foams; no marked changes in the flame retardant equipment are expected for the future. The halogen content is, at present, about 1 weight percent.

- The hopes attached to the introduction of pentane propelled PIR foam for sandwich elements do not, for the time being, seem to come true for technical (top layer adhesion) and cost reasons (adjustment of production lines because of required higher processing temperatures).

4.2 Flame retardant emissions with PUR insulation and one-component foams

Emission examination results: TCPP and other organic phosphoric acid esters are regularly found in waters and sediments as well as in interiors (samples of house dust) (see vol. II, pp. 89 ff.). The workshop discussion on the sources, unknown in particular, of such findings produced no information basically new. As the 6 % share of PUR in the insulation market does not correspond with the frequency of discovery of TCPP traces in interiors, other materials such as wall paper, flooring, upholstery etc. must also be taken into consideration as emission sources. It was further argued that PUR insulation and one-component foams are normally used as outside building material or are covered with emission arresting coating and are, therefore, not interior relevant. It was added that TCPP does not belong to the substances easily exuding gas. But in compounds of low volatility, time delayed emission increases can certainly occur. The dust binding of low volatility compounds must also be considered. The commentary by the system houses on the TCPP discoveries in river sediments (see vol. III, page 137) claimed that, in view of the vast differences in concentration, spot source loads, stemming perhaps from the cleaning of in-situ foam containers, must be assumed rather than a pervading load.

Emissions from flexible coating: Flexibly coated block and slabstock foams, in 60 % of all cases, are topped with an aluminium foil layer of about 5 µ in strength which serves as a migration barrier; approx. 40 % have a coating which allows for diffusion (mineral or blotting paper).[22] It was reported that tests carried out by order of the IVPU at the WKI (Wilhelm-Klauditz Institute – Fraunhofer Institute for Wood Research, Brunswick) of slabstock foam with diffusion permeable coating (8 to 10 day long tests in test chamber) did not show any diffusion of TCPP gas, but of propellants. More research is undertaken at the Bundesanstalt für Materialforschung/Berlin (Federal Institute for Materials Research, Berlin), within the scope of a study by the Federal Environmental Agency, into the question on the whole still rather obscure of the emission behaviour of flame retardants in PUR foams.

4.3 Disposal and waste incineration

State of affairs: The discussion confirmed that, regarding PUR foams, hardly any recycling of the primary commodities of end of life material and only very little recycling of the material itself takes place (for a summary see vol. II, pp. 92 ff.). Demolition material is deposited or burnt. The quantitative shares of each of these are unknown. In building waste, a clean separation by types is, in the opinion of the suppliers, practically impossible.

Waste and waste incineration: In the opinion of the PUR branch of industry, with the reduction of the halogen content in the pentane propelled PIR foams (reduction of brominated polyols and TCPP) to almost 1 weight percent, no problems are to be expected in incinerating in modern refuse incineration plants. Nor are, according to test data submitted by a polyol producer, toxicologically relevant quantities of dibenzodioxins and -furans found in the pyrolysis of standard PUR foam equipped with brominated polyol. A further argument states that while the incineration of small quantities of PUR foam (2 – 6 %) together with wood does increase the nitrogen content in the waste gas, it does not increase the forming of dioxin/furan because the small PUR foam addition leads to higher temperatures and thereby to a cleaner incineration. However, because of the great longevity of the products, the PUR waste on demolition sites comprises halogenated end of life material containing, as the main fraction, halogen from both the propellant and the flame retardant. To this is added the PIR foam with a reduced halogen content (but only in small quantities – see the balance of quantities employed in vol. II, page 55 – because in the main areas of usage, such as sandwich elements or one-component foam, the halogenated material is employed). Therefore, the future waste disposal will be faced with large quantities of end of life material with a high halogen content.

Interests of the system houses: The system houses explicitly pointed out that the waste legislation exerts pressure towards substituting halogen and that, for this reason, they are definitely interested in halogen substitution. They regret that the endeavours of the manufacturers to reduce halogen are not rewarded by the actual demand of the EU to turn over PUR waste with a halogen content of >1 weight percent to toxic waste incineration[23], because waste with a halogen content smaller

[22] The type of coating depends on whether the parts in question of the building (roofs for instance) are to be ventilated or sealed diffusion tight.

[23] Here total halogen content and CFC as halogenated propellant play a role. The EC incineration directive (see Official Journal L 332, page 91 of 28th December, 2000) provides, as of the end of 2005, essentially the same emission limiting values for the incineration – alone or in combination with other waste – of hazardous and of non-hazardous waste. The directive must be adopted into national law within two years; for existing plants a transitional time limit of five years applies (after entry into force). In combination with the "Regulation for the

or higher than 1 % cannot be distinguished. In their opinion, therefore, special permission should be given, when adopting the directive into national law, for the incineration of PUR waste. From the Federal Environmental Agency's point of view, the problems in registering the organic building waste components are comparatively more pressing and bigger; their separate collection is, in the PUR suppliers' opinion, practically impossible.

Problems resulting from imports: The PUR manufacturers expect increasing imports of insulation and one-component foams with the introduction of the European norm (building products directive). Then again, they say, halogenated material will come onto the market in areas of application where halogen reduction has already taken hold. A TCPP reduction, as a national measure, would then also be countered by such imported material and does not, therefore, make any sense in their eyes.

4.4 Measures proposed by the Federal Environmental Agency

Summary of proposals: As far as TCPP is concerned, the Federal Environmental Agency had proposed, "for reasons of the critical effects, not yet fully elucidated, of the proven strain on the environment, of the high tonnage and of the emission properties, to further examine the need for legal action". Special attention was to be given to emission loads in interiors. Beyond this, continued tests, under

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environmentally compatible disposal of housing estate refuse and for biological treatment plants" passed in January 2001 (end of possibility to deposit untreated organic refuse as of June 2005), the directive is of relevance also for PUR insulation foams in building rubble (see vol. II, page 92). "Classic" CFC foamed and bromine-chlorine flame protected PUR foams possess a chlorine content of approx. 6 % (Bayer AG 2001). The EC incineration directive prescribes for the incineration of hazardous waste containing more than 1 weight percent of halogenated organic matter (calculated as chloride) that the temperature of the incineration gas, after the last induction of incineration air, must be increased to 1100° Celsius for at least two seconds in order to prevent the formation of dioxins and to destroy any possible antecedent compounds. Normally a temperature so high is reached only in the rotary kilns of toxic waste incineration plants; standard waste incineration plants are designed for a maximum temperature of approx. 850 – 900° C. The PUR manufacturers point out against this that, given proper waste gas cleaning, even to-day no increase of the dioxin / furan emissions can be detected when PUR insulation foams have been added to the waste being incinerated in standard waste incineration plants (see vol. II, page 91). Accordingly, PUR foam classified as hazardous waste (waste requiring supervision) must be handed over to toxic waste incinerators. The prescribed limit of "> 1 weight percent" is either to be referred to the mono-fraction; "diluting" by mixing up with other waste is not allowed in this case. Or the limit refers to the mixed toxic waste in which the PUR foam constitutes the dominating element as regards the chlorine content. If the PUR foam, as currently prevailing, is not classified as waste requiring supervision, it can be incinerated in normal waste incineration plants even with a halogen content of > 1 weight percent.

But here a change in the waste classification is to be expected. The EC waste register (European waste catalogue, EAK; see 2000/532/EC with alterations by 2001/118/EC and 2001/573/EC), in the chapter "building and demolition waste", classifies insulation material under code 1706 into three groups: Insulation material containing asbestos (170601), "other insulation material consisting of hazardous substances or containing such substances" (code 170603) and "insulation material other than under codes 170601 and 170603" (code 170604). Classification into one of these groups depends on the hazardous substances law as well as the national interpretation of the so-called "bullet point entries" (waste which is classified as dangerous or not dangerous depending on the content of harmful contaminants; worked out by the Working Committee on Waste (LAGA) set up by the Federal states). A classification of classic PUR foams as "hazardous" waste (code 170603) is to be expected for the future because of their content of ozone layer destroying CFC. Once this has happened, the toxic waste incineration as per EC incineration directive would become necessary.

The following remarks have to be made regarding the problems connected with PUR as an incineration additive: For plant technology reasons (forming of solid crusts on the rotary tube and other machinery parts with the risk of clogging up), modern cement plants regard material added to incineration waste as problematic if the chlorine content is > 1 %. 1 % is already the upper limit, tolerable only for modern plants equipped with a "bypass". Via the "bypass" flue gases containing chlorine, alkali and heavy metals are sucked off and the contaminated dust is separated. Many cement plants do not have such a "bypass". For them a chlorine content of 0,3 % already represents a limit to be kept if at all possible (Rüdersdorfer Zementwerke 2001). An incineration of PUR foams, as additives, comes into question, if at all, only in case of non flame retarded and CFC degassed foam (such as construction foam from refrigerators) (Bayer 2001).

toxicological/ecotoxicological aspects, of halogen-free phosphoric acid esters as a product to substitute TCPP (or the disclosure of data) were demanded. Added to this were the suggestion of a voluntary commitment, supported by monitoring, to successively substitute halogenated flame retardants in the PUR insulation and one-component foams in question, inclusive of sandwich elements, and the recommendation to honour the criterion "halogen-free flame protection equipment" in future awards of the "Blue Angel" for building products.

