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ScorePP

Assessment of the feasibility of strategies for limiting releases of Priority Pollutants

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Abstract

The various source control options to reduce the emissions of priority pollutants (PP) have been described in Tasks 4.1 to 4.4 of the Source Control Options for Reducing Emissions of Priority Pollutants (ScorePP) project: substitution, application of the Best Available Technique (BAT), implementation of existing regulations and voluntary initiatives. Information from Task 5.6 on assessing the feasibility of treatment options is also included when end-of-pipe options are considered.

In this document a methodology is proposed to rank the various options on the basis of well defined technical criteria. For each of them a three level scoring is suggested which allows the calculation of a global score for each option and hence an assessment of the most appropriate option for each PP source type or use. This tool is intended to help the decision process in the choice of the most appropriate option at a local or regional level. Of course the "best" option for a given type of source and/or use is not necessarily the "best" one for other sources. The scoring approach allows the determination of the most appropriate solution when several types of sources and/or PP have to be considered in the decision. Moreover, it is also possible to allocate weightings to the criteria according to the priorities of the user.

To illustrate the methodology, several examples are discussed in detail and the corresponding scoring tables are given. Due to the limited number of available data, it was not possible to consider all PPs but the examples given cover industrial chemicals, pesticides, unavoidable by-products and metals.

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1. Introduction

In the previous work conducted in conjunction with WP4 "Limiting release of PPs", namely Tasks 4.1 to 4.4, various options for limiting the release of priority pollutants (PPs) have been reviewed. These options are briefly summarised below, as the full reports to-date are not publically available:

- **Substitution:** like any other risk management option, substitution must be based on exposure and risk assessment and not on hazard. As chemicals have all specific properties, they are not fully interchangeable. The choice of a substitute is strongly dependent on the type of use considered and should take into account the performance requirements, the risk level to human health and the environment and the socio-economical costs and benefits for the producers and downstream users. This is why substitution appears technically feasible for some of the uses of a substance but not necessarily all of them.
- The way of reducing emissions via the application of the **Best Available Techniques (BAT),** as described in the Integrated Pollution Prevention and Control (IPPC) Directive, has been reviewed. The application of the BAT could reduce emissions mainly at the level of large production plants but its extension to smaller production units should also be envisaged. The key problem is the control by the competent authorities of the effective application of this Directive. In this context, the emission reduction of unavoidable by-products with persistent, bio-accumulative and toxic (PBT) properties should be considered without endangering a large part of the industry.
- The possibilities of reducing emissions provided by the application of **existing regulations** are also reviewed in detail. International, European and National regulations can be useful tools for reducing emissions of priority pollutants under situations where they are effectively implemented and controlled.
- Beyond the existing legislation, various **voluntary initiatives or commitments** can be very useful for reducing significantly the emission of priority pollutants. Information campaigns, education initiatives, eco-labeling, green procurement and voluntary commitments undertaken by cities, industrial organizations, non-governmental organizations (NGOs) and consumers are effective ways of reducing emissions.

On top of that, two other technical possibilities should be considered:

- Any **process improvement** can also be considered by the industry to reduce the release of priority pollutants, either by modifying the reaction conditions (temperature, pressure, catalysts,…) to improve the selectivity of the process and reduce by-products or by introducing specific abatement techniques to limit the emissions to water or to air.
- The use of a **Wastewater treatment** can also be an efficient way of reducing emissions of priority pollutants and should be considered among the technical possible measures. But if this option is chosen, its applicability and its efficiency should be based on the detailed discussion presented under Task 5.6 (name) also conducted within ScorePP, where the various types of wastewater treatments are reviewed and their performance assessed as a function of the type of priority pollutant. This information should be considered in the technical review of emission reduction tools.

In a practical situation, the competent authorities or other stakeholders have to choose the most appropriate solution to a given problem. It is then important to assess the technical feasibility and efficiency of these various options on the basis of well defined criteria. A general methodology is developed here after and applied to several practical cases. A choice of criteria is proposed to rank the various options but the **weight given to each criterion will of course depend on the local conditions, local stakeholders and on the available budget.**

A similar scoring exercise has been carried out in the final Task (T5.6 Assessing feasibility of treatment options) of WP5 "Treatment options". The common objective is to propose feasible measures to limit the release of each PP considered as an individual compound in relation to its uses. To support and facilitate the integration of data at a later stage of ScorePP, it was agreed at the London ScorePP meeting that Middlesex University (MU) and ENVICAT would use a common approach in completing these Tasks (i.e. Task 4.5 (lead responsibility: ENVICAT) and Task 5.6 (lead responsibility: MU)). It was also agreed that this common approach would be informed through a series of iterative discussions between ScorePP participants with differing areas of expertise. It is indeed important to develop common criteria, indicators, benchmarks and threshold values that can be used in WP9 to propose reliable, economically acceptable emission reduction strategies.

2. Methodology

2.1. Introductory remarks

The aim of this task is to propose a tentative assessment of the technical feasibility and efficiency of the various types of source control measures listed in the previous tasks conducted in ScorePP. A general comparison is not appropriate because…?. The assessment should take into account the different types and sizes of emission sources and the different types of uses and applications for each priority pollutant. Moreover, the feasibility of process improvements should be compared to the efficiency of the "*end-of-pipe*" solutions as a function of the local conditions.

For assessing the technical suitability of a measure, criteria should be defined which allow a comparison and a ranking of the various measures. The assessment will be voluntary focused on the technical feasibility and efficiency. The socio economical aspects are considered in a purely qualitative way, the details are fully described in WP8 and WP9. For example large potential cost differences between measures will be highlighted, at least qualitatively.

For the "*end-of-pipe*" solutions, we will refer to the results of Task 5.6 in which the technical assessment of the various possibilities of this type is proposed by using similar types of criteria.

In **industrial applications and cases**, emissions to water are most often localised and correspond to **point sources**. In these conditions, a specific "*end-of-pipe*" approach is usually possible but, for sustainable solutions, process improvements or the move to a less polluting process (sustainable chemistry) will be preferable. However the implementation delay and costs may considerably differ with the development of a new process taking much more time and money than the improvement of an existing one.

The **professional or customer applications** or uses are generally leading to **diffuse sources.** The type of emission reduction measures should either focus on usage reduction or on the improvement of the municipal waste treatments, which are considered here as an "end-of-pipe" treatment.

Finally, the applicability of some measures will also depend on the **local conditions**, i.e. the size of the sources, the limitations of the existing water treatments, the public policy, the budget availability, the age and performance of the industrial plants, the monitoring capacities, etc. This implies that the best solution at a given location cannot necessarily be appropriate at another location. The competent authorities should, of course, take into account their own constraints and limitations when they choose a solution. These specific aspects cannot be included in a general ranking approach such as the one proposed in this report.

2.2. Ranking criteria

The **key principles** of the ranking methodology proposed in this report are described below.

For each use/type of priority pollutant **source**, several emission **reduction meas**ures are proposed; each of them will be assessed on the basis of different criteria; each criteria will present three different levels; a score is attributed to each of the levels; the sum of these scores is used to rank the proposed reduction measure.

The proposed criteria and the corresponding scores are:

- **Technical feasibility**: score 1 if it is already feasible, score 2 if it could be feasible or implemented in less than 10 years, score 3 if it is not feasible
- **Technical efficiency**: score 1 if it could lead to a significant reduction of emissions, score 2 if it could lead to some reduction of emissions, score 3 if it will lead to a low reduction of emission
- **Probability of reaching the Water Framework Directive (WFD) target**: score 1 high probability to reach the WFD targets (cessation/negligible load for priority hazardous substances (PHS) or below environmental quality standards (EQS) for priority substances (PS)), score 2 medium probability to reach the WFD targets, score 3 probability of exceedance of the WFD targets.
  Remark: to estimate this probability we should assume that there is no other source than the use/application considered.
- **Operational costs**: score 1 if no new operational costs are needed, score 2 if limited new operational costs are needed, score 3 if high increase in operational costs is foreseen.
  Remark: this, of course, will depend on the local conditions
- **Investment costs**: score 1 if no investment is needed, score 2 if the investment needed is low compared to turn over, score 3 if investment needed is high compared to turn over.
  Remark: this, of course, will depend on the local conditions
- **Impact on the supply chain**: score 1 if the downstream users will not be affected, score 2 if downstream users should adapt their use, score 3 if the use could be suppressed.
  Remark : This score reflects the necessity for the downstream user to change their way of working without precluding that the substitute could be a better or a worse solution. This, of course, will depend on the local conditions and on the type of downstream user involved. It has to be pointed out that most of the priority pollutants are not directly sold to the general public but mainly to industrial clients.
- **Impact on employment**: score 1 if an employment increase is foreseen, score 2 if a negligible or limited negative impact on employment is foreseen, score 3 if an important negative impact on employment is foreseen
  Remark: this, of course, will depend on the local conditions
- **Impact on drinking water production from surface water**: score 1 large positive effect on the drinking water treatment plant (DWTP), score 2 limited positive effects on DWTP, and score 3 no effect on DWTP. This criteria should be considered independently from the criteria related to the possibility of reaching the WFD criteria. This is illustrated by the following examples. For substance difficult to remove in the drinking water treatment plant, even a small decrease of its concentration in water could have an interesting positive impact on the production of drinking water even if the WFD target is not reached. On the contrary, if a substance is very easily remove in a classical drinking water plant; even a strong reduction of its concentration in water will have no positive effect on the drinking water production. Drinking water treatment efficiencies are based on …?
  Remark: this, of course, will depend on the local conditions
- **Delay of implementation**: score 1 can be implemented in a short time frame, score 2 needs 2 to 3 years delay to be implemented, score 3 needs a very long delay of implementation.

As it is not possible to consider the various local conditions, the score will be given by assuming a mean representative situation but the possible effect of variations in those conditions will also be discussed in order to try to provide some inputs into a sensitivity analysis.

The future local application of the scoring process, in particular when the case cities are considered, should of course take into account the specific local conditions.

2.3. Overall assessment

The scoring approach described here above is the first step of the ranking process.

The first simple ranking consists in ranking the various reduction measures according to the sum of their scores for a given use or source type.

The second possible ranking is to define the most appropriate measure to reduce the emissions of a given priority substance by taking into account all the uses. To do so, the total scores corresponding to each possible reduction measure are summed on the various uses/application and a ranking of the various strategies can be deduced. In this scheme, the scores of the reduction measures can be weighted according to the importance of the source.

To illustrate the assessment process, an example is presented in Table 1 below.

Table 1. Example of a scoring table for a given pollutant

Pollutant 1							
		Criteria 1	Criteria 2	……….	………	Criteria n	Total score
USE 1	Measure 1	Score 111	Score 112	……….	………..	Score 11n	
	Measure 2	Score 121	Score 122	……….	……….	Score 12n	
	………….						
	…………						
	Measure m	Score 1m1	Score 1m2	…………	……….	Score 1mn	
USE 2	Measure 1	Score 211	Score 212	……….	……….	Score 21n	
	Measure 2	Score 221	Score 222	………..	………..	Score 22n	
	…………						
	…………						
	Measure m	Score 2m1	Score 2m2	………..	………..	Score 2mn	
………							
USE u	Measure 1	Score u11	Score u12	……….	……….	Score u1n	
	Measure 2	Score u21	Score u22	………..	……….	Score u2n	
	……						
	…………						
	Measure m	Score um1	Score um2	…………	....	Score umn	

If we note the score S_{ijk} the index "i" is related to the use, the index "j" is related to the measure and the index "k" is linked to the criteria. The total score of a measure x for a given use y is given by **sum on k of S_{yxk}.** The total score of a measure x for all uses/sources of a pollutant is given by **sum on i and k of S_{ixk}**.

In case of the presence of several PPs in one source (for example household sewage or effluent from a multi-production industrial site) it is also possible to rank the various possible measures applicable to this source by adding the corresponding scores and summing them on the various substances. Moreover, it is also possible to give weights to the criteria to better take into account the local constraints and the user priorities.

Such a scoring approach appears to be very flexible and seems to be potentially applicable in many situations. Some practical examples of its application are presented and discussed in the following chapters.

2.4. How to apply the scoring system

As already mentioned, the scoring methodology proposed here is a very flexible approach and it should be pointed out that the individual scores introduced in the table should not be considered as absolute values but strongly dependent on the local situation. The choice of an option will indeed varies as a function of the type of actors involved, their nature (public authorities, industry, environmental groups, social representative, ….), the level of budget available, the repartition of the costs between the actors, …

This is then not possible to provide a scoring applicable to all situations. The methodology should be considered as a tool to help the various actors in choosing the most appropriate options for their specific situation. To do that, the actors could weight the various criteria according to their own perception of the problem.

Different situations could appear:

- In a region where the unemployment is high, the actors would probably choose the option that will not negatively impact the employment even if the cost is high
- In a location equipped with a very efficient wastewater treatment, the chosen option will probably different from the choice made in a location where no wastewater treatment exists
- In some cases, the competent authorities can impose an option to the industry and force them to support the costs, for example by postponing the permit. In other cases a negotiated solution could be chosen where the costs are shared between the actors.
- It is also possible to decide the application of two different options to solve the problem.
- As far as the cost is concerned, the score will depend on the budget available and on the paying actor. A cost benefit analysis should also be considered, it means the ratio between the investment and the possible environmental gain at the local or regional level

All these examples show that the scoring could differ from place to place. The key objective of the methodology is to allow a review of all the possible technical options and to guide the user in his choice.

In the scoring applications discussed in the following chapter, indicative scores are proposed that intend to represent a neutral case and consequently, that could be considered as partly subjective because they are referring to a general approach without taking into account the practical considerations linked to a realistic local or regional problem. Moreover, the tables presented in the annexes cannot be separated from the discussion in the text. In a practical case, the scoring should always be completed by the local conditions and constrains that justify the final choice.

3. Comparative assessment of emission reduction measures

To check the feasibility and to critically assess the methodology described in Chapter 2, the described approach has been applied to a series of 11 priority pollutants, representing the various types of sources and uses. The key uses considered are those listed in WP3 and Task 4.1. The results are presented hereafter. As explained before, for the "end-of-pipe" solutions the best choice/score described under WP5.6 should be considered in this general scoring/ranking approach even if the details are not covered in this report.

3.1. The case of industrial chemicals

We consider under this point the following substances: 1,2-dichloroethane (EDC), benzene, decabromodiphenylether (DecaBDPE) as well as octylphenol/nonylphenol and their ethoxylates because they are representative of a large number of industrial substances covering several types of uses and sources.

3.1.1. 1,2-Dichloroethane (EDC)

This substance is only used in industrial activities and consequently there are only point sources and no diffuse sources. In the professional and consumer markets there are no known products containing EDC.

The key use is as an intermediate in the production of vinyl chloride (98%) which is then used to produce polyvinylchloride (PVC). The remaining 2% is used as a raw material for the production of ethyleneamines, trichloroethylene, perchloroethylene and some fluorinated substances or as an extraction solvent in organic chemistry and a cleaning/degreasing agent of metals. EDC is a highly volatile substance which is about 97% partitioned into air and 3% into water, according to a Mackay level I calculation (1). It can then be easily remove from water by stripping.

Review of possible measures as a function of uses

The scoring table is presented in **Annex 1** and the various possible measures are discussed below in order to clarify the chosen scores.

- EDC production and EDC as an intermediate in vinyl chloride production: EDC is produced by catalytic oxichlorination of ethylene in closed systems. 98% of the EDC production is directly sent/connected to a vinyl chloride production plant. Consequently both production units should be considered together for assessing possible emission reduction measures.
    - Substitution: is not technically feasible and should not be considered because it would imply the dismantlement of a huge chemical sector (PVC industry) with very serious consequences on employment. Moreover the present process replaced several older, less effective processes
    - IPPC Directive and the BAT approach: all the EDC and vinyl chloride (VC) production plants are submitted to the IPPC Directive and should comply with the BAT described in the BREF document dealing with "Large Volume Organic Chemicals". In this context ELV should be fixed by the competent authorities in the permit in such a way that the requirements of the WFD will be satisfied. The key questions are the controlling supervision by the competent authorities and the applicability of the BAT at each production plant.