Main points of the discussion: The discussion about evaluating TCPP and TCPP emissions and the usefulness of a "voluntary commitment" and a "Blue Angel" for PUR insulation foams as building products was controversial.

Evaluation of TCPP: A number of objections were brought forward against the evaluation of TCPP made in the study (see vol. I, pp. 97-100 as well as the underlying substance profile in vol. III, pp. 124-150) (written comment submitted afterwards; see Schupp 2001; annex II to this report). In essence, the objections amount to the following points:

TCPP cannot, it was said, be regarded as potentially bio-accumulative as the log K_{ow} is under 3 and the gauged BCF or calculated BCF under 100. It was further argued that the probable dispersion behaviour of TCPP, in combination with the quick reduction in the air, makes it unlikely that TCPP persists in the environment, and that the discoveries in sediments ought to be interpreted as point loads. The deduced value for a tolerable concentration in water is seen as being exaggeratedly high. The argument went on claiming that the data available on eye and skin irritation and on mutagenicity are being over-interpreted and, as regards mutagenicity, do not support in any serious way the suspicion of carcinogenicity. Also the IPCS study on TCPP (WHO, 1998) has, it was maintained, found tests into carcinogenicity to be unnecessary. At the same time, it was criticised that various substances are allegedly being treated unequally – for TCPP the study demands a carcinogenicity test, but not for APP named as substitute despite many more open questions (knowledge deficits). From this it was concluded that the recommendation of the Federal Environmental Agency to substitute TCPP and the measures proposed by the agency cannot be upheld.

The comments and arguments mentioned contain hardly any new information. They represent primarily a different accentuation in the substance evaluation. Next to the concrete objections which shall be dealt with first, they also raised more general questions of substance evaluation.[24]

Critical examination of the objections: With TCPP, the possibility of a bio-accumulation cannot be excluded because the log K_{ow} stands at about 3. (Here too, it is not appropriate to take the lowest and therefore optimal value for the evaluation; log K_{ow} or BCF are informative.) A quick reduction in the air, as observed with TCPP, does not rule out the possibility of accumulation in other media where no such quick reduction occurs. The recommended value of 0,1 µg/l is a precautionary tolerance value referring to the bio-accumulation in the aquatic food chain and is meant to prevent the introduction into the food network. The indications of carcinogenic effects of TCPP must be taken seriously and interpreted as evaluation relevant (see related

[24] During the workshop the objections referring to substance evaluation were not discussed in detail; see FN 14.

to this and other comments Kruse 2001; Leisewitz 2001a, as annexes III and IV to this report).

<u>General questions about substance evaluation</u>: Basically, in evaluating substances from the same data base, different positions and points of view are conceivable, because normally different weighting of pertinent statements enters into the evaluation.[25] In reflecting this, one should be conscious of the character of substances evaluations being pragmatic and in need of development.[26] In the 2nd workshop, it had already been discussed within the scope of the project[27] that in the present study, the intrinsic substance properties and the principle of precaution would be stressed more strongly when compared with the given methods of evaluation (within the scope of the Chemicals Law or the EC End of Life Material directive), and this is now being set out in more detail in the present study (see vol. I, pp. 51-73). Moreover, under precautionary aspects this is definitely common practice also within the scope of risk assessments as per EC End of Life Material directive[28] and will be taken up when formulating a European chemicals policy (see EU White Book on Chemicals Policy: Ahlers and others 2001).

One cannot speak of a "discriminating treatment" of different flame retardants within the scope of the study (example given: Demand for carcinogenicity tests of TCPP, but not of APP) because the demand to conduct tests, as expensive as those into carcinogenicity, must be raised only, and only then, when the proven or suspected hazardous features as well as exposition and quantities employed of the chemicals render reasons for suspicion and clues. This must be examined in detail and is part of the substance evaluation. Naturally, one should press for a data base as comparable as possible of the flame retardants to be tested – substitutes as well as substances to be substituted. The demands for a closer characterisation of the

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[25] See, for example, the different classification of the carcinogenic potential of antimony-trioxide or of TCEP which was substituted by TCPP. There is as yet no classification of TCEP in the MAK list (but since 1997 due for review); the TRGS classifies it into category 2 (to be regarded as carcinogenic for man), the directive 67/548/EEC (Classification and Marking directive) into category 3 which means that "there is reason for anxiety because of a possible carcinogenic effect" (see HVBG 2001, page 123). According to 47/548/EEC, antimony-trioxide is also listed in group 3, but in the MAK list under category 2, "to be regarded carcinogenic for man" (see DFG 2001, pp. 23, 122). Decabromodiphenyl ether is rated carcinogenic/category 3 according to TRGS 905 (HVBG 2001, page 31).
In conformity with the agreements reached in the 2nd workshop, the "substance profiles" taken as the basis for the substance evaluations were transmitted for commentary to selected manufacturing companies which had offered their assistance, in order to ensure, within the scope of the project, a data base as consensual as possible. Vol. III of the study documents these comments. They were taken up when giving the substance profiles their final draft where-ever this seemed suitable.

[26] A state of facts that can be gleaned in current textbooks of ecotoxicology. "The evaluation of substances as to their environmental dangerousness is, by necessity, a pragmatic decision which it is possible to support, but not to prove right scientifically. The process and means of the decision-making must be and remain the object of constant debate. (...) In public, the substance evaluation must be presented as what it is: Not a scientific prognosis of the dangerousness or harmlessness, but a compromise by the authorities between the scientific standpoint, retaining the ability to act, and cost efficiency." (Holler and others 1996, page 407).

[27] 2nd workshop within the scope of the project "Substituting Environmentally Relevant Flame Retardants: Assessment Fundamentals", Berlin, Federal Environmental Agency, 6th April, 2000.

[28] "Within the scope of the EC End of Life Material directive, the flame retardant pentabromodiphenyl ether (pentaBDPE) is presently evaluated. The experts of the member states unanimously decided that, despite existing data deficiencies, the evaluation result "risk minimizing measures necessary" should apply for pentaBPDE and not "further tests necessary". The decision was made because of considerations of precaution and in the light of the properties and the information available (amongst others, concentration in mother's milk) and not on the basis of adequate scientific knowledge of the relationship between concentrations and effects. Time and expenses necessary for a definite scientific clarification *before* the taking of measures were estimated as unacceptable." (Ahlers and others 2000, page 150). Main application of pentaBDE: Polyurethane soft foam for automobile seats, upholstered furniture and packing. The risk assessment for pentaBDE is available since August 2000 and an banning application of the EU Commission since May 2001 (see FN 12).

halogen-free substitutes for TCPP are aiming precisely in this direction. But simultaneously it must be ensured that the process of substituting environmentally relevant compounds by substances less harmful to the environment is not impeded by disproportionate test demands. Besides, both the Chemical Law and the EU White Book on the Examination of Chemicals (REACH procedure) are based on such a precept of proportionality.

Other aspects of substance evaluation: In the named issues there exist, in other words, *differences in assessment*. On the other hand, it was a *consensual* opinion that the risk assessment to which TCPP is now subjected at EU level because of suspected harmfulness to the environment[29], must reflect in the measures proposed. It is, at present, difficult to foresee when results of the risk assessment will become available; the prognosis for the submission of the first draft range between the end of 2001 and of 2002 (final conclusion probably in 2005 at the latest). Also, one must wait for the results of the BAM tests of flame retardant emissions from PUR insulation foams. As to the question of TCPP caused loads in interiors, it is necessary to examine all potential TCPP sources.

Limits for measures of nation-states: As to the proposition of a voluntary self-commitment to reduce halogens, the objection must be kept in mind that future imports of insulation foam equipped with halogenated flame retardants will figure more prominently. Here then, the problem enters into the subject of the efficacy of measures adopted on the national level in the face of the growing importance of the EU economic area.

Self-commitment, labelling: The industrial side brought forward the argument against "voluntary self-commitments" that they have hardly worked so far. Here there were indications of a discussion result calling for the abandonment of this proposition. Reasons given by the acting parties: For technical (sandwich elements) or cost reasons (one-component foam), a TCPP substitution is currently impossible in the quantitatively decisive sectors of application. They also argued that one should wait for the risk assessment as they consider the evaluation of TCPP to be in dispute. In connection with the "Blue Angel", one manufacturer of one-component foam pointed out that, apart from the TCPP evaluation controversially discussed in the workshop, attention must also be paid to the isocyanate content of the one-component foams which stands in the way of labelling. But according to the Federal Environmental Agency, no special "Blue Angel" for one-component foams is envisaged, but one label for all building products.