- Existing EU and international regulations: EDC is listed in the VOC Directive and submitted to emission reporting under the E-PRTR Directive. EDC is also listed under the Hazardous Waste Directive
- Voluntary initiatives: EuroChlor members on the one side and the VC-PVC producers on the other side have demonstrated the feasibility and the efficiency of voluntary actions to reduce emission of EDC (see Deliverable 4.4.). These actions have been progressively implemented by taking realistic measures to improve the process and the wastewater treatment. This approach was supported by the EU and OSPAR authorities and should be encouraged by various types of incentive
- End of the pipe treatment: appropriate industrial wastewater treatments exist and are able to efficiently remove EDC (see Deliverable 5.6).

- EDC as raw material for production of chemicals:
  - Substitution: For the time being it is impossible to easily substitute EDC as raw material for ethylene diamine, trichloroethylene, tetrachloroethylene and some fluorinated substances production because these processes are economically and energetically optimised and because the markets are too small/decreasing to justify the development of new processes
  - IPPC Directive and the BAT approach: the EDC production plants as well as the plants where EDC is used as raw material are submitted to the IPPC Directive and should comply with the BAT described in the BREF document dealing with “Large Volume Organic Chemicals”. In this context ELV should be fixed by the competent authorities in the permit in such a way that the requirements of the WFD will be satisfied. The key questions are the control by the competent authorities and the applicability of the BAT at each production plant.
  - Existing EU and international regulations: EDC is listed in the VOC Directive and submitted to emission reporting under the E-PRTR Directive in all organic chemicals plants. Once again, the efficiency of these regulations strongly depends on the control and the monitoring by the competent authorities
  - Voluntary initiatives: At least for the production of trichloroethylene and tetrachloroethylene, EuroChlor members have demonstrated the feasibility and the efficiency of voluntary actions to reduce emission of EDC (see Deliverable 4.4.).
  - End of the pipe treatment: appropriate industrial wastewater treatments exist and are able to efficiently remove EDC (see Deliverable 5.6).
- EDC as an extraction solvent or cleaning/degreasing agent for metals:
  These uses are relatively limited compared to the previous ones but could generate important releases.
  - Substitution: EDC substitution can be considered in these applications but on a case by case basis, taking into account the type of extraction and/or the type of materials to be cleaned. This will imply process changes and some new investments.
  - IPPC Directive and the BAT approach: the plants where EDC is used as solvent or degreasing agent are generally submitted to the IPPC Directive and should comply with the BAT described in the BAT REFerence (BREF) documents (“Large Volume Organic Chemicals” or “Surface treatments using solvents”). In this context ELV should be fixed by the competent authorities in the permit in such a way that the requirements of the WFD will be satisfied. The key questions

are the control by the competent authorities and the applicability of the BAT at each production plant.

- Existing EU and international regulations: EDC is listed in the VOC Directive and submitted to emission reporting under the E-PRTR Directive. EDC is also listed under the Hazardous Waste Directive, but the reporting under these Directives is compulsory only above several thresholds. This will limit their applicability to large industrial units. Once again the efficiency of these regulations strongly depends on the control and the monitoring by the competent authorities
- Voluntary initiatives: To our knowledge there is no voluntary initiative in these types of applications and they will be difficult to organise due to the large diversity of production units working in them. Of course, the local authorities could encourage the application of benchmarking approaches for companies in their territory.
- End of the pipe treatment: appropriate industrial wastewater treatments exist and are able to efficiently remove EDC (see Deliverable 5.6). For small production units, the effluent will reach municipal wastewater treatment plants (see Deliverable 5.6 for the best choice) even if , due to the high volatility of EDC, most of the emissions are to the air with a low probability to partition to the water bodies

Conclusion for EDC:

- For the use of EDC in the VC-PVC production, it appears that industrial voluntary initiatives are the best way to ensure emission reduction and compliance to the WFD Directive, at the condition they are supported by the competent authorities and controlled by independent bodies
- For the use of EDC in ethylene diamine production, the strict application in the frame of the permit of existing EU Directives (IPPC, VOC, E-PRTR, waste) could be the most appropriate measures to reduce emissions and to reach the concentration target required by the WFD , but the control by the competent authorities is essential.
- EDC can be substituted when it is used to produce tri- and tetra-chloroethylene. Industrial processes exist that are using other raw materials. The problem is that the producers are not the same and the production plants cannot be easily transformed to change the starting material. However, when the change of raw material is not possible, the existing legislation (BAT and VOC) could be sufficient to reduce emissions in such a way that the WFD targets will be reached.
- The substitution of EDC as extraction solvent or degreasing agent can be considered on a case by case basis. This implies a feasibility study for each type of extraction. The change is in principle possible but will take time and money (R&D and investment). The corresponding cost should be compared to the cost generated by the application of the existing legislation (BAT and VOC) to comply with the WFD target, before taking a decision.
- Appropriate wastewater treatment, both industrial and municipal, exists (see Deliverable 5.6)
- To the best of our knowledge, the measured EDC concentrations in European waters are most often under the EQS value (2).

- Due to its high volatility, EDC is easily removed from water by stripping and does not pose high difficulties to the drinking water production plants (3) and has a very limited impact on the municipal wastewater treatment plant (WWTP). For the same reason, it does not affect very much the ecological status of the water and has little impact on the amenities and perception of the residents. Any emission reduction will then have a low impact on these activities

3.1.2. Benzene

Benzene is used as a raw material in various manufacturing applications. The most important productions based on benzene are ethyl benzene (for production of styrene and polystyrene), cumene (for production of phenol, raw material for fibres and resins), cyclohexane (intermediate for production of adipic acid used in nylon synthesis), nitrobenzene (basis for manufacture of aniline dyes, polyurethane foams, explosives and drugs), alkylbenzene (for surfactants in detergent production), maleic anhydride (basis for manufacture of polyester resins, plant protection products and lubricating oil additives), and chlorobenzene (for the production of insecticides, pharmaceuticals, dyestuffs, disinfectants). In all these applications the benzene ring is needed and the emissions occur as point sources.

In industry, benzene is also used as a solvent but this use is declining and can most probably be phased out.

Finally, benzene is also present in gasoline at a maximum level of 1% (diffuse source). Benzene can also be emitted from combustion plants (diffuse sources) and all other types of natural and anthropogenic combustion processes.

Due to its poor water solubility and its high volatility, benzene partitions up to 99.9% into air (4).

Review of possible measures as a function of uses

The scoring table is presented in **Annex 2** and the various possible measures are discussed below in order to clarify the chosen scores.

- Benzene production and benzene as a raw material in chemical synthesis (point sources)
  - Substitution: As petroleum remains the most important source of organic carbon, another way of producing benzene than petroleum refining is not foreseeable in the near future. Similarly, as in all synthesis in which benzene is involved the aromatic ring is needed there is no obvious substitution possible. Moreover these processes are economically and energetically optimised. The development of new greener processes (if any) would imply important investment in research and in new plants.
  - IPPC Directive and the BAT approach: Refineries producing benzene and organic chemicals plants where benzene is used as a raw material are submitted to the IPPC Directive and should comply with the BAT described in various BREF documents in particular those dealing with “Refineries” or “Large Volume Organic Chemicals”(see Deliverable 4.3). In this context ELV should be fixed by the competent authorities in the permit in such a way that the requirements of the WFD will be satisfied. Most of these industrial units are working in closed systems but the key questions are the control by the competent authorities and the effective application of the BAT at each production plant.

  - Existing EU and international regulations: Benzene is listed in the VOC Directive as well as in various Directives dealing with waste streams (see Deliverable 4.3). Benzene is also submitted to emission reporting under the E-PRTR Directive in all organic chemical plants. There are also national emission ceilings for benzene which have to be reached in 2010 (Directive 2001/81/EC) and the concentration of benzene in ambient air is limited to 5 $\mu g/m^3$ (Directive 2000/69/EC). Once again, the efficiency of these regulations strongly depends on the control and the monitoring by the competent authorities.
  - Voluntary initiatives: As described in Deliverable 4.4, there are industrial voluntary initiatives to monitor and reduce emissions in refineries with some efficiency. These initiatives should be encouraged by various types of incentive
  - End of the pipe treatment: appropriate industrial wastewater treatments exist and are able to efficiently remove benzene (see Deliverable 5.6).
- Benzene used as solvent (point sources)
  - Substitution: Benzene can be substituted by toluene in most cases where it is used as a solvent. This would imply small changes in the processes and limited investment.
  - IPPC Directive and the BAT approach: It is not obvious to know if the IPPC Directive applies to industrial units using benzene as solvent because most of them are small and are not submitted to the IPPC. The key question would be the control by the competent authorities of the emission levels at each production plant.
  - Existing EU and international regulations: Benzene is listed in the VOC Directive. Benzene is also submitted to emission reporting under the E-PRTR Directive in all organic chemicals plants. But the reporting is due only above a certain level of emission which is not necessarily reached in small units using benzene as solvent. The concentration of benzene in ambient air is limited to 5 $\mu g/m^3$ (Directive 2000/69/EC). The efficiency of these regulations strongly depends on the control and the monitoring by the competent authorities
  - Voluntary initiatives: Campaigns to encourage the substitution of benzene in small units and laboratories should be encouraged by the competent authorities through various types of incentive.
  - End of the pipe treatment: appropriate industrial wastewater treatments exist and are able to efficiently remove benzene (see Deliverable 5.6).
- Benzene in gasoline (diffuse sources)
  - Substitution: whilst petrol and diesel fuels are used as energy sources for car and trucks, they will produce traces of benzene. Only the universal introduction of electric cars will avoid this type of benzene emissions. This will take time and a drastic change in the current practice. Such a proposal is out of the scope of this study and cannot be considered as a practical solution to implement the WFD.
  - IPPC Directive and the BAT approach: The IPPC Directive does not apply to gasoline.
  - Existing EU and international regulations: The Directive 98/70/EC relating to the quality of petrol and diesel fuels includes restrictions with regard to benzene. Its concentration is limited to a maximum of 1% v/v and monitoring measures are also foreseen to check the compliance of petrol and diesel fuels to the requirement of this Directive. The member states are authorised to set more stringent conditions to protect the health of their populations.
  - Voluntary initiatives: for many years, several member states have encouraged the use of "stage II petrol vapour recovery (PVR) at petrol pumps to avoid benzene

emissions during the tank filling. Now more than half of the EU Member States have national measures of this type in place, and in some countries the technology has been mandatory since the 1990s. As a consequence of these initiatives, a new EC Directive proposal (COM(2008) 812 final) on Stage II petrol vapor recovery during fuelling of passenger cars at service stations was adopted in June 2009
    - End of the pipe treatment: Appropriate municipal wastewater treatments exist (see Deliverable 5.6)
- Benzene as by-product of combustion plants
    - Substitution: As an unavoidable by-product of combustion processes, benzene cannot be substituted.
    - IPPC Directive and the BAT approach: Benzene is considered in BAT reference documents on combustion installations as well as on waste treatment and on waste incineration. In this context ELVs should be fixed by the competent authorities in the permit in such a way that the requirements of the WFD will be satisfied. However the IPPC Directive is not considering small combustion units and if the scope is extended, the key question will be: how the competent authorities will be able to control the effective application of the BAT at each combustion plant.
    - Existing EU and international regulations: Benzene is listed in the VOC Directive that proposes general thresholds and emission controls as well as in various Directives dealing with waste streams (see Deliverable 4.3). Benzene is one of the pollutants for which national emission ceilings to be reached by 2010 are proposed in Directive 2001/81/EC. Benzene is also submitted to emission reporting under the E-PRTR Directive, but the reporting is due only above a certain level of emission which is not necessarily reached in small combustion units. The concentration of benzene in ambient air is limited to 5 $\mu g/m^3$ (Directive 2000/69/EC). Once again, the efficiency of these regulations strongly depends on the control and the monitoring by the competent authorities
    - Voluntary initiatives: To our knowledge there is no voluntary initiative in this field.
    - End of the pipe treatment: Appropriate municipal wastewater treatments exist (see Deliverable 5.6)

Conclusions for benzene

- For the use of benzene as intermediate or raw material in chemicals synthesis there are no substitutes. It appears that the strict application in the frame of the permit of existing EU Directives (IPPC, VOC, E-PRTR, waste) could be the most appropriate measure to reduce emissions, but control by the competent authorities is essential. Industrial voluntary initiatives could also lead to emission reductions and should be encouraged.
- The substitution of benzene as a solvent is progressing. It should be considered on a case by case basis and encouraged by incentives. This implies a feasibility study for each type of application. The change is in principle possible but will take time and money (R&D and investment). The corresponding cost should be compared to the cost generated by the application of the existing legislation (BAT and VOC) to comply with the WFD target, before taking a decision.
- The presence of benzene in gasoline is unavoidable. The feasibility of reducing the level of benzene in gasoline below 1% should be discussed with the petroleum

industry taking into account the possible additional investments or operating costs. Once again control by the competent authorities is essential.

- The strict application of the IPPC to combustion plants is essential to reduce benzene emissions. This implies process improvements, in particular, in the smallest units and consequently investment costs that should be considered when a decision is taken.
- Appropriate wastewater treatment, both industrial (for point sources) and municipal (for diffuse sources) exists (see Deliverable 5.6). The investment costs for end-of-pipe solutions should be compared to the costs needed to reduce the source emission levels.
- Due to its high volatility and its poor water solubility, benzene is easily removed from water by stripping and does not pose high difficulties to drinking water production plants (3) and has a very limited impact on municipal WWTPs. For the same reasons, it has little effect on the ecological status of receiving waters and has little impact on the amenities and perception of the residents. Any emission reduction will consequently have a low impact on these activities.

3.1.3. Decabromodiphenyl ether

The polybrominated diphenyl ethers are used as flame-retardants in particular in high impact polystyrene (HIPS), acrylonitrile butadiene styrene (ABS) polymer, flexible polyurethane foam, textile coatings, wire and cable insulation, electrical connectors, electronic equipment and other interior parts. The uses of pentabromo- and octabromo-diphenylethers have been phased out in the EU since August 2004.

The use of decabromo-diphenylether (DecaBDPE) as an additive flame retardant mainly in plastics (roughly 75%) and textile (roughly 25%) applications is still allowed in the EU. The major application for DecaBDPE in Electrical and Electronic Equipment is to provide flame retardancy according to the fire safety standard UL941 V-0 for HIPS, polyolefins (polyethylene (PE) and polypropylene (PP)), always in conjunction with antimony trioxide. There is no production plant for DecaBDPE in the EU but there are many users in plastic processing and textile coatings (i.e. many small point sources).

The fact that plastics or textiles containing DecaBDPE are used in many consumer products results in potential secondary diffuse sources in waste streams (for example, leaching from landfill). The major release of DecaBDPE to the air environment is expected to be due to evaporation from flame-retarded goods – about 2.55 tonnes/year - and to water from the washing of textiles - up to 120 tonnes/year (5).

DecaBDPE is an extremely lipophilic substance, which makes it difficult to predict its environmental distribution. Due to low solubility in water and low vapour pressure it will only slowly be redistributed in the environment. It will be strongly adsorbed on sediments and particulate matter and will persist for a long time. It is also adsorbed on the sludge of the water treatment plants.

Review of possible measures as a function of uses

The scoring table is presented in **Annex 3** and the various possible measures are discussed below in order to clarify the chosen scores.

- Industrial uses as flame retardant : DecaBDPE as additive in plastic and textile (point sources)

- Substitution: The manufacturers of brominated flame retardants have specifically pointed to difficulties of substituting DecaBDE in the plastics HIPS, ABS, and PBT, citing the lack of suitable alternative flame retardants that can provide good flame retardancy and good mechanical properties. The Danish Environmental Protection Agency (EPA) claims however that they have identified six potential substitutes but it seems that uncertainties still exist related to the potential environmental impacts of these substitutes (6). It seems that a substitute should be developed for each application and consequently the substitution approach should be considered on a case by case basis.
- IPPC Directive and the BAT approach: poly-brominated DPE are listed in the BREF documents on large volume organic chemicals and on waste treatment and waste incineration. The key question will be: how the competent authorities will be able to control the effective application of the BAT at each plant.
- Existing regulations: The EU Risk Assessment Report indicates that there is no need for further risk management measures. From 1 July 2006, new electrical and electronic equipment put on the market shall not contain polybrominated biphenyls or polybrominated diphenyl ethers. Poly-brominated DPE are submitted to emission reporting under the E-PRTR Directive. They are also listed under the Hazardous Waste Directive and other Directives dealing with waste streams, but the reporting under these Directives is compulsory only above several thresholds. This will limit their applicability to large industrial units. Once again the efficiency of these regulations strongly depends on monitoring by the industry and the control by authorities
- Voluntary agreements: Supported by the competent authorities, the manufacturing industry (producers and users) has instigated a voluntary initiative known as the Voluntary Emissions Control and reduction Action Programme (VECAP). New codes of good practice for sustainable use of decabromodiphenyl ether in the plastics industry and textile industry have been issued to ensure improved control of emissions. This programme is linked to an environmental monitoring programme over at least 6 years, due to the fact that this substance is persistent (7).
- End of the pipe treatment: In both industrial and municipal wastewater treatment plants, it seems that DecaBDPE is strongly adsorbed on the sludge (8).

- Disposal of products containing DecaBDPE: diffuse sources
  - Substitution: the progressive substitution of DecaBDPE in plastics and textiles will reduce the emissions from landfill disposal but it is a long term solution taking into account the life cycle of the products
  - Existing regulations: Poly-brominated DPE are listed under the Hazardous Waste Directive and other Directives dealing with waste streams. The recent Waste Framework Directive encourages the recycling of plastic materials and the reduction of the landfill disposal. This will reduce DecaDBPE emissions by leaching from waste.
  - Voluntary initiatives: The European Plastics Manufacturers Association has developed many R&D programmes to increase with success the recycling and recovery of plastics and to reduce the landfill disposal (9). These efforts should be encouraged by incentives. Information campaigns can also be organised to encourage the selective gathering of plastic waste in view of their recycling.
  - End of the pipe treatment: In both industrial and municipal wastewater treatment plants, it seems that DecaBDPE is strongly adsorbed on the sludge (8).

Conclusion for decabromodiphenyl ether

- The strict application of existing regulations to limit the use and emissions of DecaBDPE as well as the support to the industrial voluntary initiatives are the two best ways to reduce emissions of DecaBDPE both from point and diffuse sources. A regular assessment of the efficiency of these measures should be organised.
- Information campaigns to better inform on the possibilities of substituting DecaBDPE in the different applications can be encouraged by the competent authorities in collaboration with industry. In particular, whenever technically possible, the substitution of DecaBDE in household products (textiles, flooring, etc) should be encouraged and better information should be given on how to wash, clean and dispose of them.
- The wastewater treatment plants will concentrate DecaBDPE on sludge, leading to disposal limitation of the sludge. Disposal rules should be defined to avoid secondary emissions from sludge.

3.1.4. Octylphenol / Nonylphenol and the corresponding ethoxylates

Nonylphenol (NP) and octylphenol (OP) are used in the production of the corresponding ethoxylates (NPE and OPE) which are used in industrial and domestic detergents as nonionic surfactants and as ingredients of emulsifier mixtures for the manufacture of emulsion polymers and stabilizers in latex polymers. Other applications include textile processing, water-based paint, floor and surface cleaning agent, pesticide and veterinary medicine formulations as well as in the production of plastic additives.

NP and OP are mainly used in the production of phenolic resins and phenolic compounds.

Major release of OP can occur due to dispersive use of preparations, such as in pesticides, detergents, paint, textile, etc (diffuse sources). Releases can also occur resulting from manufacture and use to produce other products (point sources). NPE and OPE are the primary diffuse sources of inputs to rivers and the sea of NP and OP because ethoxylates, which have widespread applications especially in detergents, are hydrolysed in the environment to produce the corresponding phenols.

Review of possible measures as a function of uses

The scoring table is presented in **Annex 4** and the various possible measures are discussed below in order to clarify the chosen scores.

- Use as raw materials (point sources)
  - Substitution: NP and OP can be replaced by other alkylphenols (like 4-*tert*-pentyl-phenol, 2,4-di-*tert*-butylphenol, 2,6-di-*tert*-butylphenol or dodecylphenol) to produce phenolic resins. They cannot of course be substituted in the production of the corresponding ethoxylates NPE and OPE.
  - IPPC Directive and the BAT approach: octyl-and nonyl- phenols and their ethoxylates are listed in various BAT documents: large volume organic chemicals, pulp and paper, textile processing, tanning, surface treatment of metals and

production of polymers, plastics, paints, printing inks and pesticides (see Deliverable 4.3).
    - Existing regulations: octyl-and nonyl- phenols and their ethoxylates are also submitted to emission reporting under the E-PRTR Directive in all organic chemical plants.
    - Voluntary initiatives: To our knowledge there is no voluntary initiative but negotiated agreements with some national authorities have been demonstrated very efficient.
    - End of the pipe: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6 at least for NP and NPE)
- Uses in formulations (detergents, paints, textiles) (diffuse sources)
    - Substitution: The possible substitutes of NPE and OPE are mixtures of alcohol ethoxylates in the detergents, the cleaning agents and in the textile industry, while fatty alcohol ethoxylates are used as substitutes in binding polymer emulsion of water based paints or of water based adhesives and in the leather industry. These potential substitutes would need to be investigated further from an environmental point of view to see if they pose a lower risk.
    - IPPC Directive and the BAT approach: octyl-and nonyl- phenols and their ethoxylates are listed various BAT documents : large volume organic chemicals, pulp and paper, textile processing, tanning, surface treatment of metals and production of polymers, plastics, paints, printing inks and pesticides (see Deliverables 4.2 and 4.3).
    - Existing regulations: Nonylphenol ethoxylates used in cleaning agents were recommended to be phased out in 1995 for domestic use and in 2000 for industrial use under the OSPAR Convention. National initiatives have been taken in some OSPAR States on the use of NPE in water-based paints, agricultural pesticides, and emulsion polymers. At EU level restriction of NP and NPE uses is taking place under the "marketing and use" directive. NP and NPE may not be placed on the market or used as a substance or constituent of preparations in concentrations equal or higher than 0,1 % by mass NP or 1 % by mass NPE for industrial, institutional and domestic cleaning, textiles and leather processing, metal working, personal care products including shampoos
    - Voluntary initiatives: UK has had a voluntary agreement with industry not to use octylphenols or octylphenol ethoxylates in domestic detergents since 1976. This is now implemented in the EU legislation (Marketing and use directive). In Sweden a NGO's programme of textile analysis demonstrated that imported textiles are a common source of NP and OP ethoxylates (reference to Hök, 2007).
    - End of the pipe: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6 at least for NP and NPE)
- Degradation of nonyl- and octylphenol ethoxylates (diffuse sources)
    - Substitution: Possible substitutes for NPE and OPE are mixtures of alcohol ethoxylates in detergents, cleaning agents and in the textile industry, while fatty alcohol ethoxylates are used as substitutes in binding polymer emulsion of water based paints or of water based adhesives and in the leather industry. These potential substitutes would need to be investigated further from an environmental point of view to see if they pose a lower risk.
    - IPPC Directive and the BAT approach: Not applicable
    - Existing regulations: Nonylphenol ethoxylates used in cleaning agents were recommended to be phased out in 1995 for domestic use and in 2000 for industrial

use under the OSPAR Convention. National initiatives have been taken in some OSPAR States on the use of NPE in water-based paints, agricultural pesticides, and emulsion polymers. At EU level restriction of NP and NPE uses is taking place under the “marketing and use” directive. NP and NPE may not be placed on the market or used as a substance or constituent of preparations in concentrations equal or higher than 0.1 % by mass NP or 1 % by mass NPE for industrial, institutional and domestic cleaning, textiles and leather processing, metal working, personal care products including shampoos

- Voluntary initiatives: UK has had a voluntary agreement with industry not to use octylphenols or octylphenol ethoxylates in domestic detergents since 1976.
- End of the pipe: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6 at least for NP and NPE)

Conclusion for octylphenol, nonylphenol and their ethoxylates

- In most applications octylphenol, nonylphenol and their ethoxylates can be substituted either by other alkylphenols in the production of phenolic resins or by various alcohol ethoxylates in other applications. These potential substitutes would however need to be investigated further from an environmental point of view to see if they pose a lower risk. A case by case analysis is needed. As the potential substitutes are not necessarily produced by the same companies, the cross economic impacts caused by this move should be evaluated.
- The strict application of existing regulations can also strongly reduce the uses (via the marketing and uses Directive) and the emissions to water (by application of the IPPC Directive, for example).

3.2. The case of pesticides

As in the context of ScorePP the focus is put on urban areas, the pesticides should be considered mainly in the maintenance of public areas, gardening as well as private uses in paint, roofs, control of insects, etc. The use of pesticide in agriculture exceeds the urban uses significantly. In this context, we consider under this point the following substances: chlorpyrifos and isoproturon

3.2.1. Chlorpyrifos

The use of chlorpyrifos is authorized in Europe under the Directive 91/414

Chlorpyrifos is a leading insecticide for locust control, termites, cockroaches, and mosquitoes for which its use is authorized in Europe. It is particularly used in southern Europe (Portugal) to fight against potato wireworm for which it appears to be the only solution (see Deliverable 4.1). Substitution appears to be impossible for this application.

Chlorpyrifos is also the key insecticide in southern Europe (Greece) to fight against scale in citrus culture. As it is the only organophosphate authorized in the EU, its substitution will remove an important mode of action from the pesticide toolbox with the consequence of increasing the pest resistance. The use volume is about 1000 t/y in the EU-15.

Review of possible measures as a function of uses

The scoring table is presented in **Annex 5** and the various possible measures are discussed below in order to clarify the chosen scores.

- Fight against the potato wireworm and scale in citrus culture (specific insecticide)

- Substitution: it appears that chlorpyrifos cannot be substituted in these applications because it has a unique mode of action and if this disappears, this will a induce a higher pest resistance to other insecticides
- Existing regulations: Directive 91/414 specifies at which doses chlorpyrifos should be used to be effective and to minimise the risk to environment and human health. In principle these doses should be respected but the competent authorities are generally not equipped to control the applications in the field, due to the large number of users.
- Voluntary initiatives: information/education campaigns organized for the users by the producers on a voluntary basis as well as voluntary agreements (that could be encouraged by the competent authorities) appear to be the best approaches to limit over use reaching the EQS levels recommended by the WFD. It appears that the main emissions generally arise during cleaning of the machines used to spray the insecticide: new cleaning practices should be promoted.
- End of the pipe: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6)

- Fight against locust, termites, cockroaches and mosquitoes (general insecticide)
  - Substitution: chlorpyrifos could be substituted in these applications but appropriate substitutes should be chosen for each type of pest and climate; this could imply large R&D costs and take time
  - Existing regulations: Directive 91/414 specifies at which doses chlorpyrifos should be used to be effective and to minimise the risk to environment and human health. In principle these doses should be respected but the competent authorities are generally not equipped to control the applications in the field, due to the large number of users
  - Voluntary initiatives: information/education campaigns organized for the users by the producers on a voluntary basis as well as voluntary agreements (that could be encouraged by the competent authorities) appear to be the best approaches to limit over use reaching the EQS levels recommended by the WFD. It appears that the main emissions generally arise during the cleaning of the machines used to spray the insecticide: new cleaning practices should be promoted.
  - End of the pipe: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6)

Conclusion for chlorpyrifos

- Chlorpyrifos is a leading insecticide for a large variety of applications. For some of them it could be substituted but appropriate substitutes should be chosen for each type of pest and that could imply large R&D costs and take time. For some other applications in particular in southern Europe, it cannot be replaced now and we cannot foresee when an appropriate substitute with a similar mode of action could come on the market.
- In the mean time, for all applications, information/education campaigns organized for the users by the producers on a voluntary basis as well voluntary agreements (that could be encouraged by the competent authorities) could be sufficient to limit over use and to achieve the EQS levels recommended by the WFD and consequently reduce the burden on the municipal WWTP and on the drinking water production plants.

Particular attention should be given to the way the spraying machines are cleaned after usage.
- If there are domestic uses, information campaigns and may be some use restriction could be organized by the competent authorities.

3.2.2. Isoproturon

The use of isoproturon is authorized in Europe under Directive 91/414

Isoproturon is an herbicide used for the pre- and post- emergence control of annual grasses and broad-leaved weeds in spring and winter wheat, barley, rye and triticale.

One of the major uses of isoproturon is the destruction of blackgrass in wheat, barley and oats crops (in particular in the UK). The substitution of isoproturon would increase the risk of resistance of blackgrass to the remaining pesticides due to the loss of an important mode of action.

Isoproturon is also used as a total herbicide for the maintenance of public areas.

Review of possible measures as a function of uses

The scoring table is presented in **Annex 6** and the various possible measures are discussed below in order to clarify the chosen scores.

- Use as herbicide for control of annual grasses in wheat, barley and oats
  - Substitution: it appears that isoproturon cannot be substituted in these applications because it has a unique mode of action and if this disappears, a higher resistance of some grasses, in particular blackgrass to other herbicides will be induced.
  - Existing regulations: Directive 91/414 specifies at which doses isoproturon should be used to be effective and to minimise the risk to the environment and human health. In principle these doses should be respected but the competent authorities are generally not equipped to control the applications in the field, due to the large number of users.
  - Voluntary initiatives: information/education campaigns organized for users by the producers on a voluntary basis as well as voluntary agreements (that could be encouraged by the competent authorities) appear to be the best approaches to limit the over use in order to achieve the EQS levels recommended by the WFD. It appears that the main emissions generally arise during cleaning of the machines used to spray the herbicide: new cleaning practices should be promoted.
  - End of the pipe: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6)

- Use as total herbicide in maintenance of public areas
  - Substitution: isoproturon could be substituted in this application but comparative risk assessment should be carried out for the appropriate substitutes
  - Existing regulations: Directive 91/414 specifies at which doses isoproturon should be used to be effective and to minimise the risk to the environment and human health. In principle these doses should be respected but the competent authorities are generally not equipped to control the applications in the field, due to the large number of users
  - Voluntary initiatives: information/education campaigns organized for the users by the producers on a voluntary basis as well as voluntary agreements (that could be encouraged by the competent authorities) appear to be the best approaches to limit the over use in order to achieve the EQS levels recommended by the WFD. It

appears that the main emissions generally arise during cleaning of the machines used to spray the herbicide: new cleaning practices should be promoted. In Swedish cities the use of herbicides in the treatment of public areas has not been accepted for several years and mechanical treatment is encouraged.
    - End of the pipe: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6

Conclusion for isoproturon

- Isoproturon is one of the key herbicides for the destruction of blackgrass in wheat, barley and oats crops. It cannot be replaced now and we cannot foresee when an appropriate substitute with a similar mode of action could come on the market.
- When isoproturon is used for maintenance of public areas, it can be substituted if its substitute is demonstrated to cause a lower risk to human health and the environment.
- Information/education campaigns organized for the users by the producers on a voluntary basis as well voluntary agreements (that could be encouraged by the competent authorities) could be sufficient to limit the over use of isoproturon. This could enable achievement of the EQS levels recommended by the WFD and consequently reduce the burden on municipal WWTPs and on the drinking water production plants.
- If there are domestic uses, information campaigns and may be some use restrictions could be organized by the competent authorities.

3.3. The case of by-products

We consider in this section the following substances: hexachlorobenzene (HCB) and benzo[a]pyrene (representing PAH)

3.3.1. Hexachlorobenzene

Hexachlorobenzene (HCB) is no longer produced in the EU but it occurs as an unintentional, unavoidable by-product from the chlorine industry, cement and ceramic production, secondary aluminium industry and waste incineration plants. The data show that discharges from the chemical industry and waste are the main sources for surface waters. Losses from historically contaminated soils should also be considered.