4.5 Conclusion: Revised proposals regarding polyurethane insulation and one-component foams

Considering the workshop discussion, the revised measures proposed by the Federal Environmental Agency for the sector of polyurethane insulation and one-component foams (see annex IX to this report) contains the following points:

[29] 4th priority list of 25th October, 2000. Responsible editor is UK/Ireland (see FN 40).

A) Legal regulations

A1: In the case of TCPP, in view of the critical effects not yet fully elucidated, of the proven strain on the environment, of the high tonnage and of the emission properties, legal action must be examined further. This goes in particular for the applications of PUR insulation and one-component foams close to the consumer. In this context, special attention is to be paid to loads in interiors, and the evaluation of TCPP at present conducted within the scope of the European end of life materials evaluation must be taken into account.

B) Further measures

B1: With a view to PUR insulation and one-component foams, the Federal Environmental Agency regards necessary on-going tests of the halogen-free phosphoric acid esters as substitution products for TCPP (toxicological/eco-toxicological properties of the pure substances and of the flame protected products) and the disclosure of data by the companies participating in the product chain.

B3: The Federal Environmental Agency recommends honouring the criterion "halogen-free flame protection outfitting" in future "Blue Angel" environment labels for insulation foams.

5. What promotes and what hinders substituting and decreasing environmentally relevant flame retardants?

5.1 Contradictory trends in the investigated application areas

When summarizing in brief the qualitative results of the study and workshops on substitution and reduction of environmentally relevant flame retardants in the last ten years, the following picture emerges:

- In all areas of application examined, products with halogen-free flame protection or constructive fire protection have been developed;

- in some of the applications these developments have also been put into actual practice and environmentally relevant, primarily halogenated flame retardants have been substituted or reduced in application;

- only in one area of utilization at present (still) insoluble technical problems exist.

Taking the quantitative side into consideration, the different areas of application can be characterized as follows:

In *duroplastic construction elements for vehicles on rails*, the halogenated flame protection has largely been substituted by newly developed mineral-based flame retardants (thermo-stabilized ATH).

As to *duroplastic printed circuit boards*, laminates have been developed equipped with halogen-free flame protection on the basis of phosphoric organic/nitrogen compounds instead of tetrabromobisphenol A. They are in the introductory phase, but do not as yet play a quantitatively significant part in the market.

In *thermoplastic exterior casings for IT and TV appliances*, a clear change away from halogenated to constructive flame protection (especially in TV sets) and the use of halogen-free flame retardants (phosphoric organica) can be registered. But the positive picture is darkened by the fact that, due to the strong growth in IT and TV appliances sales, the volume of electrical and electronic appliances equipped with environmentally relevant flame protection continues to be large and hardly decreases.

Thanks to a changed foam formulation (PIR block and slabstock foam), the use of halogenated flame retardants (brominated polyols, TCPP) in *polyurethane insulation and one-component foams* has, in part, decreased distinctly. Partly, however, the development observed of relevant halogen-free flame retardant formulations has not led to any practical applications in quantities worth mentioning (one-component foam). The manufacturers even forecast an increasing consumption of halogenated flame retardants. This contrasts with a still non-existent satisfactory alternative, in spite of many years of development trials, for the most important area of application of halogenated flame retardants in PUR insulation foams, i.e. the sandwich elements. (Corresponding alternatives for the quantitatively insignificant in-situ foams are not being developed.)

With *upholstery composites (textile coverings/PUR flexible foam)*, the question of substitution does not, at present, arise because the extent of outfitting with flame retardants still is, as hitherto, very low. Here for most of the areas of application practically tested alternatives to halogenated flame retardants are available.

Trend evaluation: In spite of far-reaching possibilities, substitution and reduction of the application of the so-called environmentally relevant flame retardants have, in other words, progressed to a limited extent only (IT and TV exterior casings, PUR slabstock and block foams, components made of unsaturated polyester resins for rail vehicles). As for duroplastic printed circuit boards and one-component foams, the introduction of the available development products (such as halogen-free flame retardants, halogen-free flame retarding polymers and finished products) has to battle with massive obstacles to their application; for sandwich elements technically satisfactory alternatives have not yet been found.

The picture is, in other words, full of contradictions. On the one hand, the case studies lie within the frame of the trends, reported in vol. I, of the total consumption of flame retardants (see vol. I, pp. 21 ff.: Decline in the case of brominated and chlorinated compounds – without TCPP; stability in the case of mineral-based flame retardants; increase in the case of phosphoric organica and others). This is also true in respect of the trend statements, cited in vol. I, of flame retardant manufacturers (growing importance of products which have low steam pressure and are migration stable and halogen-free). On the other hand, the substitution and reduction potentials created over the last years by the new application developments have only partly been used.

Promoting and retarding elements: This contradictory situation raises in closing the question to be answered about the moments promoting and retarding the reduction and substitution of environmentally relevant flame retardants. The overview shows that quite a few factors and interests are influencing the attitudes of the actors – of the manufacturers of flame retardants and of flame protected products, of the industrial and private consumers and of the governmental (national and supranational) institutions. Aside from technical factors, these are mainly the "political shaping" through norms and legislation and economic factors mostly interpreted as "economic compulsions by the objects" and connected with cost competition and changes in the sales markets. The question of how the relationship of technical conditions, political framework setting and "economic compulsions by the objects" turns out in detail, very much depends on the assertion of the differing interests of the actors involved, e.g. the producers of flame retardants and of flame protected products and of the consumers, on the markets as well as in public and in the political arena. From our point of view, the following factors are relevant:

- Technical development;
- norms;
- environmental politics and legislation;
- internationalisation of products and markets;
- costs;
- differing interests of producers and consumers.

To begin with, we shall examine the factors in the stricter sense of a technical nature.

5.2 Technical development possibilities and development co-operation

Technical retardants: It is only in a few areas that serious obstacles against the substitution or reduction of environmentally relevant flame retardants exist despite appropriate technical developments having been started. Examples for such technical obstacles at present still in existence are PUR sandwich elements, printed circuit boards with a higher glass transition temperature or exterior casings made of ABS with flame retardant additives.

Development conditions for the substitution of flame retardants: The developments in the various areas of application show that, generally, the solutions lie in making adjustments. The 1:1 substitution of one flame retardant by another in the drop-in fashion is, in fact, not possible anywhere because of the substance specific interplay between flame retardant, polymer and properties of the finished product. In addition, the processing properties have to be considered. The substitution of flame retardants takes place in a technical environment subject to change. Examples are the miniaturizing of electrical and electronic appliances; the change-over in propellants for PUR foaming; multilayer technology as well as increasing glass transition temperature requirements and lot substitution in printed circuit boards; the change in manufacturing materials for exterior casings or changes in the testing requirements in conjunction with the European directive for building products. As a rule therefore, the development must be organized as a co-operative process of all participants in the value adding chain, e. g. the flame retardant suppliers, polymer producers and finished product manufacturers. They all have to contribute their specific product and development competence as well as interests. It has been reported that various developments were carried out by development partnerships (see for example UP resins for vehicles on rails, vol. II, pp. 23/24; printed circuit boards, vol. II, pp. 175 ff. and workshop "printed circuit boards"; casings: vol. II, pp. 249 ff.).

Time taken by developments and substitution: As a general rule, the development time is proportional to the complexity of the product. The time which elapses between the development of a product and it's market introduction can be up to ten years. With halogen-free flame protected *FR4 printed circuit boards*, the development time for flame retartands and laminates amounted to a little more than ten years: The Siemens partnership project sponsored by the Federal Ministry for Education and Research ran from 1990 to 1995; it's conversion into marketable products lasted another five years without the substitution as such having started (vol. II, pp. 175 ff.). The development of *CEM3 printed circuit boards* flame protected by thermo-stabilized ATH required only a little time less (see vol. II, pp. 169, 173). With *UP resins for vehicles on rails*, the halogen substitution required approx. 5–7 years (see vol. II, pp. 22 ff.), and also in the case of *casings*, the substitution dragged on for almost ten years without even being completed (vol. II, pp. 245 ff.). Where-ever the change-over from PUR foams to PIR foam with reduced addition of flame retardants has taken place, the development also lasted some years and, according to reports, is still underway at different stages of accomplishment in respect of one-component foams and sandwich elements.