Review of possible measures as a function of sources

The scoring table is presented in **Annex 7** and the various possible measures are discussed below in order to clarify the chosen scores.

- Emission from point sources (various plants: chlorine industry, cement, ceramic aluminium industry and waste incineration)
    - Substitution: As hexachlorobenzene is an unavoidable by-product, it cannot be substituted
    - IPPC Directive and the BAT approach: the main plants producing hexachlorobenzene as by-product are listed in various BAT documents (see Deliverable 4.3). In this context Emission Limit Values (ELV) should be fixed by the competent authorities in the permit in such a way that the requirements of the WFD will be satisfied. The key questions are the control by the competent authorities and the applicability of BAT at each production plant.
    - Existing regulations: hexachlorobenzene is also submitted to emission reporting under the E-PRTR Directive and several waste directives strongly limit its

emissions. Once again the efficiency of these regulations strongly depends on the control and the monitoring by the competent authorities.
  - Voluntary initiatives: EuroChlor members on the one hand and the VC-PVC producers on the other hand have demonstrated the feasibility and the efficiency of voluntary actions for reducing emissions of hexachlorobenzene (see Deliverable 4.4.). These actions have been progressively implemented by taking realistic measures to improve the process and the wastewater treatment. These types of initiatives should be encouraged by the competent authorities.
  - End of the pipe: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that hexachlorobenzene could be strongly adsorbed on sludge
- Re-emission from old sources (diffuse sources, mainly sediments re-suspended during dredging)
  - Substitution: Not applicable
  - IPPC Directive and the BAT approach: Not applicable
  - Existing regulations: No specific regulation exists at EU level but, sediment management is an integral part of river basin management and should be addressed in the implementation of the WFD. Environmental clean-up is usually done by removing hot spots of sediment pollution by dredging. The waste regulation should consider how to treat and/or process polluted sediment. In the future, an appropriate sediment management may help to reduce contamination to such levels that, during maintenance dredging, relocation of sediment within the same water system can take place without special restrictions. An EU approach regarding sediment management would be a valuable contribution
  - Voluntary initiatives: There are some international agreements to discuss the problems linked to the sediment management at a river basin scale (for example the Dutch-German Exchange on Dredged Material). There are several demands to further develop this type of approach.
  - End of the pipe: Wastewater treatment not applicable but sediment remediation needed.

Conclusion for hexachlorobenzene

- As hexachlorobenzene (HCB) is an unavoidable and unintended by-product of industrial processes, the only realistic emission reduction measures should be based on the existing legislation and in particular on the BAT approach. The strict application of these regulations to point sources could be sufficient to achieve the EQS levels recommended by the WFD and consequently reduce the burden on municipal WWTPs and on the drinking water production plants. HCB is a PBT chemical but releases cannot be completely phased out. A negligible level of release should be defined for each river basin based on a risk assessment approach.
- Further process improvements or increases in efficiency of existing WWTPs could also be considered but they could be linked to huge investments. These investment costs should be compared to the potential environmental benefits of reducing emissions. This implies a complete cost/benefit analysis.
- Some voluntary agreements within the industry can also positively contribute to the reduction of emissions
- “Historical HCB”levels exist in sediments of European rivers and in several industrial deposits. The only possible measure is soil remediation or sediment cleaning by

dredging. This requires a political will and the decision should be based on a complete cost benefit analysis in relation to local conditions. An EU approach is needed.

3.3.2. Benzo[a]pyrene (representing PAH)

The following substances are generally considered under PAH: Benzo[k]fluoranthene (CAS 207-08-9) , Benzo[a]pyrene (CAS 50-32-8), Indeno[1,2,3-cd]pyrene (CAS 193-39-5), Benzo[b]fluoranthene (CAS 205-99-2), and Benzo[ghi]perylene (CAS 191-24-2). Benzo[a]pyrene is one of the more toxic being members of the PAH group and is selected here to represent this group of compounds.

Primarily, PAH arise from incomplete combustion or pyrolysis of organic substances such as wood, carbon, coal or mineral oil in industrial plants, domestic combustion devices and combustion processes in landfills. There are also discharges of PAH to storm runoff as a result of the wash-off of car exhaust particles from road surfaces. PAHs are formed when an organic compound is exposed to temperatures above 700°C in an oxygen deficient atmosphere. It should then be considered as an unavoidable by-product of combustion processes**.**

A key source of PAH is the production and use of creosote resulting from the distillation of coal tar which itself is a by-product of the high-temperature destructive distillation of bituminous coal to form coke. Creosote can contain up to 85% of various PAHs.

Review of possible measures as a function of uses / sources

The scoring table is presented in **Annex 8** and the various possible measures are discussed below in order to clarify the chosen scores.

- Creosote production as PAH through coal tar distillation (point sources)
  - Substitution: this source cannot be substituted because it is not technically feasible to distil coal tar without generating PAHs in various fractions
  - IPPC Directive and the BAT approach: the creosote production plants are submitted to the IPPC Directive and should comply with the BAT described in the BREF document dealing with “Large Volume Organic Chemicals”. In this context ELV should be fixed by the competent authorities in the permit in such a way that the requirements of the WFD will be satisfied. The key questions are the control by the competent authorities and the applicability of the BAT at each production plant.
  - Existing EU and international regulations: there are many EU and international regulations limiting PAH emission in chemical processes. PAHs are also submitted to emission reporting under the E-PRTR Directive (see Deliverable 4.3.)
  - Voluntary initiatives: To our knowledge there is no voluntary initiative reported but these activities should be encouraged by various types of incentive
  - End of the pipe treatment: appropriate industrial wastewater treatments exist and are able to remove PAHs (see Deliverable 5.6), but they can be strongly adsorbed on sludge.
- Use of creosote and similar distillates (diffuse sources):
  - Substitution: it seems possible to substitute creosote as a biocide in wood protection and a complete ban is considered in the EU.
  - IPPC Directive and the BAT approach: the creosote production plants as well as the plants where creosote or similar distillates are used as raw material are submitted to the IPPC Directive and should comply with the BAT described in

the BREF document dealing with "Large Volume Organic Chemicals" where the PAH emissions are regulated. These emissions should be defined by the local authorities in the permit in such a way that the requirements of the WFD are satisfied. The key questions are the control by the competent authorities and the applicability of BAT at each production plant.

- Existing EU and international regulations: PAH emissions are strongly limited at international level (UNEP POP convention). The use of creosote in the treatment of wood is now forbidden in the EU and wood so treated may not be placed on the market. Similarly, the construction products Directive intends to minimise the content of coal tar in asphalt. PAHs are also submitted to emission reporting under the E-PRTR Directive in all organic chemicals plants. Once again, the efficiency of these regulations strongly depends on control and monitoring by the competent authorities
- Voluntary initiatives: To our knowledge there is no voluntary initiative reported but these should be encouraged by various types of incentive
- End of the pipe treatment: appropriate industrial wastewater treatments exist and are able to remove PAHs (see Deliverable 5.6), but they can be strongly adsorbed on sludge

- PAHs resulting from incomplete combustion in industrial plants and in waste incineration (point sources)
  - Substitution: these sources cannot be substituted because it is not technically feasible to burn organic matter without generating PAHs, at least as unavoidable by-products.
  - IPPC Directive and the BAT approach: industrial combustion plants are submitted to the IPPC Directive and should comply with the BAT described in the BREF documents. Emissions of PAHs are also considered in other IPPC categories: gas refineries, iron and steel industry, non ferrous metals production and waste incineration. In this context ELVs should be fixed by the competent authorities in the permit in such a way that the requirements of the WFD will be satisfied. The key questions are the control by the competent authorities and the applicability of the BAT at each combustion plant.
  - Existing EU and international regulations: PAHs are submitted to emission reporting under the E-PRTR Directive. PAHs are also listed under the Hazardous Waste Directive, but the reporting under these Directives is compulsory only above several thresholds. This will limit their applicability to large industrial units. European standards for small and solid fuel combustion appliances are under development. The Directive on air quality sets a target value of 1ng PAH/m^3 in ambient air. Once again the efficiency of these regulations strongly depends on the control and monitoring by the competent authorities
  - Voluntary initiatives: To our knowledge there is no voluntary initiative reported but these should be encouraged by various types of incentive. Improvement of the combustion process should be encouraged.
  - End of the pipe treatment: appropriate industrial wastewater treatments exist and are able to remove PAHs (see Deliverable 5.6), but they can be strongly adsorbed on sludge. For small combustion units, the effluent will reach municipal wastewater treatment plants (see Deliverable 5.6 for the best choice)
- PAHs resulting from incomplete combustion: domestic devices and landfill burning (diffuse sources)

- Substitution: these sources cannot be substituted because it is not technically feasible to burn organic matter without generating PAHs, at least as an unavoidable by-product.
- IPPC Directive and the BAT approach: the IPPC directive is not applicable to domestic devices and to landfill burning.
- Existing EU and international regulations: European standards for small and solid fuel combustion appliances are under development. The Directive on air quality sets a target value of 1ng PAH/m³ in ambient air but these regulations are almost impossible to apply to domestic devices.
- Voluntary initiatives: To our knowledge there are no voluntary initiatives reported but they should be encouraged by various types of incentive, for example support to encourage people to renew their domestic heating devices and to improve the insulation of their houses. Information/education campaigns organized for the general public to avoid landfill burning of waste appear to be a good approach for limiting this type of emissions. Improvement to the combustion process should be encouraged.
- End of the pipe treatment: For small combustion units and domestic devices the PAH emissions will reach municipal wastewater treatment (see Deliverable 5.6 for the best choice). The PAHs can however be strongly adsorbed on sludge

- PAHs emissions from fuel and road traffic (diffuse sources):
  - Substitution: these sources cannot be substituted because it is not technically feasible to burn organic matter without generating PAHs, at least as unavoidable by-products.
  - IPPC Directive and the BAT approach: the IPPC directive is not applicable to vehicles
  - Existing EU and international regulations: There is a limit value on the content of PAHs in diesel fuel of 8% w/w from 2010. EU regulations on new vehicles that meet the EURO 4 emission standards will bring about a reduction of PAH as an important side-effect. PAH are adsorbed on the particles contained in the exhaust gas of diesel engines and to meet the new particle emission standard of 0.05 g/km heavy vehicles should be equiped with diesel particle filters. The PAH content of extender oils used to make tyres should be lower than 10 parts per million (ppm). The Directive on air quality sets a target value of 1ng PAH/m³ in ambient air. The efficiency of these regulations strongly depends on the control and monitoring by the competent authorities
  - Voluntary initiatives: To our knowledge there are voluntary initiatives by the car and diesel engine producers to reduce emission of particle and other pollutants. They should be encouraged by various types of incentive. The development of electric vehicles as well as incentives for renewing cars should also be encouraged.
  - End of the pipe treatment: the PAH emissions from road traffic will reach municipal wastewater treatment plants (see Deliverable 5.6 for the best choice). The PAHs can however be strongly adsorbed on sludge.

Conclusion on PAH

- As most of the PAH emissions result from combustion processes as unavoidable and unintended by-products, even if it is a PBT chemical, the releases cannot be completely phased out but a negligible level of release should be defined for each river basin, based on a risk assessment approach.

- The creosote production and uses should be strictly limited and substituted as much as possible. Limits in PAH content of other coal tar distillates like asphaltic products should be set and applied by the competent authorities.
- For industrial combustion or incineration plants, the only realistic emission reduction measures should be based on the existing legislation and in particular on the BAT approach. The strict application of these regulations to point sources could be sufficient to reach the EQS levels recommended by the WFD and consequently reduce the burden on the municipal WWTP and on the drinking water production plants.
- Further process improvements or an increase in efficiency of the existing WWTP could also be considered but they could require huge investments. These investments costs should be compared to the potential environmental benefits of reducing emissions. This implies a complete cost/benefit analysis.
- For domestic combustion devices and landfill burning, information campaigns should be organized to promote the use of high temperature combustion devices, to limit wood burning and to avoid open air burning of waste. Positive incentives could be used to encourage people to renew their heating devices. In the same spirit, European standards for small and solid fuel combustion appliances should be developed to encourage the producers to develop more efficient units.
- For PAH emissions from road traffic the new EU regulation on diesel fuel will be very effective, but the practical efficiency strongly depends on the control and monitoring introduced by the competent authorities. Incentives to encourage the move towards electric vehicles can also be very efficient in reducing PAH emissions on a longer term perspective.

3.4. The case of metals

We consider under this point the following substances: lead, mercury and cadmium. Contrary to organic compounds, the metals cannot be mineralized and should ideally be recycled.

3.4.1. Lead

The main use of lead is the manufacture of lead-acid batteries and for the time being it seems difficult to find an appropriate substitute for lead in batteries for automotive applications.

The manufacture of lead sheets, rolled and extruded products is the second main application domain of lead. These sheets are mainly used in the building and construction industry and it is difficult to find substitutes for lead in these building applications. Lead pipes have not been used for domestic water supplies for 10 years. However, in some countries considerable amounts of lead pipe work are still in service. Lead from pipes can dissolve very slowly in soft water areas. Lead is also used for shielding and protective coatings in particular in medical applications.

The third largest consumption of lead is in the form of lead compounds, the largest current application for lead compounds being electrical glasses (shielding glass, cathode ray tubes, and fluorescent tubes). Lead compounds are used as a stabiliser in PVC. Lead compounds are also used as pigments in various plastic materials, coatings and paints. Several types of crystal glass and ceramic glaze contain a large proportion of lead (minimum 24% lead oxide for crystal).

There are several minor uses of lead, each of them representing a few percent of the consumption. These are:

- Sheathing for electrical cables to prevent water penetration of underwater power and telecommunication cables. In future, this use will be limited to applications at sea, for which it is difficult to find substitutes.
- Lead shot for ammunition in particular for hunting has been prohibited in designated areas by certain member states, but about 80% of the lead shot is used as additive to certain steel alloys to improve the steel
- Lead weights are mainly used as vehicle wheel balancing weights. Most of these lead weights enter the environment by falling off the wheels or when the vehicle is disposed of. Non-lead substitutes may easily be used for this application. The replacement requires however the cooperation of all stakeholders: wheel weight manufacturers, retailers, automobile manufacturers and trade associations. Other minor uses of lead weights are curtain weights or fishing sinkers, but these applications are so small that the economic incentive for replacing lead is very poor. Specific local actions are needed to stimulate substitution.
- Lead in alloys for solders were mainly used to attach electronic components to circuit boards. Alternative alloys exist but they are more brittle than solder with lead, so the fragility of lead-free designs remains a big concern, in particular their long-term reliability. However in the EU electronic products must be lead-free since July 1, 2006 and the electronics producers are made responsible for recycling electrical and electronic equipment.
- Lead additive in gasoline has been banned in the EU since the end of 2002 and efficient substitutes exist.

Review of possible measures as a function of uses

The scoring table is presented in **Annex 9** and the various possible measures are discussed below in order to clarify the chosen scores. Production and key uses are considered in this review.