Co-operation in development: Once instigated, quality and speed of progress of a development process do not only depend on the technical possibilities, e.g. whether appropriate practical solutions can be found, but also on the extent of common interests in the value adding chain. It proved to be of advantage to the Japanese manufacturers of printed circuit boards that, most of the time, they pressed on with the project of "green electronics" under the roof of one group of companies because this made it much easier to co-ordinate the individual steps in production. The development reported in the workshop for printed circuit boards, of a halogen-free flame protected printed circuit board for landline telephones was carried out within a product orientated working committee (laminator/manufacturer of the printed circuit boards/end user). Reversely, differences in interest between companies engaged in the value adding chain can have a retarding effect (for instance in case of lacking demand by the finished product manufacturer: An example is the design-based fire protection, by means of inner metal nets, of monitors; on the whole, insufficient demand for halogen-free flame protected printed circuit boards or V1 material). Equal competence instead of distinct states of dependence between participants in the production chain should certainly be conducive to accomplishing developments (example: The development of block and slabstock foam by companies preparing their own formulations). As far as discernible, the dynamic factor in development chains is to be found rather on the demand side, e.g. among the marketing intermediate and finished product manufacturers who formulate and make demands on their suppliers and react to the demands of the market.

5.3 Technical norms, labelling

Norms and labelling represent aspects of the "technical-political shaping" of a frame work of conditions for flame retardant equipment.

Technical norms serve the standardization of industrial products. Besides the institutionally created norms of the recognized national and international norm institutions (like DIN or CEN), the "informal" norms of industrial associations established on the market and, therefore, practically binding for the producers must also be acknowledged. Environment related labels awarded by various institutions have a similar informal-normative function (Blue Angel/RAL; TCO and others).

The technical norms belong to the general conditions which have to be observed in substitution and reduction processes. Besides others, they also include the safety and fire prevention norms. Norms, material properties and production and processing procedures mostly represent a complex optimized over a longer period of time which impedes the changing of individual parameters (such as, for instance, flame retardant equipment of a material), because the other parameters are to remain unchanged. For example, the market established informal norm for fire protection equipment of FR-4 printed circuit boards (UL 94-V0)[30] has a substitution impeding effect which, according to all actors participating in the manufacture of printed circuit boards, cannot, in fact, be removed without government intervention, although under fire protection aspects, this norm would not be necessary in many areas (workshop "printed circuit boards").

Change of norm: The change of norms can ease or only make possible alternatives in fire prevention. Examples for such effects: Whilst formerly certain flammability

[30] For the norming of printed circuit boards see vol. II, pp. 142 ff. and 157 ff. The market demands as standard FR-4 material meeting the requirements of the National Electronics Manufacturers Association (NEMA, USA) material corresponding to the fire prevention class V0 of the Underwriters' Laboratories (which belong to insurance companies). Here on the one hand, the NEMA norm and, on the other hand, an informal "market norm" have established themselves, because NEMA does not prescribe V0 as fire protection, but only "at least V1".

properties were prescribed for the rear panels of TV sets, the safety norm valid today also opens the possibility of constructive flame protection (see vol. II, pp. 221 ff.). The change, connected with the European directive for building products and with the SBI test, of the fire safety norms, in the future probably causes an increased application of flame retardants in one-component foams equipped with halogenated flame retardants. But this would not hinder the substitution of halogenated flame retardants which, at present, does not progress for a different reason – higher costs of the halogen-free products (workshop "PUR insulation foams"). With the growing attention given to by-products of fires in fire safety norms such as smoke gas density and toxicity (example vehicles on rails; see vol. II, page 9; building products, ibidem, page 53), factors gain in importance which support the halogen substitution.[31] The mineral-based flame protection in duroplastics for vehicles on rails could not have succeeded without the new requirements as formulated by the London Underground. Thus, norming also reflects different interests (ways of achieving fire safety) and value orientations (like weighting of fire by-products).

Market impact of norms: Norms must also be regarded as elements of "market demarcation" and "market forming" (example: Whilst on the US market UL 94-V0 is demanded for materials of TV outer casings, in Europe the fire protection of TV sets as prescribed in the EU norm can be guaranteed constructively, without equipping the casing materials as per UL 94-V0). Therefore, the introduction of consumer orientated safety standards (protection from fire hazards) is, from the viewpoint of the flame retardant producers, an interesting lever for expanding the market. Respective attempts to shape the market with informal norms by influencing the public through the media can be observed as regards outer casings for TV appliances and monitors and of upholstery furniture, where, amongst others, the producers of flame retardants mobilize, for the purpose of flame retardant equipment, safety needs of the consumers. As reported in the workshop on outer casing materials, large internationally operating OEMs also feel forced to follow such trends even if they really don't consider it necessary to equip the outer casings with flame retardants in view of the given constructive fire protection. In contrast herewith, the upholstery furniture industry, being orientated towards national markets, in most EU countries rejects a general equipment of it's products with flame retardants partly for cost reasons and partly because of the scepticism of it's

Labelling: Customer orientated environmental labels like the Blue Angel or the TCO seal demanding flame retardants to be free from halogen (see vol. II, pp. 246-248) are, to a certain extent, comparable with technical norms. They, too, contain technical regulations and influence the market. But they are stipulated by institutions which are more open than the norming institutions, beyond the technical-economic

[31] When plastics penetrated the electrical and building sectors after World War II, their equipment with flame retardants proved to be a key factor in expanding the markets. The technical norms for fire safety were developed in connection with this market expansion (see Schramm and others, pp. 23 ff., pp. 32 ff.). The narrowing, then having taken place for pragmatic reasons, to the criterion of fire adverseness favoured the halogenated flame retardants because of their effectiveness and versatility in application, but their fire by-products were left out of account. Both it's test technical advantages (review of one factor) and the fact that, with sufficient fire protection, a fire incident (and consequently also the fire by-products) is relatively rare, spoke for this approach. With the increased use of flame protected synthetic materials, the growing importance of fire protection in closed rooms and the evacuation problem (aircraft, vehicles on rails, buildings etc.), the fire by-products moved more into the centre of attention (see Troitzsch 1990, pp. 75 ff.). As has been exhibited in the individual case studies, moments triggering the substitution efforts of the last decade and a half were large fire incidents (for instance in the London Underground) and the general debate about dioxin.

sector, to public debate and the political decision making process.[32] In view of the tendency towards world-wide markets ("globalisation"), the great finished products manufacturers are inclined to combine and enforce globally the norms which, under safety and environmental aspects, are the most severe. Here, conflicts between environmental and safety aspects are to be expected (workshop "Casings"). In fire safety one must insist that it is effected in the environmentally most compatible way.

Voluntary abandonment of PBDE: As a "norm with limited reach" one can also regard the voluntary self-commitment of the VKE and TEGEWA members to abandon the use of PBDE in the Germany. It represented a reaction of the respective industrial associations to the public dioxin debate, binding the members. The commitment was only of limited effect because of the free access processors without association membership had to PBDE and because of the occurrence of PBDE in imported articles, but it was not without importance for the substitution process as it reduced the use of PBDE and directly proved that PBDE can be relinquished.

5.4 Environmental policies and legislation

Environmental politics and legislation, where-in the social debate and altercation over the handling of chemical risks is condensed into a legally binding regulation, are a decisive element, similar to the norms relevant to fire safety, amongst the general conditions for the substitution of flame retardants. The discussion in the workshops of possibilities for and limitations of regulating measures adopted on the nation-state level of Germany points to the shift, presently taking place, of the regulating competence from the national to the supra-national level of the EU and to the side by side existence of national and European regulations. When coming to the question of whether and where directives by the law have in the past perhaps been the driving element behind the substitution of flame retardant, the interlocking of national and supra-national level must always be remembered as both levels were already closely intertwined in the past. The environment law belongs to those sectors of law where EU communization is most thorough. We shall first have a look at the German, then at the European level of chemicals politics.

Chemicals policies in Germany: In Germany, except for a few exceptions, no direct prohibitions or restrictions exist with regard to the flame retardants and areas of application[33] reviewed within the scope of the study. But some indirect regulations are of importance.

In the eighties, the dangers emanating from dioxins and furans came into the visual field of the environmental concerns in Germany.[34] Next to the polychlorinated dioxins and furans discussed at first, this also applied, beginning in 1985, to the polybrominated dibenzodioxins and -furans (PBDD/DF). An initial report on PBDD/DF was submitted by the Federal Environmental Agency in 1985, followed by a second

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[32] In the Federal Republic of Germany for example the RAL/Deutsches Institut für Gütesicherung und Kennzeichnung e.V. (German Institute for Quality Protection and Labelling), which in conjunction with the Federal Environmental Agency and the Federal States and with the participation of a jury awards the "Blue Angel" as environmental label (label utilization contract). The "Blue Angel" was introduced in 1977 by the ministers of the Federal States and of the Federation responsible for the environmental protection.

[33] Prohibition of tris-2,3-dibromopropylphosphate, phosphoric acid triethylimide and PBB in articles of convenience manufactured with the use of textiles (see vol. II, page 292).