- Lead emissions in metallurgy and from various industrial plants
  - Substitution: lead cannot be substituted in lead production plants and it is also an unavoidable by-product of combustion plants and plants using mineral ores like the cement and fertilizers industry. Lead can indeed be present as impurity in the raw materials.
  - IPPC Directive and the BAT approach: Various BAT reference documents of the IPPC Directive are relevant for lead releases. IPPC categories covering the processing of ferrous and non-ferrous metal, steel and iron production, cement and glass production, inorganic chemicals and fertilizers, combustion installations and refineries. BAT reference documents on waste treatment and on waste are also considering lead releases In this context ELVs should be fixed by the competent authorities in the permit in such a way that the requirements of the WFD will be satisfied. The key question is the control by the competent authorities and the applicability of BAT at each plant.
  - Existing EU and international regulations: The Directive on large combustion plants (LCPs) is likely to have some impact on heavy metals emissions, including lead, from coal- and oil-fired LCPs as it sets limit values for total dust emissions in air.The Directive on air quality sets a target value of 0.5 µg lead/m³ in ambient air. Lead is also submitted to emission reporting under the E-PRTR Directive The efficiency of these regulations strongly depends on the control and monitoring by the competent authorities

   - Voluntary initiatives: To our knowledge there are no voluntary initiatives in this field
   - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that lead will remain adsorbed on sludge and that the lead content in sewage sludge used in agriculture is restricted.
- Lead in lead-acid batteries (diffuse sources):
   - Substitution: for the time being it is difficult to find an appropriate substitute for lead in batteries for automotive applications even if some new developments based on lithium look promising.
   - IPPC Directive and the BAT approach: the IPPC directive is not applicable
   - Existing EU and international regulations: The Directive 91/157 on batteries and accumulators calls for measures to reduce the content of lead in batteries and to reduce the amount of batteries with lead. For some waste streams which include lead, specific regulations exist like end-of life vehicles or batteries. The Directive on air quality sets a target value of 0.5 µg lead/m³ in ambient air. Lead is also submitted to emission reporting under the E-PRTR Directive. The efficiency of these regulations strongly depends on the control and monitoring by the competent authorities.
   - Voluntary initiatives: Various clean recycling processes have been developed by the industry to recover very pure lead from used batteries. Information campaigns are still needed to increase the collected fraction of used batteries.
   - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that lead will remain adsorbed on sludge and that the lead content in sewage sludge used in agriculture is restricted.
- Lead sheets, rolled and extruded products in the construction industry (diffuse sources):
   - Substitution: It is difficult to find substitutes of lead in these building applications. However, lead pipes are not used anymore for domestic water supplies.
   - IPPC Directive and the BAT approach: the IPPC directive is not applicable to this type of industry but BAT reference documents on waste treatment and on waste consider lead releases
   - Existing EU and international regulations: Directive on the quality of water intended for human consumption contains quality standards for lead. To achieve the standards, water pipes with lead have to be replaced by suitable alternatives. It has to be pointed out that, in some countries, considerable amounts of lead pipe work are still in service. There is no specific EU regulation on the use of lead in the construction industry
   - Voluntary initiatives: To our knowledge there are no voluntary initiatives in this field
   - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that lead will remain adsorbed on sludge and that the lead content in sewage sludge used in agriculture is restricted.

- Lead for shielding and protective coatings in particular for medical applications (diffuse sources):
  - Substitution: new materials like plastics and composite materials, some that are mixed with less toxic metals, can be used as lead substitutes for shielding applications and protective coatings, but the type of substitute will depend on each specific application
  - IPPC Directive and the BAT approach: the IPPC directive is not applicable
  - Existing EU and international regulations: Except the Directive on air quality which sets a target value of 0.5 µg lead/m³ in ambient air, there is no specific EU regulation in this field.
  - Voluntary initiatives: to our knowledge there are no voluntary initiatives in this field
  - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that lead will remain adsorbed on sludge and that the lead content in sewage sludge used in agriculture is restricted.
- Lead in lead compounds used in stabilizers and pigments for plastic materials and paints (diffuse sources):
  - Substitution: It is technically possible to substitute lead stabilisers in all PVC products mainly by calcium/zinc or barium/zinc stabilisers. It is also technically possible to substitute lead pigments in all types of paints, but the choice of pigment will be decided on the basis of desired characteristics, e.g. colour, brilliance, weather resistance. Red lead may still be necessary for maintenance of old ships and iron constructions.
  - IPPC Directive and the BAT approach: the IPPC directive is not applicable to this type of industry but BAT reference documents on waste treatment and on waste consider lead releases
  - Existing EU and international regulations: Directive 1989/677/EEC prohibits the use of lead carbonates and lead sulphates as substances and constituents of paints. The Directive on air quality sets a target value of 0.5 µg lead/m³ in ambient air.
  - Voluntary initiatives: Even if there is no specific EU regulation on the use of lead stabilizers in plastic materials, the PVC Industry has pledged to phase out lead stabilizers by 2015 as part of the Vinyl 2010 Voluntary Commitment. In line with this Commitment, the pipes industry has phased out lead stabilizers in potable water pipes from 2003.
  - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that lead will remain adsorbed on sludge and that the lead content in sewage sludge used in agriculture is restricted.
- Lead in electrical, crystal and ceramic glasses (diffuse sources):
  - Substitution: it appears that several metals tested (e.g. bismuth, barium, strontium, zinc and titanium) can be good technical alternatives to lead in the manufacture of crystal glass. These alternatives can reduce the potential occupational hazard for glass workers but there is no risk to users of crystal glass as virtually no lead leaches from glass during normal use (10). Substitution is more difficult for cathode ray tubes and fluorescent tubes.
  - IPPC Directive and the BAT approach: the IPPC directive is relevant for lead releases in cement and glass production. The BAT reference documents on waste

treatment and on waste also consider lead releases. In this context ELVs should be fixed by the competent authorities in the permit in such a way that the requirements of the WFD will be satisfied. The key question is the control by the competent authorities and the applicability of the BAT at each plant.
    - Existing EU and international regulations: the European definition of lead crystal is a glass that contains a minimum of 24% lead oxide. As glass waste could pose long-term problems for waste disposal, several directives on waste streams are applicable including hazardous waste and the incineration of municipal waste. Lead is also submitted to emission reporting under the E-PRTR Directive. The Directive on air quality sets a target value of 0,5 µg lead/m³ in ambient air. The key question is the control by the competent authorities and the applicability of these directives.
    - Voluntary initiatives: To our knowledge no voluntary initiatives exist in this field
    - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that lead will remain adsorbed on sludge and that the lead content in sewage sludge used in agriculture is restricted.
- Lead in sheathing for electrical cable (diffuse sources):
    - Substitution: Lead is extruded into a continuous covering to prevent water penetration of underground or underwater power and telecommunication cables. It is difficult to find substitutes of lead in particular for applications at sea.
    - IPPC Directive and the BAT approach: the IPPC directive is not applicable to this industry but BAT reference documents on waste treatment and on waste consider lead releases.
    - Existing EU and international regulations: There is no specific EU regulation in this field but lead is submitted to emission reporting under the E-PRTR Directive. The Directive on air quality sets a target value of 0.5 µg lead/m³ in ambient air
    - Voluntary initiatives: To our knowledge no voluntary initiatives exist in this field but recycling after use should be encouraged.
    - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that lead will remain adsorbed on sludge and that the lead content in sewage sludge used in agriculture is restricted.
- Lead in lead shot and weights (diffuse sources):
    - Substitution: Non-lead substitutes like tin, tungsten and some alloys may easily be used to replace lead in vehicle wheel balancing weights. The replacement requires however the cooperation of all stakeholders. Similarly lead can be substituted in shot for hunting or in fishing sinkers and curtain weights
    - IPPC Directive and the BAT approach: the IPPC directive is not applicable to this industry but BAT reference documents on waste treatment and on waste consider lead releases.
    - Existing EU and international regulations: Directive 2000/53/EC restricts the content of lead in materials and components of vehicles. There is no specific EU regulation in this field but lead is submitted to emission reporting under the E-PRTR Directive. The Directive on air quality sets a target value of 0.5 µg lead/m³ in ambient air
    - Voluntary initiatives: Voluntary initiatives have been taken by certain member states to prohibit the use of lead shot for hunting in designated areas. Also

fishing sinkers have been prohibited in designated areas. Such type of initiatives could be extended. In order to reduce the potential impact of lead tyre weights on human health and the environment, the competent authorities should encourage the cooperation of all stakeholders: wheel weight manufacturers, retailers, automobile manufacturers and trade associations. Other initiatives have been taken to avoid the use of lead in jewellery and toys for children

  - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that lead will remain adsorbed on sludge and that the lead content in sewage sludge used in agriculture is restricted.

- Lead in solder alloys in electronic equipment (diffuse sources):
  - Substitution: Lead-free, safe, and cost effective soldering alloys (such as tin-silver-copper) exist as substitutes for lead-bearing solders in most of the applications in electronics manufacturing.
  - IPPC Directive and the BAT approach: the IPPC directive is not applicable
  - Existing EU and international regulations: EU Directive 2002/95/EC prohibits the use of lead in electronic products placed on the market in the EU after July 2006. This applies to household appliances, IT & telecommunication equipment, consumer equipment, lighting equipment, electrical and electronic tools and toys. In addition, the EU has banned the export of hazardous electronic waste from any European country to any developing country. The EU has made electronics producers responsible for recycling electrical and electronic equipment and forced them to consider waste management when designing new equipment. Moreover, specific regulations exist for lead in electrical and electronic equipment waste streams. The key questions is the control by the competent authorities and the applicability of these directives to imported products
  - Voluntary initiatives: To our knowledge no voluntary initiatives exist in this field but recycling after use should be encouraged in particular for end users.
  - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that lead will remain adsorbed on sludge and that the lead content in sewage sludge used in agriculture is restricted.

Conclusion on lead.

- Whenever possible products containing lead should be recycled and incentives to do so should be developed at all stages of the consumer chain.
- In wastewater treatment plants, lead is not destroyed and generally remains in sludge. This strongly limits the use of these sludges in agriculture. They should then be incinerated.
- Lead can be substituted in several applications: in pipes for domestic water supply, in some protective coatings, in stabilizers and pigments in plastics and paints, in crystal glass, in some lead weights and in most solder alloys for electronic equipment. These substitutions have been favoured either by the implementation of existing regulations (electronic equipment) or by voluntary industrial initiatives (stabilizers and pigments). Other substitutions can be encouraged by the development of education and information campaigns or by positive incentives. The control by the competent authorities is key for implementing substitution.

- Lead cannot be substituted in lead-acid batteries, in sheathing for electrical cable and in sheets, rolled and extruded products for the construction industry. In these cases, the recycling of used products is one of the key measures to be encouraged and implemented. Incentives should be given to facilitate such recycling, in particular the collection of used products and waste management. Voluntary initiatives exist (in lead-acid batteries for example) but the competent authorities act to strictly apply the existing regulations. Also lead containing commodities should be labelled with handling instructions which when followed minimizes release of lead from the commodities.

3.4.2. Mercury

As for other metals, mercury is persistent and cannot be degraded into harmless products but it has the characteristic of being **permanently recycled** through physical, chemical and biological processes in the environment, through reduction-oxidation cycles. In the environment, mercury mainly occurs as elemental mercury and as inorganic mercury compounds (chlorides, hydroxides, oxides and sulphides), but mercury can also be transformed by biochemical and biological reactions into more toxic organic compounds (e.g. methyl mercury). There are also several natural large emission sources of mercury: volcanic eruptions and geothermal activities (about 800 t/y), erosion and degassing from soils (about 700 t/y), escape from the earth's subsurface crust (about 1000 t/y). Even if small scale gold extraction does not exist in Europe, it appears to be one of the largest sources of mercury in the world and consequently to make a significant contribution to the total amount of mercury cycling in the world environment. Due to the cycling of mercury between the different compartments of the environment, its long residence time in soil and the re-emission processes, it is difficult to distinguish between direct anthropogenic input and natural or re-emission inputs at a regional scale.

Mercury is mainly used as a cathode in mercury cells in the chlor-alkali industry, in dental amalgam, in measuring and control equipment, and in batteries and lamps.

- The mercury cell process for producing chlorine, alkali, sodium hydroxide, potassium hydroxide from the corresponding chlorides.
- Mercury continues to be used in dental amalgam
- Mercuric-oxide and mercury-zinc (medical) "button cell" batteries
- Measuring and control equipment : mercury is used in clinical mercury-thermometers and non-medical thermometers, as a "heavy liquid" in pressure gauges, pressure switches and pressure transmitters, in electrical and electronic components like conventional relays and other contacts
- Mercury is used in fluorescent and energy-efficient lamps.
- Mercury used in laboratories
- Mercury as an unavoidable by-product or contaminant in many industrial processes, mainly landfill or incineration of refuse and combustion of coal, fuel and wood.

It has to be pointed out that there are several previous uses of mercury that have been banned such as the production and use of pesticides containing mercury, applications of mercury compounds in marine anti-fouling paints, wood preservation and textile treatment. All the mercury mines in Europe have been closed and consequently there is no more new production of mercury but only recycling

Review of possible measures as a function of uses

The scoring table is presented in **Annex 10** and the various possible measures are discussed below in order to clarify the chosen scores. Production and key uses are considered in this review.

- Mercury in mercury cell processes (point sources):
  - Substitution: mercury cell processes can be replaced by membrane technology or by non-asbestos diaphragm technology which can both be considered as BAT but this requires high capital investment costs for conversion.
  - IPPC Directive and the BAT approach: A specific BAT reference document of the IPPC Directive applies to chlor-alkali production proposing the alternative processes as BAT. The substitution of the mercury-cell processes generate a huge amount of mercury which has to be recycled or disposed of in an appropriate way. At the initiative of the chlorine industry, a process to ensure the permanent safe storage of this mercury was recently adopted by the EU authorities. The BAT reference documents on waste treatment and on waste incineration within the IPPC Directive are limiting mercury releases.
  - Existing EU and international regulations: there are many EU and international regulations limiting mercury emission (see Deliverable 4.3). Mercury is also submitted to emission reporting under the E-PRTR Directive. The Directive on the landfill of waste contains specific provisions with regard to mercury discharges/emissions. A Commission proposal for the banning of exports and the safe storage of metallic mercury has been recently adopted.
  - Voluntary initiatives: For many years the chlorine industry voluntarily decided to drastically reduce the mercury emissions from their chlor-alkali plants to meet a voluntary mercury emission target of 1 g/t chlorine capacity on a national basis by 2007, with no individual plant exceeding 1.5 g/t capacity. Moreover, in spite of the high capital investment costs for conversion to membrane or diaphragm processes, the European chlorine industry developed a voluntary agreement to replace all mercury cells by 2020. This agreement has been approved by the EU authorities.
  - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that mercury will remain adsorbed on sludge and that the mercury content in sewage sludge used in agriculture is restricted.
- Mercury in dental amalgam (diffuse sources):
  - Substitution: Even if various alternatives (cold silver, gallium, ceramic, porcelain, polymers, composites, glass ionomers, etc.) are commercially available, there is not yet a consensus that substitutes can adequately replace mercury amalgams in all dental applications, in particular fillings in adult molars. None of the alternatives require the specialized wastewater treatment equipment that dental professionals need to meet environmental regulations in many countries.
  - IPPC Directive and the BAT approach: the IPPC directive is not applicable

- Existing EU and international regulations: there are many EU and international regulations limiting mercury emissions (see Deliverable 4.3). A Community Strategy concerning mercury exists which intends to reduce the impact of mercury and the risks it poses for the environment and human health by reducing mercury emissions by the implementation of existing legislation and by the management of certain sources like small combustion plants and dental amalgam.
- Voluntary initiatives: In Sweden and Denmark voluntary substitution agreements have been put in place, which aim at exchanging the amalgam and in Stockholm also to clean drain syphons for accumulated mercury.
- End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that mercury will remain adsorbed on sludge and that the mercury content in sewage sludge used in agriculture is restricted.