[34] A summary is given in Federal Environmental Agency 1989, pp. 2/3, and Pohle 1990.

state of affairs report in 1989. In the public debates (in parliamentary committees of the lower house of the German parliament and of federal state parliaments, in the media, in joint commissions of the Federal Government and state governments etc.), recourse was taken to publications of the American Environmental Protection Agency EPA. The US EPA, in late 1985, also initiated a first regulation for chemical products to be tested for contamination with dioxin/furan (mainly brominated flame retardants; inauguration 1987). On the side of the industry there followed, in 1985, the foundation of the "Brominated Flame Retardant Industry Panel" (amalgamation of the American producers of brominated flame retardants for the purpose of safeguarding their interests in the dioxin debate). In Germany, the TEGEWA/VKE enterprises, in 1986, declared their readiness to use substitution products instead of PBDE and to stop using PBDE. The decomposition tests of halogenated flame retardants and plastics equipped with flame retardants initiated in the same year by VCI and Federal Environmental Agency showed, amongst other things, that PBDD/DF can form also under normal conditions of processing synthetic materials. This led to workplace inspections and medical examinations of long standing employees in the plastics extrusion at BASF (1989), in which increased PBDE loads were discovered (see also vol. I, page 81, vol. III, page 18). The state of affairs report of the Federal Environmental Agency of 1989 and the report of the UMK working committee "brominated flame retardants" of 1989 led to further public discussions and regulations by law.[35]

Amongst the regulations by law and next to the 17th BlmSchV (1990; dioxin/furan ambient standards for incineration plants; see Johnke 1993), the dioxin ordinance of the chemicals law of 1994[36] (dioxin/furan ambient standards in preparations and products) must be specially emphasized. The ordinances mentioned attach to the disposal (waste incineration) as well as processing and recycling of plastics equipped with flame retardants. When it is said that plastics equipped with brominated flame retardants can "safely" be incinerated, along with other waste, in normal incineration plants, it should be kept in mind that this is only thanks to the expensive exhaust emission control as a result of the 17th BImSchV. The dioxin ordinance, on the other hand, has a rather precautionary character. It limits, in practice, the use of PBDE and, thereby, promotes the search for substitutes in a general way. The Technical Guideline (TA) "Housing Estate Refuse" of 1993 which is to eliminate, in the long term, the deposit of untreated organic refuse in landfill sites, is important in view of the future[37]. According to the technical guideline, plastics equipped with flame retardants such as PUR foams must be incinerated as of 2005. Here pressure is

[35] In 1989, the Federal Environmental Agency had already recommended banning PBDE in accordance with § 17 Chemicals Law, initiating a EC guideline acting in the same direction and regulating PBDD/DF in the GefStoffV (hazardous substances ordinance) like PCDD/DF. See Federal Environmental Agency 1989 and Pohle 1990. The UMBK working committee "brominated flame retardants" assumed that a general prohibition of PBDE in the Federal Republic would be in conflict with the law of the European Community and, therefore, advocated a EU uniform banning regulation. The proposal to ban PBDE, introduced in 1991 by the Federal Republic, the Netherlands, Denmark and Sweden, was rejected by the EU Commission under pressure from the UK, France and Italy. Referring to the PBDE tests initiated by the OECD, the EU Commission also argued that the results of these tests should be awaited before contemplating actions. See Schramm and others 1996, pp. 119 ff., 130. The pending prohibition of pentaBDE has already been mentioned.

[36] First ordinance to change the Chemicals Prohibition Ordinance of 15th July, 1994, BGBl (Federal Law Bulletin) 1994, part I, pp. 1493-1495. The "dioxin ordinance" is the first also to cover brominated dioxin/furan. Because of carcinogenicity, for dioxin/furan a TRK value instead of a MAK value applies. Other than the dioxin ordinance, this value (50 pg/m³), established in 1993, only applies to chlorinated dioxin/furan. For PBDD/DF a value recommended by the AGS (also 50 pg/m³) is valid since 1998 (see HVBG 2001).

[37] For depositing, the "Directive for the Environmentally Compatible Disposal of Housing Estate Refuse and for Biological Treatment Plants" (see FN 21).

being exerted to minimize the use of halogen, as by the European Incineration Directive (2001).

The *Hazardous Substances Law and the setting of limiting values* do not yield any direct causes for substitution. The *obligation* established by the Hazardous Substances Regulation (GefStoffV) *to label* substances in conformity with the EC classification guideline (67/548/EEC) is relevant for substitutions[38] to the extent that it offers, in a limited measure, a yard stick for comparing different substances as to their individual classification (hazard symbol, R and S sets).

<u>*OECD chemicals policies*</u>: In 1994, the OECD published a study, based on the OECD Council Acts for "Co-operative Investigation and Risk Reduction of Existing Chemicals" adopted in 1990, on the risks of brominated flame retardants (OECD 1994). The background for this study was also the debate on dioxins/furans in the USA and Europe. The study was followed by a voluntary commitment of the most important producers of brominated flame retardants to pursue risk minimizing measures (amongst others mechanistic and toxicity studies; locking in of the status-quo coupled with an abandonment of production and importation/exportation of PBB with the exception of decaBB and of the non-commercial PBDE provided they are not an ingredient of the trading products; improvement of the substance purity; emission reducing measures). Respective reports went to the OECD in 1998 and 1999 (see vol. I, pp. 30 ff.)[39].

<u>*EC End of Life Regulation*</u>: In the EU, for end of life materials the directive 793/93/EC of the Council on Evaluation and Control of the Environmental Risks of Chemical End of Life Materials of 1993 applies. This directive is the legal basis of the risk assessments which a number of flame retardants are presently subjected to. Legally binding risk minimizing measures must be initiated if, in these assessments, risks to the environment and health are discovered.[40] The flame retardants affected are the three most important PBDE (octa-, penta and decaBDE), TBBA and HBCD, TCEP and TCPP as well as antimony trioxide. An application to prohibit pentaBDE is pending (see FN 12). The length of time required for and the comparatively great effort connected with this testing of used materials have rather delayed a quick regulatory dealing with the respective flame retardants and thereby proves to be an at least temporary continuance guarantee because, with reference to the ongoing risk assessment, national measures as demanded by, amongst others, the

[38] The abandonment of TCEP was a reaction to the R 40 classification of TCEP ("irreversible damages possible"). As the EC classification directives are based on article 95 (ex-article 100a) of the EEC treaty, the respective classifications are binding for the member states. In *industrial safety*, the EC regularizations represent minimum standards so that vis-à-vis the EU substance classification perhaps further-reaching national regulations such as the TRGS 905 ("Listing of carcinogenetic and mutagenetic substances and of substances dangerous to reproduction") must be observed (see Bender 2000). Such differing classifications by DFG, EEC and TRGS 905 came to light, for example, in the case of TCEP and antimony trioxide or decabromodiphenyl ether (see FN 25). More severe national regulations must be authorized by the EU Commission in accordance with article 95.3 of the EEC treaty as justified exceptions. This requires the existence and recognition of a special national problem.

[39] "Voluntary Industry Commitment by the US and European Producers of Selected Brominated Flame Retardants covered under OECD's Risk Reduction Programme" of 30th June, 1995. Reporter was the CMA (US-Chemical Manufacturers Association) in the name of BFRIP as a CMA member and of the European Flame Retardant Producers' Association) (EBFRIP as member of CEFIC).

[40] The selection of substances takes place in accordance with a fixed procedure by means of priority lists. Between 1994 and 2000, four priority lists with a total of 140 substances have been passed. Flame retardants affected: 1st priority list (1994): DecaBDE, octaBDE; 2nd priority list (1995): TCEP, HBCD, pentaBDE; 4th priority list (2000): TBBA, ATO, TCPP. Final reports have meanwhile come to hand for 11 of these 140 risk assessments, all of these being substances of the 1st priority list of 1994 with the exception of pentaBDE which is in the 2nd priority list (see: http://ecb.ei.jrc.it).

Scandinavian countries are being put on hold.[41] The development of quicker and more flexible test methods better seizing on the intrinsic substance properties (for example PBT criteria) is the object of re-conceiving the European chemicals politics with the EU white book (see Ahlers and others 2001).

EU directives on electronic scrap (WEEE, ROHS): The drafts passed by the Council on 7th June, 2001 of the two electronic scrap directives provide, with a view to environmentally relevant flame retardants, for the following: Firstly, the removal of printed circuit boards and of plastics equipped with brominated flame retardants from electric and electronic appliances intended for recycling (WEEE). The recycling quotas stipulated in the WEEE limit the possibility of unrestricted utilization and disposal by incineration of contaminated plastics. The duty to dismantle makes the disposal of brominated plastics more expensive. Secondly, the prohibition of PBB and PBDE as of the 1st of January, 2007 (ROHS). The list of prohibited substances is to be actualized two years after the directive has taken effect, taking the principle of precaution into consideration.[42] Both measures will enhance the substitution of brominated flame retardants (see workshop on printed circuit boards).

EU incineration directive: The EU incineration directive passed in 2001 (see section 4.3) enforces the incineration as toxic waste of waste classified as hazardous (requiring monitoring) with a halogen content over 1 weight percent. If in future, as the result of a revision of the European waste catalogue, PUR waste (rubble) should be classified as "hazardous" (in need of monitoring), the disposal of corresponding PUR insulation foams would become considerably more expensive (logistics; incineration costs).

Limits set by EU law to independent regulatory measures of Germany: In all the workshops, this problem played a role in the discussion of the measures to be taken. If a European legal regulation exists based on article 95 of the EC treaty (alignment of the legal and administrative regulations of the member states) as is, for instance, the case with the ROHS regulation, the room for independent measures is narrowly limited. Article 95.3 calls for "a high level of protection" to be secured in the areas of health, safety and environmental and consumer protection, and that in this pursuit "all new developments based on scientific results" must be considered. Whilst article 95 does principally allow for regulations deviating from EC law by individual Member States for the protection of the environment or the working environment, this is subject to a notification procedure, i.e. approval or rejection of the respective regulation by the EU Commission. This procedure is to check whether the regulation proposed by the individual member state is justified by a "specific problem" of the member state, or whether it represents "a means of arbitrary discrimination and a veiled infringement of the free trade between member states" hindering the functioning of the common market (article 95.6). Here, the supreme object is the completion of the common market. In regulations on the bases of article 175.1 of the

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[41] See Ministry of the Environment, Sweden/ Ministry of Environment and Energy, Denmark, 24th November 1999, "Memorandum from Sweden and Denmark on Brominated flame retardants – Environmental Council 13-14 December 1999". This memorandum recommended to stop, as quickly as possible, the use of PBDE and PBB on a European level. Against the background of, amongst others, a study by the Swedish Chemicals Authority KEMI: "Phase-out of PBDEs and PBBs. Report on a Governmental Commission, Solna 1999" (also see KEMI press release of 15th March, 1999 and Arbeit&Ökologie-Briefe Nr. 12 of 16th June, 1999, page 5), the Environmental Directorate of the EU Commission, in 1999, proposed a corresponding ban. See ENDS Daily of 12th August, 1999.

[42] See European Council, press release 2355. Conference of the Environmental Council on the 7th June, 2001.

EC treaty (Protection of the environment – minimum standards), e.g. the WEEE, the scope is somewhat larger because Member States basically have the possibility " to uphold or introduce stricter safety measures". Here also it applies that the measures must be in conformity with the EC treaty and that the Commission must be notified (article 176 EC treaty).

In practice, this impedes further-reaching national regulations in the interest of preventive environmental protection and requires a time consuming negotiation and compensating process for bringing about corresponding regulations at the EU level founded "on new scientific knowledge". From the viewpoint of the *public debate and opinion forming in environmental politics in Germany*, at the EU level retarding moments rather influence the substitution of environmentally relevant flame retardants.

Conclusion, environmental policy: Retrospectively, environmental policy measures to promote the substitution of environmentally relevant flame retardants were instigated by the public dioxin debate at the end of the eighties, but, except for a few legal regulations at national level in the first half of the nineties, only progressed slowly. This was very much due to the enormous amount of time required by the EC existing substances evaluation. The presently relevant measures stem mainly from the European waste law sector (WEEE, ROHS). With environmental legislation taking place at the European level, a second supra-national compensation mechanism acquires an importance overriding the national "lobby and compensation level" where the diverse interests of the actors along the value adding chain, of producers, consumers etc., in the course of their taking influence on the legislative process, assert themselves and are being worked off. Translating the debate in society on chemicals (primarily at national level) into legislation (increasingly at European level) is subjected to a further filter which, because of the necessary intergovernmental co-ordinating and execution mechanisms, is time consuming and opens wide corridors of influence to business interests organized in associations.

5.5 Costs

In examining the cost factor, we move to the economic factors which present themselves to producers and consumers as factual compulsions largely beyond their influence, but which are, nevertheless, quite subject to political influence (for instance disposal costs).

Production and processing costs: A decisive factor at all stages in the substitution/reduction of environmentally relevant flame retardants are the costs incurred. This goes for the costs of primary products (flame retardants, flame protected polymers) and the willingness of industrial clients, if necessary, to accept cost increases for the substitution of environmentally relevant flame retardants, as much as for the costs of the finished product where, as a rule, it is argued that higher prices, if that is the case, for ecologically optimized products cannot be realized "in the marketplace". Where alternatives offer cost advantages, there, too, the cost argument is the decisive argument in favour of substitution. The costs of the flame protected material (polymer) or of the finished product depend only in part on the costs of the flame retardant. This makes the cost advantage usually attached to brominated flame retardants somewhat relative. Also, in the concrete case the change-over costs (development, changes in production procedures and manufacturing equipment) may be more determinating than the pure primary product prices. Furthermore, the costs of toxicological/ecotoxicological substance tests of the flame retardants are a problem constantly discussed. In these tests it is weighed whether a product can bring in the costs of a carcinogenicity test, or whether such an investment, in view of limited sales prospects, would make the flame retardant too expensive and is, therefore, in-opportune.

Cost bearing and cost development: With production costs, the question regularly arises of who is to bear them within the labour divisional value adding chain and to what extent they can be passed on. This depends, in each individual case, on the market power of the primary product suppliers and end-users. However, the costs are very much subject to scale effects, i.e. the quantity of goods sold. For this reason, it is agreed everywhere that, with the proliferation of the change-over to flame retardants environmentally less relevant, their costs and the costs of the materials equipped with them will sink (see workshop on PUR insulation foams and printed circuit boards).

Disposal costs: Next to the manufacturing costs, the costs incurred in connection with disposal are becoming more important (for example as a result of the electronic scrap directive, waste classification and incineration guideline). In contrast to the production costs, these are almost always costs accruing in economic enterprises as the result of corresponding legal acts imposing upon the enterprises costly obligations (taking back of end of life products, recycling, environmentally compatible disposal) as to the handling of waste. This cost type is, in other words, highly dependent upon politics.

Printed circuit boards: With printed circuit boards, the basic material producers designate the higher costs of the phosphorus organically flame protected basic material (differences in price of between 10 and 30 % were mentioned) and conversion costs in reprocessing (drying because of higher water absorption; changes in drilling etc.) as the ultimately decisive obstacle. They claim that the end-user clients would only accept moderate price increases. However, examples of a cost neutral change-over already exist (see workshop on printed circuit boards). The Japanese manufacturers, in their market strategy, expect the European consumer to be willing to pay higher prices for "green electronics" (see vol. II, pp. 154/155). Their quicker market presence with material equipped with halogen-free flame retardants is likely to be due also to a simpler cost apportionment of the development and changer-over costs within the conglomerates. Sony, however, as the leading enterprise in the switch-over to "halogen-free", does not use in-house developed basic material. In the future, the energy costs connected with the WEEE could exert pressure in the direction of substitution (sorting out printed circuit boards containing brominated flame retardants).

Casings: Casings show that the system price for compounds is more decisive than the price of the individual flame retardant. The domain of the low-cost (brominated) flame retardants is chiefly in terminals of the lower price segment. Here, too, the WEEE related disposal costs should become a sensitive element supporting the halogen substitution.

PUR foams: The cost aspect is the driving force behind the environment relieving switch-over from PUR to PIR *insulation foams* (block and slabstock foam) as PIR foams offer a cost advantage (see workshop on PUR insulation foams). In contrast, the higher costs of halogen-free flame protection in *one-component foams* have a hampering effect and the manufacturers assume that the hotly contested market will not yield higher prices without legal flanking. As to the *sandwich elements*, in addition to technical conversion problems, the conversion costs resulting from the higher processing temperatures of PIR foam were also mentioned (investment into new equipment where-ever the existing manufacturing lines cannot be equipped with new heating aggregates).

Costs versus expanding markets: Higher production costs expected for a number of the analysed applications in case of a switch-over to halogen-free flame protection are, however, only one factor in the cost calculation of the enterprises; on the other hand, calculations are made about market shares and over-all revenue, and in doing so, the marketing effects and possible stabilisation or expansion of sales markets with the help of environmentally compatible products must be considered. This is an important aspect for enterprises favouring "green electronics".

Constructive fire protection: The workshop came to the conclusion that no clear trend can be predicted about the costs of measures to achieve fire safety by construction. Besides saving effects through abandoning flame retardants, a possible higher material consumption and weight increase and similar effects must be taken into consideration which could lead to cost increases (e.g. in transport expenses; see workshop on casings).

Trend: On balance the impression is that substituting and reducing the use of environmentally relevant flame retardants only partially leads to cost increases for the finished products, but that the costs unavoidably added to application and processing by development and conversion as well as the initially higher costs incurred when introducing new products until scale effects are achieved, constitute an essential, if not the decisive obstacle against conversion. At the same time it appears that a political "turning of the cost screw" not necessarily only by tax regulations, but possibly also by administrative directions (e.g. recycling quotas and procedures), can be an important lever for speeding up substitutions desirable from an environmental policy point of view.