- Mercury in "button-cell" batteries (diffuse sources):
  - Substitution: Mercury button-cell batteries can be substituted by virtually mercury-free zinc-air batteries (actually still containing less than 10 mg of mercury) and lithium cells which contain no mercury. All other mercury-based standard and rechargeable batteries can now be substituted by mercury- and cadmium-free versions. There are some reports indicating that mercury oxide batteries are still the best technical option for some medical uses such as pacemakers.
  - IPPC Directive and the BAT approach: the IPPC directive is not applicable
  - Existing EU and international regulations: there are many EU and international regulations limiting mercury emissions (see Deliverable 4.3). The last Directive on batteries prohibits the placing on the market of batteries and accumulators with a mercury content of more than 0.0005% by weight of mercury (except for button cells, which must have a mercury content of less than 2% by weight).
  - Voluntary initiatives: Information campaigns to promote the recycling of batteries are giving excellent results in many EU countries. The recycling after use should be encouraged in particular for end users. However batteries still remain a significant problem in the municipal waste stream of most countries.
  - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that mercury will remain adsorbed on sludge and that the mercury content in sewage sludge used in agriculture is restricted.
- Mercury in measuring and control equipment (diffuse sources):
  - Substitution: many alternatives to mercury exist for clinical and non-medical thermometers. The choice of alternative depends on the temperature range, the specific application, and the need for precision. Mercury may be substituted without any loss of accuracy or reliability in pressure gauges, pressure switches and pressure transmitters.
  - IPPC Directive and the BAT approach: the IPPC directive is not applicable
  - Existing EU and international regulations: there are many EU and international regulations limiting mercury emission (see Deliverable 4.3). The Directive 2007/51/EC imposes restrictions on the marketing of certain measuring devices containing mercury in particular fever thermometers and other measuring devices intended for sale to the general public (e.g. manometers, barometers, sphygmomanometers, thermometers other than fever thermometers). Directive

2002/95/EC restricts or prohibits the use of mercury in electrical and electronic equipment.
    - Voluntary initiatives: To our knowledge no voluntary initiatives exist in this field but recycling after use should be encouraged in particular for end users. This should be encouraged by information/education campaigns.
    - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that mercury will remain adsorbed on sludge and that the mercury content in sewage sludge used in agriculture is restricted.
- Mercury in fluorescent and energy-efficient lamps (diffuse sources):
    - Substitution: For mercury use in fluorescent lamps, which are known for their low energy consumption, work has been done to reduce the amount of mercury needed in each lamp. For use to be allowed, the European Ecolabel must be present on a single-ended compact fluorescent lamp, indicating that the mercury content does not exceed 4 mg and the life of the lamp will exceed 10,000 hours. The use of light emission diodes (LED) appears more and more as an energy-efficient substitute. Until mercury-free alternatives are widely deployed, the mercury in fluorescent lamps can be managed by collection of used lamps and recycling or proper waste treatment. No commercially mature alternatives are yet available but the EU approves the phasing-out of incandescent bulbs by 2012
    - IPPC Directive and the BAT approach: the IPPC directive is not applicable
    - Existing EU and international regulations: there are many EU and international regulations limiting mercury emissions (see Deliverable 4.3). A Community Strategy concerning mercury exists which intends to reduce the impact of mercury and the risks it poses for the environment and human health by reducing mercury emissions by the implementation of existing legislation and by the management of certain sources.Mercury is mentioned in various waste streams relevant to the hazardous waste Directive
    - Voluntary initiatives: To our knowledge no voluntary initiatives exist in this field but recycling after use should be encouraged in particular for end users. Information campaigns and recycling schemes should be organised.
    - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that mercury will remain adsorbed on sludge and that the mercury content in sewage sludge used in agriculture is restricted.
- Mercury uses in laboratories (diffuse sources):
    - Substitution: It is entirely possible to restrict mercury use in school or university laboratories to a few specific, controllable uses (mainly references and standard reagents). This initiative has already been implemented in Swedish and Danish legislation..
    - IPPC Directive and the BAT approach: the IPPC directive is not applicable
    - Existing EU and international regulations: No specific regulations exist at EU level but restrictions have been implemented in Swedish and Danish legislation..
    - Voluntary initiatives: To our knowledge no general voluntary initiatives exist in this field but through information campaigns the limitation of use and the recycling of mercury after use should be encouraged, in particular in universities or technical schools.
    - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that mercury

will remain adsorbed on sludge and that the mercury content in sewage sludge used in agriculture is restricted.

- Mercury as an unavoidable by-product or contaminant (diffuse sources):
    - Substitution: not possible
    - IPPC Directive and the BAT approach: Various BAT reference documents are relevant for mercury releases, in particular documents related to ferrous and non-ferrous metal, chlor-alkali production, inorganic chemicals, combustion installations and refineries (see Deliverable 4.3). The BAT reference documents on waste treatment and on waste incineration within the IPPC Directive limit mercury releases.
    - Existing EU and international regulations: there are many EU and international regulations limiting mercury emission (see Deliverable 4.3). A Community Strategy concerning mercury exists which intends to reduce the impact of mercury and the risks it poses for the environment and human health by reducing mercury emissions by the implementation of existing legislation and by the management of certain sources. Mercury is mentioned in various waste streams relevant to the hazardous waste Directive. Mercury is also submitted to emission reporting under the E-PRTR Directive The Directive on large combustion plants (LCPs) is likely to have some impact on heavy metals emissions, including mercury, from coal- and oil-fired LCPs as it sets limit values for total dust into the air. Directives on the incineration of waste and Directive on the landfill of waste contain specific provisions with regard to mercury discharges or emissions
    - Voluntary initiatives: To our knowledge no voluntary initiatives exist in this field
    - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that mercury will remain adsorbed on sludge and that the mercury content in sewage sludge used in agriculture is restricted.

Conclusion on mercury

- Whenever possible, products containing mercury should be recycled or permanently and safely stored. Incentives and information campaigns to do so should be developed at all stages of the consumer chain.
- In wastewater treatment plants, mercury is not destroyed and generally remains in sludge. This strongly limits the use of this sludge in agriculture. The sludge should then be incinerated, if measures to reduce the content of mercury in incoming water do not succeed.
- Mercury can be substituted in several applications: this substitution should be encouraged by incentives and information campaigns.
    - In mercury cell processes for chlor-alkali industry; delay for conversion is occurring due to the huge investment costs involved. Voluntary agreements to phase out mercury cell processes in 2020 have been developed by the chlorine producers.
    - Most of the batteries containing mercury can be substituted and the conversion is already going on. Some particular medical applications (pacemakers) could still require mercury based batteries.
    - The use of mercury in measuring and control devices can be easily replaced by various alternatives, the choice of which will depend on the type and conditions of uses.

- Mercury uses can be strongly reduced in several applications: these reductions should be enforced by the strict application of existing legislation and control by the competent authorities.
  - In dental amalgams various alternatives are commercially available but there is not yet a consensus that substitutes can adequately replace mercury amalgams in all dental applications, in particular fillings in adult molars. Nevertheless, the use of mercury in dental amalgam can be reduced in many applications.
  - In energy efficient and fluorescent lamps the content of mercury per lamp bulb can be strongly reduced and the development of LED could provide an alternative in the medium term.
  - In laboratory practice it is entirely possible to restrict mercury use to reference and standard reagents.
- The emission of mercury cannot be avoided as a by-product or contaminant in many industrial processes. The strict application of existing legislation can effectively reduce the mercury emission in this field, but control by the competent authorities is key to reaching the objectives.

3.4.3. Cadmium

There are six classes of applications for which cadmium is utilized as a deliberate additive. These are batteries, pigments, coatings, stabilizers, alloys, and electronic compounds. The 2006 market analysis of cadmium consumption indicates that 82.5% is consumed in batteries, 10% in pigments, 6% in coatings, 1% in stabilizers, and 0.5% in alloys and electronic compounds and other minor uses. Cadmium also appears as an unavoidable by-product or contaminant in many industrial processes, as well as in phosphorous fertilizers.

Review of possible measures as a function of uses

The scoring table is presented in **Annex 11** and the various possible measures are discussed below in order to clarify the chosen scores.

- Cadmium as an unavoidable by-product or contaminant (point and diffuse sources):
  - Substitution: not possible
  - IPPC Directive and the BAT approach: Various BAT reference documents are relevant to cadmium releases, in particular documents covering metal industries, electroplating, steel and iron production, cement production, organic chemicals, inorganic chemicals, fertilizers including phosphoric acid production, combustion installations, refineries, pulp and paper industry, surface treatment , textile pretreatment, pharmaceuticals and coal gasification all involve cadmium emissions (see Deliverable 4.3). The BAT reference documents on waste treatment and on waste incineration within the IPPC Directive are limiting cadmium releases.
  - Existing EU and international regulations: there are many EU and international regulations limiting cadmium emissions (see Deliverable 4.3). Cadmium is mentioned in various waste streams relevant to the hazardous waste Directive. Cadmium is also submitted to emission reporting under the E-PRTR Directive The Directive on large combustion plants (LCPs) is likely to have some impact on heavy metals emissions, including cadmium from coal- and oil-fired LCPs as it sets limit values for total dust into the air. Directives on the incineration of

waste and Directive on the landfill of waste contain specific provisions with regard to cadmium discharges or emissions. There are several Directives limiting the content of cadmium in various applications, for example in fertilizers and in sewage sludge used in agriculture.
    - Voluntary initiatives: To our knowledge no voluntary initiatives exist in this field, except for use of low cadmium fertilizers or manure in agriculture, resulting in less cadmium in crops and so in the wastewater to wastewater sewage plants.
    - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that cadmium will remain adsorbed on sludge and that the cadmium content in sewage sludge used in agriculture is restricted.
- Cadmium in batteries (diffuse sources):
    - Substitution: today Li-ion batteries are gradually replacing most other battery chemistries in consumer applications. NiCd batteries are still widely used in power tools, emergency lighting and cordless phones because of their cost-performance characteristics and will be substituted mainly based on market/performance/price attributes rather than legislation. It is not readily possible to lower the cadmium content of a specific type of NiCd battery without hurting its performance
    - IPPC Directive and the BAT approach: IPPC not applicable to this field but BAT reference documents on waste treatment and on waste incineration within the IPPC Directive are limiting cadmium releases.
    - Existing EU and international regulations: there are many EU and international regulations limiting cadmium emission (see Deliverable 4.3). The current EU Battery Directive exempts NiCd batteries for power tools and for industrial applications. Cadmium is mentioned in various waste streams relevant to the hazardous waste Directive. Cadmium is also submitted to emission reporting under the E-PRTR Directive. Directives on the incineration of waste and Directive on the landfill of waste contain specific provisions with regard to cadmium discharges or emissions
    - Voluntary initiatives: Voluntary industrial attempts have been made to replace nickel-cadmium (NiCd) particularly in portable consumer applications as opposed to large industrial applications.
    - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that cadmium will remain adsorbed on sludge and that the cadmium content in sewage sludge used in agriculture is restricted.
- Cadmium in electronic equipment (diffuse sources):
    - Substitution: substitution has been achieved in most of electronic products on the market. However substitution is not possible for electronic equipment utilizing cadmium sulfide and cadmium telluride materials used in electronic gates, sensors, switches, detectors, relays and photovoltaic solar cells. These are all very minor uses and involve highly insoluble cadmium compounds, which minimizes their environmental or human health impact. It has to be pointed out that CdTe is one of the most promising solar cell materials available.
    - IPPC Directive and the BAT approach: there are many EU and international regulations limiting cadmium emission (see Deliverable 4.3). The BAT reference

documents on waste treatment and on waste incineration within the IPPC Directive are limiting cadmium releases.
  - Existing EU and international regulations: there are many EU and international regulations limiting cadmium emission (see Deliverable 4.3). The use of cadmium is also prohibited in electronic products placed on the market in the European Union after July 2006. This applies to household appliances, IT & telecommunication equipment, consumer equipment, lighting equipment, electrical and electronic tools and toys. Several exemptions are foreseen. Cadmium is mentioned in various waste streams relevant to the hazardous waste Directive. Cadmium is also submitted to emission reporting under the E-PRTR Directive. Directives on the incineration of waste and the Directive on the landfill of waste contain specific provisions with regard to cadmium discharges or emissions
  - Voluntary initiatives: To our knowledge no voluntary initiatives exist in this field
  - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that cadmium will remain adsorbed on sludge and that the cadmium content in sewage sludge used in agriculture is restricted.
- Cadmium in alloys (diffuse sources):
  - Substitution: Most alloy applications for cadmium-containing alloys have been successfully substituted; this includes brazing and soldering alloys. But alloy applications where substitution has not been possible include the copper-cadmium and copper-cadmium-titanium thermal and electrical conductivity alloys, and the silver-cadmium oxide electrical contact alloys.
  - IPPC Directive and the BAT approach: Various BAT reference documents are relevant for cadmium releases, in particular documents related to ferrous and non-ferrous metal (see Deliverable 4.3). The BAT reference documents on waste treatment and on waste incineration within the IPPC Directive are limiting cadmium releases.
  - Existing EU and international regulations: there are many EU and international regulations limiting cadmium emission (see Deliverable 4.3). Cadmium is mentioned in various waste streams relevant to the hazardous waste Directive. Cadmium is also submitted to emission reporting under the E-PRTR Directive. Directives on the incineration of waste and the Directive on the landfill of waste contain specific provisions with regard to cadmium discharges or emissions
  - Voluntary initiatives: Voluntary industrial attempts have been made to replace cadmium based alloys while keeping the technical performance.
  - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that cadmium will remain adsorbed on sludge and that the cadmium content in sewage sludge used in agriculture is restricted.
- Cadmium in pigments (diffuse sources):
  - Substitution: Several substitutes exist and cadmium-based pigments have slowly been declining in use. Only the absolutely essential uses are maintained in applications that encounter either high temperature or high stress processing or situations where cadmium pigments are one of the few materials which will not degrade. Substitutes do not exhibit the bright, long-lasting hues of cadmium pigments.

- IPPC Directive and the BAT approach: Various BAT reference documents are relevant for cadmium releases, in particular documents relating to ferrous and non-ferrous metal, and inorganic chemicals (see Deliverable 4.3). The BAT reference documents on waste treatment and on waste incineration within the IPPC Directive are limiting cadmium releases.
- Existing EU and international regulations: there are many EU and international regulations limiting cadmium emission (see Deliverable 4.3). The use of cadmium as colorant in plastic materials and paints is prohibited (maximum allowed concentration 0.01%) with certain exemptions for product colored for safety reasons or if reliability is required. Cadmium is mentioned in various waste streams relevant to the hazardous waste Directive. Cadmium is also submitted to emission reporting under the E-PRTR Directive. Directives on the incineration of waste and the Directive on the landfill of waste contain specific provisions with regard to cadmium discharges or emissions
- Voluntary initiatives: Industrial voluntary programmes to progressively phase out the use of cadmium based pigments have been initiated by the PVC industry (see Deliverable 4.4). Several education campaigns have been organised in Nordic countries to reduce the use of cadmium pigment by artists (see Deliverable 4.4)
- End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that cadmium will remain adsorbed on sludge and that the cadmium content in sewage sludge used in agriculture is restricted.

- Cadmium compound used as stabilizers in plastics (diffuse sources):
  - Substitution: Cadmium based stabilizers for PVC have been successfully substituted by calcium-zinc and barium-zinc compounds which show equal performance and are just as cost effective.
  - IPPC Directive and the BAT approach: Various BAT reference documents are relevant for cadmium releases, in particular documents related to inorganic and organic chemicals (see Deliverable 4.3). The BAT reference documents on waste treatment and on waste incineration within the IPPC Directive are limiting cadmium releases.
  - Existing EU and international regulations: there are many EU and international regulations limiting cadmium emission (see Deliverable 4.3). Cadmium is mentioned in various waste streams relevant to the hazardous waste Directive. Cadmium is also submitted to emission reporting under the E-PRTR Directive. Directives on the incineration of waste and the Directive on the landfill of waste contain specific provisions with regard to cadmium discharges or emissions
  - Voluntary initiatives: Cadmium stabilizers are an area where substitution has been accomplished largely due to voluntary industry phase-out (see Deliverable 4.4)
  - End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that cadmium will remain adsorbed on sludge and that the cadmium content in sewage sludge used in agriculture is restricted.
- Cadmium in coating (diffuse sources):
  - Substitution: Cadmium coatings are used where the combination of corrosion, electrical conductivity and/or frictional characteristics are required. There are some alloy coatings which offer equivalent corrosion resistance **or** equivalent electrical or equivalent frictional characteristics, but there have been no

substitutes which combine all three properties. They cannot readily be substituted for in many critical applications However, cadmium coatings have been substituted for in automotive applications, large appliances such as dishwashers, washing machines and refrigerators, and in furniture, and small consumer hardware.

- IPPC Directive and the BAT approach: Various BAT reference documents are relevant for cadmium releases, in particular documents covering metal industries, ferrous and non-ferrous metal and electroplating (see Deliverable 4.3). The BAT reference documents on waste treatment and on waste incineration within the IPPC Directive are limiting cadmium releases.
- Existing EU and international regulations: there are many EU and international regulations limiting cadmium emissions or uses (see Deliverable 4.3). But in these Directives there are a number of exemptions to the cadmium coatings prohibitions including mining, offshore, defense and some electrical components. Cadmium is mentioned in various waste streams relevant to the hazardous waste Directive. Cadmium is also submitted to emission reporting under the E-PRTR Directive. Directives on the incineration of waste and the Directive on the landfill of waste contain specific provisions with regard to cadmium discharges or emissions
- Voluntary initiatives: To our knowledge no voluntary initiatives exist in this field
- End of the pipe treatment: Appropriate industrial and municipal wastewater treatments exist (see Deliverable 5.6) but it has to be pointed out that cadmium will remain adsorbed on sludge and that the cadmium content in sewage sludge used in agriculture is restricted.

Conclusion for cadmium

- Whenever possible products containing cadmium should be recycled. Incentives and information campaigns to do so should be developed at all stages of the consumer chain.
- In wastewater treatment plants, cadmium is not destroyed and generally remains on sludge. This strongly limits the use of this sludge in agriculture. It should then be incinerated.
- Cadmium can be substituted in several applications: this substitution should be encouraged by incentives and information campaigns:
  - in batteries for consumer applications but not for power applications. Life cycle analyses of battery systems indicate that there is actually little difference in the environmental and human health impacts of the different battery systems, and that collection and recycling affects the life cycle impact far more than the battery chemistry.
  - in most electronic applications; however CdTe appears to be one of the most promising solar cell materials for the future.
  - in soldering alloys but not in thermal and electrical conductivity alloys.
  - in pigments except for some special uses
  - in plastic stabilizers
  - in coatings for automotive applications but not in many critical applications where the combination of corrosion, electrical conductivity and frictional characteristics are required

- Thus, there has already been considerable substitution for cadmium in some product areas, while in others, it simply has not been possible, and exemptions have been granted for those areas where substitution is not possible
- Cadmium cannot be avoided as a by-product or contaminant in many industrial processes. The strict applications of existing legislations can effectively reduce the mercury emission in this field but control by the competent authorities is a key to reaching the objectives.

4. Link to other tasks

The final Tasks in both WP4 and WP5 involve an assessment of the feasibility of emission reduction measures considered within earlier respective WP tasks. The common objective is to propose feasible measures to limit the release of each PP considered as an individual compound and in relation to its uses.

To support and facilitate the integration of data at a later stage of ScorePP, it was agreed that a common approach in completing Tasks 4.5 and 5.6 should be used. It was also agreed that this common approach would be informed through a series of iterative discussions between ScorePP participants with differing areas of expertise in order to develop common criteria, indicators, benchmarks and threshold values.

The technical feasibility as estimated in Tasks 4.5 and 5.6 should indeed be included in the global evaluation of the various possible strategies to define measures for reducing emissions of priority pollutants. This global assessment is foreseen in WP 9 and in its different tasks. To carry out this global assessment clear criteria and/or indicators are needed on which a final evaluation or decision should be based. The ranking of the various strategies on the basis of these criteria implies the use of thresholds units/values expressed by several scores. But the choice of these scores should be fully described or justified. The ranking results could indeed strongly depend on the existing field conditions and a strategy fully valid in one place could appear impossible to implement in another.

This is why the tables proposed in the annexes and giving numerical scores values to technical solutions should not be viewed as absolute rankings in all circumstances but as a qualitative help for decision-making. This numerical ranking should indeed be tempered by the comments in the present document. These comments provide more nuanced indications for each use of the priority substances and will give better information to WP9 than a simple numerical table.

As already mentioned before, the criteria can also be weighted depending on the priorities of the decider and on the local situation. For example, in a region where the un-employment is high, the social aspects could determine more the choice than the technical ranking.

5. Conclusions

The technical analysis of the feasibility of possible emission reduction measures in the case of several PPs shows some clear trends that can be summarized as follow:

- There are many possibilities of technical substitution that should be encouraged by the competent authorities either by positive incentives or by the conclusion of voluntary agreements with industry. The technical feasibility of a substitution does not imply its economic feasibility and reasonable delay for substitution should be given to the industry.
- For many PPs the number of pieces of legislation is very high and it would be much more efficient for reducing emission to effectively implement the existing regulations than to develop new ones. The efficiency of these regulations strongly depends on the control and the monitoring by the competent authorities who do not always have the adequate resources to act, in particular when the number of users is important.
- Information and education campaigns oriented to the general public may be very effective in reducing the uses of certain PPs and consequently their emissions. In the case of metals, campaigns and incentives to encourage the recycling can also be very effective. Positive incentives are generally more efficient than penalties, because people will always find ways to escape from penalties.
- In general the industrial and municipal Wastewater Treatment Plants are able to remove or destroy important fractions of the PPs present in effluents. A detailed analysis is provided in WP5 and in particular in Deliverable 5.6.
- The choice of the most appropriate measures at a given location will also depend on the local technical and economic conditions and the general evaluation given in this document should only be considered as guidance for decision making, the socio-economic aspects being reviewed in WP9.

6. References

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Annex 1

1,2-Dichloroethane (EDC)											
		Criteria									
Type of use Type of source	**Possible measure**	**Technical feasibility**	**Technical efficiency**	**Probability to reach WFD target**	**Operational costs**	**Investment costs**	**Impact on the supply chain**	**Impact on employment**	**Impact on drinking water**	**Delay of implementation**	**Total score**
Intermediate for vinyl chloride production. Point source	Substitution	3	1	1	3	3	3	3	1	3	21
	IPPC directive BAT	1	2	1	1	2	1	2	2	2	14
	Process improvement	2	2	1	2	2	1	2	2	2	16
	Regulations (VOC)	1	2	2	1	2	1	2	2	1	14
	Voluntary initiative	**1**	**1**	**1**	**1**	**2**	**1**	**2**	**2**	**1**	**12**
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14
Raw material for chemical synthesis Point source	Substitution	3	1	1	3	3	3	3	1	3	21
	IPPC directive BAT	1	2	1	1	2	1	2	2	2	14
	Process improvement	2	2	1	2	2	1	2	2	2	16
	Regulations (VOC)	1	2	2	1	2	1	2	2	1	14
	Voluntary initiative	2	1	1	2	2	1	2	2	1	16
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14
Extraction solvent Point source	Substitution	2	1	1	2	2	1	2	2	2	15
	IPPC directive BAT	1	2	1	1	2	1	2	2	2	14
	Process improvement	2	2	1	2	2	1	2	2	2	16
	Regulations (VOC)	1	2	2	1	2	1	2	2	1	14
	Voluntary initiative	3	1	2	2	2	1	2	2	2	17
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14

Conclusion

- In the VC-PVC production the best solution is to encourage voluntary initiatives
- In organic chemical synthesis as a raw material or as a solvent the best solutions are the application of existing regulations and the use of appropriate WWTPs

Annex 2

Benzene											
Type of use Type of source	**Possible measure**	**Criteria**									
		Technical feasibility	**Technical efficiency**	**Probability to reach WFD target**	**Operational costs**	**Investment costs**	**Impact on the supply chain**	**Impact on employment**	**Impact on drinking water**	**Delay of implementation**	**Total score**
Production and use as raw material for chemical synthesis Point source	Substitution	3	1	1	3	3	3	3	1	3	21
	IPPC directive BAT	1	2	1	1	2	1	2	2	2	14
	Process improvement	2	2	1	2	2	1	2	2	2	16
	Regulations (VOC)	1	2	2	1	2	1	2	2	1	14
	Voluntary initiative	1	1	1	2	2	1	2	2	2	14
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14
Use as solvent Point source	Substitution	1	1	1	1	2	1	1	2	2	12
	IPPC directive BAT	1	2	1	1	2	1	2	2	2	14
	Process improvement	2	2	1	2	2	1	2	2	2	16
	Regulations (VOC)	1	2	2	1	2	1	2	2	1	14
	Voluntary initiative	1	1	1	1	2	1	1	2	2	12
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14
Benzene in gasoline Diffuse sources	Substitution	3	1	1	3	3	3	3	1	3	21
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	2	2	1	2	2	1	2	2	2	16
	Existing Regulations	1	2	2	1	2	1	1	2	1	14
	Voluntary initiative	NOT APPLICABLE									
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14
Benzene as unavoidable by product of combustion plants Point sources	Substitution	NOT APPLICABLE									
	IPPC directive BAT	1	2	1	1	2	1	2	2	2	14
	Process improvement	2	2	1	2	2	1	2	2	2	16
	Existing Regulations	1	2	2	1	2	1	1	2	1	14
	Voluntary initiative	NOT APPLICABLE									
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14

Conclusion

- For benzene production, its use as a raw material in chemical synthesis, its presence in gasoline and its emission in combustion plants, the strict application of existing regulations in the frame of the permits and the use of appropriate WWTPs appear to be the best solutions
- For the use of benzene as a solvent, the best solution is substitution by toluene. It should be encouraged by incentives or the signing of voluntary agreements

Annex 3

Decabromodiphenyl ether											
Type of use Type of source	**Possible measure**	**Criteria**									
		Technical feasibility	**Technical efficiency**	**Probability to reach WFD target**	**Operational costs**	**Investment costs**	**Impact on the supply chain**	**Impact on employment**	**Impact on drinking water**	**Delay of implementation**	**Total score**
Use as flame retardant in plastics and textiles. Point sources	Substitution	2	2	1	1	2	2	1	1	2	14
	IPPC directive BAT	1	3	2	1	1	1	1	2	1	13
	Process improvement	2	2	2	1	2	1	1	1	2	14
	Existing Regulations	1	2	2	1	1	1	2	1	2	13
	Voluntary initiative	1	1	1	2	1	1	1	1	2	11
	Wastewater Treatment	1	1	1	2	2	1	2	1	2	13
Disposal of products containing DecaBDPE	Substitution	NOT APPLICABLE TO EXISTING WASTE									
	IPPC directive BAT	1	3	2	2	1	1	1	2	2	15
	Process improvement	NOT APPLICABLE									
	Existing Regulations	1	2	1	1	2	1	2	1	2	13
	Voluntary initiative	1	1	2	1	2	1	1	1	2	12
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14

Conclusion

- The strict application of existing regulations and the encouragement of voluntary initiatives are the best solutions for reducing emissions.
- Substitution is possible but this implies technical difficulties for implementation because different substitutes are needed as a function of the application.

Annex 4

Octylphenol / Nonylphenol and the corresponding ethoxylates											
		Criteria									
Type of use Type of source	**Possible measure**	**Technical feasibility**	**Technical efficiency**	**Probability to reach WFD target**	**Operational costs**	**Investment costs**	**Impact on the supply chain**	**Impact on employment**	**Impact on drinking water**	**Delay of implementation**	**Total score**
Production and use as raw material Point sources	Substitution	1	1	1	2	2	1	2	1	1	12
	IPPC directive BAT	1	2	2	1	2	1	2	2	1	14
	Process improvement	2	2	1	2	2	1	2	2	2	16
	Regulations (VOC)	1	2	2	1	2	1	2	2	1	14
	Voluntary initiative	1	2	2	2	2	1	2	2	2	16
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14
Use in formulations Diffuse sources	Substitution	1	1	1	2	2	1	1	1	2	12
	IPPC directive BAT	1	2	2	1	2	1	2	2	1	14
	Process improvement	2	2	1	2	2	1	2	2	2	16
	Regulations	1	1	1	1	2	2	1	1	1	13
	Voluntary initiative	1	1	2	2	2	1	2	2	2	15
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14
Degradation product of ethoxylates	Substitution	1	1	1	2	2	1	1	1	2	12
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	2	2	1	2	2	1	2	2	2	16
	Regulations	1	1	1	1	2	2	1	1	1	13
	Voluntary initiative	1	1	2	2	2	1	2	2	2	15
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14

Conclusion

- As the substitution of octyl- and nonyl-phenols and their ethoxylates is technically feasible and the regulations strongly limit the use of these substances, actions should be focused on their effective substitution and on the strict application of the existing regulations. It is however important to investigate if the substitutes used pose unacceptable burden to the health and the environment.
- There are efficient wastewater treatments for these substances.

Annex 5

Chlorpyrifos											
Type of use Type of source	**Possible measure**	**Criteria**									
		Technical feasibility	**Technical efficiency**	**Probability to reach WFD target**	**Operational costs**	**Investment costs**	**Impact on the supply chain**	**Impact on employment**	**Impact on drinking water**	**Delay of implementation**	**Total score**
Use as specific insecticide	Substitution	3	1	1	3	3	3	3	1	3	21
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	1	1	2	1	2	1	2	2	1	13
	Regulations	1	1	2	1	2	1	2	2	1	13
	Voluntary initiative	1	1	2	2	2	1	2	2	2	15
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14
Use as general insecticide	Substitution	2	1	1	2	3	2	2	1	2	16
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	NOT APPLICABLE									
	Regulations	1	2	2	2	2	1	2	2	1	15
	Voluntary initiative	1	1	1	1	2	1	2	2	1	12
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14

Conclusion

- When used as a specific insecticide, chlorpyrifos cannot be substituted. The strict application of the limitations and doses foreseen in the regulations as well as the education of professional users to help them using the best environmental practices and avoiding over-use, are the most appropriate emission reduction measures but require important resources.
- To reduce the use of chlorpyrifos as a general insecticide, mainly by the general public, voluntary information campaigns and education initiatives are the most appropriate measures
- Efficient wastewater treatments exist.

Annex 6

Isoproturon											
		Criteria									
Type of use Type of source	**Possible measure**	**Technical feasibility**	**Technical efficiency**	**Probability to reach WFD target**	**Operational costs**	**Investment costs**	**Impact on the supply chain**	**Impact on employment**	**Impact on drinking water**	**Delay of implementation**	**Total score**
Use as specific herbicide	Substitution	3	1	1	3	3	3	3	1	3	21
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	1	2	2	1	2	1	2	2	é	15
	Regulations (VOC)	1	1	2	1	2	1	2	2	1	13
	Voluntary initiative	1	1	2	2	2	1	2	2	2	15
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14
Use as total herbicide	Substitution	2	1	1	2	3	2	2	1	2	16
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	NOT APPLICABLE									
	Regulations (VOC)	1	1	2	2	2	2	2	2	2	16
	Voluntary initiative	1	1	2	1	2	1	1	2	2	13
	Wastewater Treatment	1	1	1	2	2	1	2	2	2	14

Conclusion

- When used as a specific herbicide, isoproturon cannot be substituted in the foreseeable future. Information/education campaigns for the users organized on a voluntary basis are the most appropriate way to reduce emissions and losses. The control by the competent authorities of the strict application of the limitations and doses foreseen in the regulations is also very important but requires important resources.
- When used for the maintenance of public areas, isoproturon can be substituted. Voluntary initiatives encouraging the best environmental practices and/or the mechanical treatment can be very efficient
- Efficient wastewater treatments exist.