5.6 Internationalizing/globalizing of markets

Internationalizing products and sales markets ("globalizing") certainly falls in with the factors influencing the flame retardant conversion. Ceding environmental policy making and legislation to the European level (see section 5.4) is a reflex and an accelerating element of internationalizing. It also shows that this is not a purely economic process but one which can be influenced politically.

Internationalizing of markets versus environmental standards: In the workshop discussions it was underlined that in the sectors where globally acting enterprises and globalized procurement and sales markets exist – this is especially so in the case of electrical and electronic appliances and their components, printed circuit boards and outer casings – , forces of product and cost competition are at work which out-reach the EU. Internationalizing markets can be connected with a generalization of standards disregarding environmental interests. It can mean an increase of international trade lowering, because of price competition, regionally existing product standards of environmental compatibility (where regulations are not legally binding); for economic reasons it can lead to uniformity in product ranges eliminating, in contradiction to internal market related regulatory measures, products environmentally more compatible.

Printed circuit boards: To-day, electrical and electronic appliances and their components are traded internationally. For *printed circuit boards*, a global market exists for material of world-wide standards (mainly FR4, V0, conforming to the NEMA norm). International standardization obstructs the TBBA substitution. For the same reason, manufacturers consider a partial change in the fire safety norm (from V0 to V1) hardly possible. On the whole, the dominance and demands of the US market exert themselves here (see workshop on printed circuit boards). The levers to set substitution in motion were government subsidies for research (Federal Ministry for Education and Research (BMBF)-Siemens project 1995; BMBF project "green TV set") and the ensuing "green electronics" campaign as pursued especially by Japanese companies. Real changes require one or a few original equipment manufacturers (OEMs) to lead the way, which could be supported, for instance, by labelling (stimulation of demand).

Exterior casings are also traded internationally. Great international markets with different fire safety standards (norms) must be distinguished (Europe: Fire safety more by construction; USA: Fire safety additively according to UL94 V0). On single markets (in Europe: Germany, Scandinavia), the substitution of halogenated flame retardants has advanced markedly under public pressure (dioxin debate; halogen debate by the environmental leagues; devaluation of halogenated flame retardants in test journals and other media). But despite acceptance by the Underwriter's Laboratories, constructively flame protected PC monitor casings (Nokia; Samsung-BASF model) could not establish themselves on the US market because of the reservations which exist here against casings without flame protection (see vol. II, page 250). These reservations are rooted, amongst others, in the product liability laws of many US Federal States which (different from the liability laws for example in Germany) include penal compensation for damages and thus the risk of high recourse sums. In connection with globally orientated production and marketing (uniform material, uniform products) and the inclination to combine standards which are as "safe" as possible, a tendency towards increased out-fitting with flame retardants is reported on the international floor, for instance in casings for TV appliances (workshop on casings). The interests of the US market are aggressively pursued here (see fire marshals, threat to curtail trade; see vol. II, page 222).

Polyurethane insulation foams (block and slabstock foams) are marketed more regionally, but the markets of *sandwich elements* and especially of *canned foams* are more or less Europe-wide. The system houses supplying the PUR intermediate products operate world-wide. The internationalizing is evidenced by the high import quotas already existing (in the case of one-component foams > 75 % of domestic sales; see vol. II, page 72) and by the increase in insulation slabs expected for the future once the European norm of the building materials guideline takes effect. It is doubted whether national measures for substituting flame retardants (brominated polyols, TCPP) are feasible or would be effective in curbing possible imports containing halogen (workshop on PUR insulation foams).

5.7 Differing interests of producers and consumers

Finally, enhancing and retarding moments result from differing interests of producers and consumers.

Interests of producers and consumers: On the *producers' side*, one must see that, in the value adding chain from the flame retardant producer via the materials/polymer supplier to the finished product manufacturer, the enterprises are decreasingly tied to certain production materials and procedures, making them more readily prepared to substitute. On the *consumers' side*, their emphases on products as low-priced as possible, on safety and on health and environmental protection aspects are usually contending. Costs, safety and environmental protection are, at the same time, important factors in producer competition on the various levels of the value adding chain.

Finished product manufacturers: In all applications examined and in all three workshops, it became clear that the *finished product manufacturers* are primarily interested not in the use of specific substances, but in meeting the norms demanded, and partly also in the exclusion of certain substances undesired for industrial and consumer safety reasons. If, for reasons of demand side pressure by the end-users or of legal regulations or of costs, big original equipment manufacturers are interested in halogen-free flame retardants, they can push their interest through either with the help of constructive measures of their own (manufacturers of TV sets) or by their market power (demands made on the materials suppliers) (electrical/electronic industry; see Siemens, workshop on printed circuit boards). The latter depends on the availability of alternatives. If no legal compulsion exists, the finished product manufacturers decide by cost aspects and profit chances. This is true also within the scope of international competitive relations and also applies to the marketing concept for "green electronics" which is based on the assumption that environmental protection standards will obtain more weight and that the end-consumer will be willing to pay higher prices for ecologically improved products (see vol. II, page 155).

Suppliers: Conversely, the *producers of the various flame retardants* depend on marketing their respective products or product lines and on the expansion of their market areas. Their strong dependence on certain of their products[43] leads them, by necessity, to try to prevent the toxicological/ecotoxicological properties of their substances to impede their sales. The same also applies to the producers of

[43] The importance of brominated flame retardants for the three big enterprises in the bromine industry can be gleaned from the following facts: Flame retardants are quantity-wise the most important sales segment in the bromine industry. Between 1975 and 2000, the share of brominated flame retardants in the consumption of bromine increased from 8 to 38 %; the total consumption increased tenfold in this period. Dibromethane (ethylene bromide, antiknock agent for plombiferous fuels), which in 1975 with about 52 % represented the largest share in the bromine consumption, fell to 11 % in the same period. Total consumption here fell to one third (Arias 2001, page 2). Amongst all products, TBBA and decaBDE are by far the most important. According to information given by BSEF for 1999, 59 % of world wide consumption of brominated flame retardants fell to TBBA and 27 % to decaBDE, i.e. 86 % to both together. PentaBDE, about to be prohibited, only accounted for 4 % (see vol. I, page 20, table II/3). Amongst the organic phosphoric acids used as flame retardants dominates by far TCPP on which fells in Europe a share of about around 80 percent of the total consumption of chlorinated phoshphorus organic flame retardants.

intermediate products who consider the respective flame retardants as essential and impossible to substitute (example: Polyurethane foams). This became particularly obvious in the workshop discussion on the evaluation of TCPP and TBBA as two products which, quantity and value-wise, are of central importance to the producers of phosphorus organic and of brominated flame retardants. It is plain that the producers of environmentally relevant flame retardants recommended for substitution are demanding continuity protection for their existing products[44] and are lobbying towards that end.[45]

Restructuring of the flame retardant industry: The sensitization, connected with the public debate of chemicals – especially since the eighties the dioxin debate, but also the debate in the media of the discoveries of phosphorus organic flame retardants (amongst others TCEP, TCPP) in interiors – , especially for halogenated compounds, the growing number of regulatory measures in this area and the development of substitutes have led to a re-grouping of the flame retardant industry during the last five years. The producers of brominated flame retardants have freed themselves from the all-exclusive linkage to this substance class and have (mainly by buying other companies) developed into large producers of phosphorus based flame retardants (see vol. I, page 22; Arias 2001, page 8). The take-over, in 2001, of the most important producer of mineral-based flame retardants (Alusuisse Martinswerk GmbH, Bergheim) by the Albemarle Corp. (one of the three large producers of brominated flame retardants) is a continuation of this trend of re-structuring the flame retardant industry. This also could, in the long run, facilitate the change to flame retardants less environmentally encumbering, but it also means a stricter control by the bromine industry over the entire flame retardant industry. The competing producers of phosphorus organic compounds and mineral-based flame retardants have, on their part, made efforts to impinge on the market of brominated flame retardants with substitutes (see the extensive development work undertaken to substitute halogenated flame retardants in UP resins for vehicles on rails or the development of halogen-free flame protected casing materials; vol. II, pp. 23-28, pp. 226-233).

Consumers: *Consumer behaviour* as a demand factor is greatly determined by price considerations. The different out-fitting with flame retardants as, for instance, reported for IT and TV appliances of the lower and upper price brackets (halogenated/halogen-free; see workshop on exterior casings), is linked to this attitude.

Fire protection/protection of the environment: Apart from this, the end consumer is torn between two *value in use* interests: Safety from fire accidents, i.e. fire protection, on the one hand, and protection from chemical pollution (ecological and healthy products) on the other. The emphasis placed on both these interests or value

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[44] Risk minimizing measures taken by the flame retardant producers for the purpose of securing tolerance of continued usage ("clean production") consist, among others, in increasing product purity and reducing emissions in production, transport, marketing and by the processed product, inclusive of comparable measures to be taken by their clients (counselling of processing clients). They also consist in attempts to influence the disposal (recycling of flame retardants). An example are the voluntary risk minimizing steps taken, within the scope of the OECD, in the case of brominated flame retardants (see section 5.4) or risk minimizing steps in connection with EU risk assessments.