Annex 7

Hexachlorobenzene											
Type of use Type of source	**Possible measure**	**Criteria**									
		Technical feasibility	**Technical efficiency**	**Probability to reach WFD target**	**Operational costs**	**Investment costs**	**Impact on the supply chain**	**Impact on employment**	**Impact on drinking water**	**Delay of implementation**	**Total score**
Emission from point sources	Substitution	NOT APPLICABLE									
	IPPC directive BAT	1	2	1	1	2	1	2	2	2	14
	Process improvement	2	2	1	2	3	1	2	2	2	17
	Regulations	1	2	2	1	2	1	2	2	1	14
	Voluntary initiative	1	2	1	1	2	1	2	2	2	14
	Wastewater Treatment	1	2	2	2	2	1	2	1	2	15
Re-emission from old sources	Substitution	NOT APPLICABLE									
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	NOT APPLICABLE									
	Regulations	1	2	2	3	2	1	1	2	3	17
	Voluntary initiative	1	2	2	2	2	1	1	2	2	15
	Wastewater Treatment	NOT APPLICABLE									

Conclusion

- As hexachlorobenzene is an unavoidable by-product, the only reasonable measure for point sources should be based on existing regulations and in particular on the BAT approach. Voluntary initiative sshould also be encouraged.
- For “historical hexachlorobenzene” the only solution is soil remediation and/or sediment cleaning but this implies huge operational costs and a real political will. There is a need for EU regulation in this field.
- Appropriate wastewater treatments exist but as hexachlorobenzene is strongly adsorbed on sludge, these cannot be used in agriculture

Annex 8

Benzo[a]pyrene representing PAHs

Type of use Type of source	Possible measure	Technical feasibility	Technical efficiency	Probability to reach WFD target	Operational costs	Investment costs	Impact on the supply chain	Impact on employment	Impact on drinking water	Delay of implementation	Total score
Creosote production	Substitution	NOT APPLICABLE									
	IPPC directive BAT	1	2	2	1	2	1	2	2	2	15
	Process improvement	2	2	2	1	3	1	2	1	3	17
	Regulations	1	2	2	1	2	1	2	1	2	14
	Voluntary initiative	1	1	2	2	2	1	2	1	2	14
	Wastewater Treatment	1	2	1	2	2	1	2	1	2	14
Use of creosote and similar distillates	Substitution	1	1	1	2	3	2	3	1	3	17
	IPPC directive BAT	1	2	2	1	2	1	2	2	2	15
	Process improvement	2	2	2	2	2	1	2	1	3	17
	Regulations	1	2	2	1	2	1	2	1	3	15
	Voluntary initiative	1	1	2	2	2	1	2	1	2	14
	Wastewater Treatment	1	2	1	2	2	1	2	1	2	14
PAHs as by-product of industrial combustion plants	Substitution	NOT APPLICABLE									
	IPPC directive BAT	1	2	2	1	2	1	2	2	2	15
	Process improvement	2	2	2	2	2	1	2	1	3	17
	Regulations	1	2	2	1	2	1	2	1	3	15
	Voluntary initiative	1	1	2	2	3	1	2	2	2	16
	Wastewater Treatment	1	2	1	2	2	1	2	1	2	14
PAHs as by-product of domestic or landfill combustion	Substitution	NOT APPLICABLE									
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	NOT APPLICABLE									
	Regulations	1	1	2	1	2	1	2	1	3	14
	Voluntary initiative	1	1	2	2	3	1	2	2	2	16
	Wastewater Treatment	1	2	1	2	2	1	2	1	2	14
PAHs emission from fuel and road traffic	Substitution	NOT APPLICABLE									
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	NOT APPLICABLE									
	Regulations	1	1	2	2	2	2	2	2	3	17
	Voluntary initiative	1	1	1	1	3	2	2	1	2	14
	Wastewater Treatment	1	2	1	2	2	1	2	1	2	14

Conclusion

- Creosote production and uses should be strictly limited and/or substituted as much as possible

- For industrial combustion or incineration plants, the only realistic emission reduction measures should be based on the existing legislation and in particular on the BAT approach. The strict application of these regulations to point sources could be sufficient to reach the EQS levels recommended by the WFD
- For domestic combustion devices and landfill burning, information campaigns should be organized to promote the use of high temperature combustion devices, to limit the wood burning and to avoid the open air burning of waste. Positive incentives could be used to encourage people to renew their heating devices. Simiarly, European standards for small and solid fuel combustion appliances should be developed to encourage the producers to develop more efficient units.
- For PAH emissions from road traffic the new EU regulation on diesel fuel will be very effective, but the practical efficiency strongly depends on the control and monitoring by the competent authorities. Incentives to renew the car park and to encourage the move towards electric vehicles can also be very efficient in reducing PAH emissions on a longer term perspective.

Annex 9

Lead (1)											
Type of use Type of source	**Possible measure**	**Criteria**									
		Technical feasibility	**Technical efficiency**	**Probability to reach WFD target**	**Operational costs**	**Investment costs**	**Impact on the supply chain**	**Impact on employment**	**Impact on drinking water**	**Delay of implementation**	**Total score**
Emissions from metallurgy and industrial plants	Substitution	NOT APPLICABLE									
	IPPC directive BAT	1	2	1	1	2	1	2	2	2	14
	Process improvement	2	2	2	1	3	1	2	1	3	17
	Regulations	1	2	2	1	2	1	2	1	2	14
	Voluntary initiative	NOT APPLICABLE									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Lead in lead-acid batteries	Substitution	2	1	1	3	3	3	3	1	3	20
	IPPC directive BAT	NOT APPLICABLE except for waste									
	Process improvement	NOT APPLICABLE									
	Regulations	1	2	2	1	2	1	2	1	2	14
	Voluntary initiative	1	1	1	2	3	1	1	1	2	13
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Lead sheet and extruded product in the construction industry	Substitution	3	1	1	3	3	3	3	1	3	20
	IPPC directive BAT	NOT APPLICABLE except for waste									
	Process improvement	NOT APPLICABLE									
	Regulations	No specific regulations									
	Voluntary initiative	No known concerted initiatives									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Lead for shielding and protective coating	Substitution	1	2	2	1	2	2	2	2	2	16
	IPPC directive BAT	NOT APPLICABLE except for waste									
	Process improvement	NOT APPLICABLE									
	Regulations	No specific regulations									
	Voluntary initiative	No known concerted initiatives									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Lead in compound used as pigment or stabilizers	Substitution	1	1	2	1	2	2	2	2	1	14
	IPPC directive BAT	NOT APPLICABLE except for waste									
	Process improvement	NOT APPLICABLE									
	Regulations	1	2	2	1	2	1	2	1	2	14
	Voluntary initiative	1	1	1	2	3	1	1	1	2	13
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14

Lead (2)											
Type of use Type of source	**Possible measure**	**Criteria**									
		Technical feasibility	**Technical efficiency**	**Probability to reach WFD target**	**Operational costs**	**Investment costs**	**Impact on the supply chain**	**Impact on employment**	**Impact on drinking water**	**Delay of implementation**	**Total score**
Lead in electrical and crystal glasses	Substitution	1	2	2	1	3	2	2	2	3	18
	IPPC directive BAT	1	2	2	1	2	1	2	2	2	15
	Process improvement	NOT APPLICABLE									
	Regulations	1	3	2	1	2	2	2	2	2	17
	Voluntary initiative	No known concerted initiatives									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Lead in sheathing for electrical cable	Substitution	3	1	1	3	3	3	3	1	3	20
	IPPC directive BAT	NOT APPLICABLE except for waste									
	Process improvement	NOT APPLICABLE									
	Regulations	No specific regulations									
	Voluntary initiative	No known concerted initiatives									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Lead in shot and weights	Substitution	1	1	2	1	1	1	2	2	3	14
	IPPC directive BAT	NOT APPLICABLE except for waste									
	Process improvement	NOT APPLICABLE									
	Regulations	No specific regulations									
	Voluntary initiative	1	1	2	1	1	1	2	2	2	13
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Lead in solder alloys in electronic	Substitution	1	1	2	1	1	1	2	2	2	13
	IPPC directive BAT	NOT APPLICABLE except for waste									
	Process improvement	NOT APPLICABLE									
	Regulations	1	1	2	1	1	2	2	2	2	14
	Voluntary initiative	No known concerted initiatives									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14

Conclusion

- Whenever possible products containing lead should be recycled and incentives to do so should be developed at all stages of the consumer chain.
- In wastewater treatment plants, lead is not destroyed and generally remains on sludge. This strongly limits the use of these sludge in agriculture. They should then be incinerated.
- Lead can be substituted in several applications: in pipes for domestic water supply, in some protective coatings, in stabilizers and pigments in plastics and paints, in crystal glass, in some lead weights and in most solder alloys for the electronic equipment. These substitutions have been favoured either by the implementation of existing regulations (electronic equipment) or by voluntary industrial initiatives (stabilizers and pigments). Other substitutions can be encouraged by the development of education and information campaigns or by positive incentives. The control by the competent authorities is key for implementing substitution.
- Lead cannot be substituted in lead-acid batteries, in sheathing for electrical cables and in sheets, rolled and extruded products for the construction industry. In these cases, the recycling of used products is one of the key measures to be encouraged and implemented. Incentives should be given to facilitate such a recycling, in particular the collection of used products and waste management. Voluntary initiative exists (in lead-acid batteries for example) but the competent authorities should act to strictly apply the existing regulations.

Annex 10

Mercury(1)											
Type of use Type of source	**Possible measure**	**Criteria**									
		Technical feasibility	**Technical efficiency**	**Probability to reach WFD target**	**Operational costs**	**Investment costs**	**Impact on the supply chain**	**Impact on employment**	**Impact on drinking water**	**Delay of implementation**	**Total score**
Mercury cells processes	Substitution	1	1	1	1	3	1	2	1	3	14
	IPPC directive BAT	1	1	1	2	2	1	2	1	2	13
	Process improvement	1	1	1	2	2	1	2	1	2	13
	Regulations	1	1	1	2	2	1	2	1	2	13
	Voluntary initiative	1	1	1	2	2	1	2	1	2	13
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Mercury in dental amalgam	Substitution	1	1	1	1	2	2	2	2	3	15
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	NOT APPLICABLE									
	Regulations	1	2	2	1	2	2	2	2	2	16
	Voluntary initiative	1	1	1	1	2	2	2	2	3	15
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Mercury in “button-cell” batteries	Substitution	1	1	1	1	2	2	2	2	2	14
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	NOT APPLICABLE									
	Regulations	1	1	1	1	2	2	2	2	2	14
	Voluntary initiative	1	2	2	1	2	2	2	2	2	16
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Mercury in measuring and control equipment	Substitution	1	1	1	1	2	2	2	2	2	14
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	NOT APPLICABLE									
	Regulations	1	1	1	1	2	2	2	2	2	14
	Voluntary initiative	No known concerted initiative									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Mercury in fluorescent lamps	Substitution	1	1	1	1	2	2	2	2	3	15
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	1	2	2	1	2	2	2	2	2	16
	Regulations	1	2	2	1	2	2	2	2	2	16
	Voluntary initiative	No known concerted initiative									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14

Mercury (2)											
Type of use Type of source	Possible measure	Criteria									
		Technical feasibility	Technical efficiency	Probability to reach WFD target	Operational costs	Investment costs	Impact on the supply chain	Impact on employment	Impact on drinking water	Delay of implementation	Total score
Mercury used in laboratories	Substitution	1	2	2	1	2	2	2	2	3	17
	IPPC directive BAT	NOT APPLICABLE									
	Process improvement	NOT APPLICABLE									
	Regulations	No specific regulations at EU level									
	Voluntary initiative	No known concerted initiative									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Mercury as unavoidable by-product or contaminant	Substitution	NOT APPLICABLE									
	IPPC directive BAT	1	2	2	2	2	1	2	1	2	15
	Process improvement	1	2	2	2	3	1	2	2	2	17
	Regulations	1	2	2	2	2	1	2	2	2	15
	Voluntary initiative	No known concerted initiative									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14

Conclusion

- Whenever possible, products containing mercury should be recycled or permanently and safely stored. Incentives and information campaigns to do so should be developed at all stages of the consumer chain.
- In wastewater treatment plants, mercury is not destroyed and generally remains in sludge. This strongly limits the use of this sludge in agriculture. The sludge should then be incinerated, if measures to reduce the content of mercury in incoming water do not succeed.
- Mercury can be substituted in several applications: in mercury cell processes for chlor-alkali industry; in most of the batteries containing mercury, and in measuring and control devices. These substitutions should be encouraged by incentives and information campaigns.
- Mercury uses can be strongly reduced in several applications: in dental amalgam , in energy efficient and fluorescent lamps and in laboratory practice. These reductions should be obtained by the strict application of existing legislation, the control by the competent authorities and education campaigns.
- Mercury cannot be avoided as a by-product or contaminant in many industrial processes. The strict applications of existing legislations can effectively reduce the mercury emissions in this field, but control by the competent authorities is key to reaching the objectives.

Annex 11

Cadmium (1)											
Type of use Type of source	**Possible measure**	**Criteria**									
		Technical feasibility	**Technical efficiency**	**Probability to reach WFD target**	**Operational costs**	**Investment costs**	**Impact on the supply chain**	**Impact on employment**	**Impact on drinking water**	**Delay of implementation**	**Total score**
Cadmium as unavoidable by-product or contaminant	Substitution	NOT APPLICABLE									
	IPPC directive BAT	1	2	2	2	2	1	2	1	2	15
	Process improvement	1	2	2	2	3	1	2	2	2	17
	Regulations	1	2	2	2	2	1	2	2	2	15
	Voluntary initiative	No known concerted initiatives									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Cadmium in batteries	Substitution	1	1	2	1	2	2	2	2	2	15
	IPPC directive BAT	NOT APPLICABLE except for waste									
	Process improvement	NOT APPLICABLE									
	Regulations	1	1	1	1	2	2	2	2	1	13
	Voluntary initiative	No known concerted initiatives									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Cadmium in electronic equipment	Substitution	1	1	2	1	2	2	2	2	1	14
	IPPC directive BAT	NOT APPLICABLE except for waste									
	Process improvement	NOT APPLICABLE									
	Regulations	1	1	2	1	2	2	2	2	1	14
	Voluntary initiative	No known concerted initiatives									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Cadmium in alloys	Substitution	1	2	2	1	2	2	2	2	2	16
	IPPC directive BAT	1	2	2	2	2	1	2	1	2	15
	Process improvement	1	2	2	2	3	1	2	1	2	16
	Regulations	NOT APPLICABLE except for waste									
	Voluntary initiative	2	2	2	1	2	2	2	2	2	17
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Cadmium in pigments	Substitution	1	1	1	1	1	2	2	2	2	13
	IPPC directive BAT	NOT APPLICABLE except for waste									
	Process improvement	NOT APPLICABLE									
	Regulations	1	1	1	1	1	2	2	2	2	13
	Voluntary initiative	1	2	2	1	2	2	2	2	2	16
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14

Cadmium (2)											
		Criteria									
Type of use Type of source	**Possible measure**	**Technical feasibility**	**Technical efficiency**	**Probability to reach WFD target**	**Operational costs**	**Investment costs**	**Impact on the supply chain**	**Impact on employment**	**Impact on drinking water**	**Delay of implementation**	**Total score**
Cadmium as stabilizers in plastics	Substitution	1	1	1	1	1	2	2	2	2	13
	IPPC directive BAT	NOT APPLICABLE except for waste									
	Process improvement	NOT APPLICABLE									
	Regulations	1	2	1	2	1	2	2	2	2	15
	Voluntary initiative	1	1	1	1	1	2	2	2	2	13
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14
Cadmium in coating	Substitution	2	2	2	2	2	2	2	2	2	18
	IPPC directive BAT	1	2	2	2	2	1	2	1	2	15
	Process improvement	1	1	2	2	3	1	2	2	2	16
	Regulations	1	2	2	1	2	2	2	2	1	15
	Voluntary initiative	No known concerted initiatives									
	Wastewater Treatment	1	2	2	1	2	1	2	1	2	14

Conclusion

- Whenever possible products containing cadmium should be recycled. Incentives and information campaigns to do so should be developed at all stages of the consumer chain.
- In wastewater treatment plants, cadmium is not destroyed and generally remains on sludge. This strongly limits the use of this sludge in agriculture. It should then be incinerated.
- Cadmium can be substituted in several applications: in batteries for consumer applications but not for power applications, in most electronic applications but CdTe appears to be one of the most promising solar cell materials, in soldering alloys, in pigment, in plastic stabilizers and in coating for automotive applications. These substitutions should be encouraged by incentives and information campaigns but exemptions have to be granted for those areas where substitution is not possible
- Cadmium cannot be avoided as a by-product or contaminant in many industrial processes. The strict applications of existing legislations can effectively reduce mercury emissions in this field but control by the competent authorities is a key to reaching the objectives.