[45] See "Bromine is best ... A newsletter from the Bromine Flame Retardant Industry" 2001, no. 1-4, issued by the "Bromine Science and Environmental Forum" (BSEF) of the bromine industry in connection with the controversy about the WEEE andf ROHS guidelines. The Alusuisse Martinswerk GmbH reacted with their own "Fact-Sheet of a Halogen-Free Flame Retardants Producer" (Bergheim, May 2001).

orientations differs regionally and socially, each depending upon cultural and political special features. In contrast to Europe, on the US market environmental aspects, for instance, play a lesser role than the safety aspect. In appliances safety, for economic and cultural reasons the US American fire safety philosophy traditionally places more emphasis on exterior ignition sources, whereas the European fire safety regulations are usually only meant to protect from inner ignition sources. Definition and weighting of both these usually competing interests in safety from fire hazards and protection from chemical pollution are subject to debate in society. In this, all actors and their associations – producers of flame retardants and of products equipped with flame retardants, fire safety institutions including the fire-brigade, consumer and environmental associations, political institutions – partake including the media. This was also demonstrated by the question dealt with in the workshop discussion about the inclusion of the Federal Environmental Agency in the debate about "fire safety philosophy" (importance of external ignition sources).

Changing risk perception: The shift, observed in reaction to the big chemical accidents of the seventies and eighties, in public risk perception and evaluation has led to the protection of the environment and of health being more highly appreciated within the spectre of public interests. It is also probably the most important factor, mediated by environmental policy and consumer demand, which has over the last few years brought about, to at least a limited extent, the substitution and reduction of environmentally relevant flame retardants and the development of alternatives of possible future importance.

6. Sources and references

Ahlers, J./ T. Beulshausen/ B. Schwarz-Schulz / H.-Chr. Stolzenberg 2000: Anwendbarkeit des Vorsorgeprinzips. EU-Kommission und Bewertungspraxis; in: UWSF – Z. Umweltchem. Ökotox. 12, 2000, pp. 149-151

Ahlers, J./ B. Schwarz-Schulz/ H.-Chr. Stolzenberg, 2001: Strategie für eine zukünftige Chemikalienpolitik. Das neue EU-Weißbuch, in: UWSF – Z. Umweltchem. Ökotox. 13, 2001, pp. 75-78

Arias, P.A. 2001: Brominated Flame Retardants – An Overview. The Second International Workshop on Brominated Flame Retardants, May 14 - 16, Stockholm University, Sweden (manuscript)

Bayer AG, 2001: Dr. Eckehard Weigand, Bayer AG, Leverkusen, personal statement

Bender, H.F.2000: Sicherer Umgang mit Gefahrstoffen. Sachkunde für Naturwissenschaftler, 2.A., Weinheim u.a. 2000

DFG 2001: Deutsche Forschungsgemeinschaft. Senatskommission zur Prüfung gesundheitsschädlicher Arbeitsstoffe, Mitt. 37: MAK- und BAT-Werte-Liste 2001, Weinheim 2001

EBFRIP 2001: European Brominated Flame Retardant Industry Panel, Dr. Klaus Rothenbacher, letter to the Federal Environmental Agency (Umweltbundesamt) of 18.6.2001, annex I to this report

EUJRC 2001: European Commission, Joint Research Centre, European Chemical Bureau: Diphenylether, Pentabromo Derivative, Summary Risk Assessment Report, Ispra 2001 (http://ecb.ei.jrc.it)

Elastogran GmbH 2001: Elastogran GmbH, Geschäftsbereich Hartschaum und Blockweichschaum, Lemförde, Dr. Thomas Schupp, letter to the Federal Environmental Agency of 18.6.2001, annex II to this report

Hellmig, K.-D. 2001: Klaus Dieter Hellmig, Nelko-Dielektra, Köln, personal statement

Holler, S./ C. Schäfers/ J. Sonnenberg 1996: Umweltanalytik und Ökotoxikologie, Berlin-Heidelberg-New York 1996

HVBG 2001: Hauptverband der gewerblichen Berufsgenossenschaften, BIA-Report 4/2001, Grenzwertliste 2000, Sankt Augustin 2001

Isola AG 2001: Herr Schumacher, Isola AG, Düren, personal statement

Johnke, B. 1993: Dioxinemissionen aus Abfallverbrennungsanlagen, in: UTA, H. 5/1993, pp. 383-387

Krüger, E./W. Bach 2001: Die grüne Leiterplatte – LP frei von Halogen und Blei, Charts Vogt electronic, February 2001

Kruse, H. 2001: Comments about the letters of EBFRIP and Elastogran of 18.6.2001 to the Federal Environmental Agency, annex III to this report

Leisewitz, A. 2001a: Comments about the letter of Dr. Rothenbacher, EBFRIP, to the Federal Environmental Agency (Umweltbundesamt) of 18.6.2001, annex IV to this report

Leisewitz, A. 2001b: Comments about the letter of Dr. Schupp, Elastogran, to the Federal Environmental Agency (Umweltbundesamt) of 18.6.2001, annex V to this report

OECD 1994: Risk Reduction Monograph No. 3: Selected Brominated Flame Retardants. Background and National Experience with Reducting Risk, Paris 1994 (author: Pedro Arias)

Öko-Institut 2001: Thermoplastische Leiterplatten für die Elektronik von morgen, press release of 25.7.2001

PARK nelco 2001: Die Grüne Leiterplatte. LP frei von Halogen und Blei. Erfahrungen Vogt Fuba Nelco-Dielektra auf dem Weg zur grünen Leiterplatte, Charts, 29.03.2001

Pohle, H. 1990: Polybromierte Diphenylether. Verbot als Flammschutzmittel, in: UWSF - Z. Umweltchem. Ökotox. 3, 1990, pp. 148-150

Rüdersdorfer Zementwerke 2001: Dr. Uta Tietze, Rüdersdorfer Zementwerke GmbH, Rüdersdorf, personal statement

Schlott, St. 2001: Im Auto soll die Spannung steigen, in: VDI-Nachrichten of 30.7.2001

Schramm, E. u. a., 1996: Stoffflüsse ausgewählter umweltrelevanter chemischer Stoffe: Beispiele für ein Produktliniencontrolling, Umweltbundesamt Texte 80/96, Berlin 1996

Troitzsch, J. H. 1990: International Plastics Flammability Handbook. Principles – Regulations – Testing and Approval. 2nd Ed., Munich u.a. 1990

UBA 1989: Umweltbundesamt, Sachstand Polybromierte Dibenzodioxine (PBDD), Polybromierte Dibenzofurane (PBDF), February 1989

UMK Working Committee 1989: "Polybromierte Dibenzodioxine und Dibenzofurane (PBDD/PBDF) aus bromhaltigen Flammschutzmitteln – Risikoabschätzung und Maßnahmenvorschläge." Report by the UMK Working Committee "Bromhaltige Flammschutzmittel" to the conference of the ministers for the environment, Bonn, September 1989

Zeininger, H. 2001: Dr. Heinz Zeininger, Siemens AG/Erlangen, Halogenfree Electronics, Charts UBA Workshop of 29.5.2001

Appendix

EBFRIP 2001: European Brominated Flame Retardant Industry Panel, Dr. Klaus Rothenbacher, letter to the Federal Environmental Agency (Umweltbundesamt) of 18.6.2001, annex I

Elastogran GmbH 2001: Elastogran GmbH, Geschäftsbereich Hartschaum und Blockweichschaum, Lemförde, Dr. Thomas Schupp, letter to the Federal Environmental Agency (Umweltbundesamt) of 18.6.2001, annex II

Kruse, H. 2001: Comments about the letters of EBFRIP and Elastogran of 18.6.2001 to the Federal Environmental Agency (Umweltbundesamt), annex III

Leisewitz, A. 2001a: Comments about the letter of Dr. Rothenbacher, EBFRIP, to the Federal Environmental Agency (Umweltbundesamt) of 18.6.2001, annex IV

Leisewitz A. 2001b: Comments about the letter of Dr. Schupp, Elastogran, to the Federal Environmental Agency (Umweltbundesamt) of 18.6.2001, annex V

Schill+Seilacher 2001: Schill+Seilacher "Struktol" Aktiengesellschaft, Hamburg, Dr. Stephan Sprenger, letter to the Federal Environmental Agency of 4.7.2001, annex VI

Federal Environmental Agency (Umweltbundesamt): Measures proposed Printed circuit boards, annex VII

Federal Environmental Agency (Umweltbundesamt): Measures proposed Outer casings for IT and TV appliances, annex VIII

Federal Environmental Agency (Umweltbundesamt): Measures proposed Polyurethane insulation and onecomponent foams, annex IX