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The Fourth Air Quality Daughter Directive:

Impacts and consequences of mandatory limit values

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SUMMARY

1 The European Commission has presented a proposal for a Directive relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons (PAHs) in ambient air. Unlike the three previous 'daughter' Directives to the Air Quality Framework Directive, this proposal does not contain any mandatory limit values for the concentrations of the pollutants. The European Parliament's Environment Committee has voted in favour of amendments which would introduce such limit values in the Directive, in accordance with the Framework Directive's requirements and the recommendations of the Commission's Working Groups.

2 The main reason to regulate ambient air concentrations of arsenic, cadmium, nickel and PAHs is their impact on human health (for mercury, ambient air concentrations in Europe are below a level where they have adverse effects on human health). Given the evidence of the carcinogenic effects of these substances, it seems obvious that limit values are called for. These should be based on unit risk factors, reflecting the fact that there is no known threshold below which the substances have no impact on human health. It is likely that such values would also ensure adequate protection as regards other health impacts, as well as to crops and ecosystems.

3 Existing EU legislation, international agreements and policies already have a large potential to reduce emissions, and hence ambient concentrations, of the pollutants involved here. However, air quality limit values may be an essential complement to emission oriented measures in ensuring the lowest reasonably achievable level of harmful impacts from air pollution on human health and the environment.

4 The limit values proposed in the amended draft Directive lie within the ranges recommended by the Commission's Working Groups, but exceed the WHO guideline values. They are already a kind of compromise, as they take into account feasibility and uncertainty considerations.

5 The proposed limit value for arsenic seems to be achievable by 2010 for all relevant sectors, with a small number of possible exceptions in the sectors of copper and lead production. In both sectors there is at least one plant which is expected to be able to comply. Therefore, a more detailed analysis of the reasons why compliance by the other plants would be impossible seems to be justified.

6 The proposed cadmium limit values are generally feasible. In a limited number of cases in the non-ferrous metal industry the limit value may cause problems. Due to a lack of detailed information, the exact nature and magnitude of these problems cannot be assessed. It seems likely that the exemption procedures that will be required under the proposed Directive (as amended) could fill this information gap.

7 It seems likely that the proposed limit value for nickel will be achievable in the majority of cases. In some sectors, it would require investments beyond BAT, and in the iron and steel sector it might require the acceptance of high stacks. A few derogations could be needed in the copper production sector.

8 The proposed limit value for B(a)P (used as a marker for PAHs) is in principle achievable, with the probable exception of sites close to cokeries. In practice, the feasibility of achieving the limit value in areas where solid fuels are used for domestic heating may also be questionable.

9 The economic evaluation for the three metals suggests that the costs of achieving the limit values probably outweigh the benefits. However, the quantified benefits may be significant underestimates of the total benefits, as they only relate to human health impacts. Furthermore, the appropriateness of the methodology used to value these human health impacts may be questioned.

10 The available information does not allow any firm statements on the net benefits of introducing the limit value for B(a)P. Nevertheless, at least for the residential sector (using solid fuels for heating) substantial health benefits can be achieved and they are likely to be in the same order of magnitude as the costs.

11 Secondary benefits, which have not been quantified in the economic evaluations, may include the following types:

- avoided damage to ecosystems, crops etc, due to the reduction in exposure to the targeted pollutants;
- avoided non-environmental damage (eg in terms of improved occupational health and safety) due to the reduction in exposure to the targeted pollutants; or
- avoided damage due to a reduction in non-targeted pollutants, resulting from measures taken to achieve compliance with the limit values.

Whereas the first kind of benefits could be relatively small, occupational health and safety, as well as traffic safety might be very important secondary benefit categories. The same could be true for some of the non-targeted pollutants such as particulates, lead and CO_2. Other potentially relevant benefits include technological innovation. Given the lack of information on the size of secondary and other benefits, a direct comparison of the estimated costs and benefits will necessarily lead to biased conclusions.

12 Given the large uncertainties and information gaps, a precautionary approach seems to be advisable. The introduction of mandatory limit values based on unit risk factors would fit well with such an approach. Temporary exemption possibilities for the small number of situations where the limit values cannot be achieved at reasonable cost could be justifiable.

POLICY BRIEF FOR THE EP ENVIRONMENT COMMITTEE
EP/IV/A/2003/09/01

THE FOURTH AIR QUALITY DAUGHTER DIRECTIVE: IMPACTS AND CONSEQUENCES OF MANDATORY LIMIT VALUES

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1 Introduction and Background

In July 2003, the European Commission presented its Proposal for a Directive relating to arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons (PAHs) in ambient air[1]. This proposed Directive will be the fourth 'daughter' Directive of the Air Quality Framework Directive 96/62/EC[2]. The three existing daughter Directives relate to sulphur dioxide, nitrogen oxides, particulate matter and lead (1999/30/EC)[3], benzene and carbon monoxide (2000/69/EC)[4], and ozone (2002/3/EC)[5], respectively.

According to Article 4(1) of Directive 96/62/EC, the Commission had to present proposals (by 31 December 1999) for limit values for the substances to which the current proposal relates. A limit value is a 'level fixed on the basis of scientific knowledge, with the aim of avoiding, preventing or reducing harmful effects on human health and/or the environment as a whole, to be attained within a given period and not to be exceeded once attained' (Art. 2(5) of Directive 96/62/EC). However, the Commission has decided not to meet this requirement. Instead of limit values, a 'target value' is proposed for benzo(a)pyrene (BaP, as an indicator of PAHs), whereas 'assessment thresholds' are proposed for arsenic, cadmium, nickel and BaP. The target value for BaP should be attained 'as far as possible and without entailing excessive costs', whereas the assessment thresholds indicate concentrations above which monitoring would become mandatory. The stated reason for not proposing limit values is that near some specific industrial installations the attainment of ambient air concentration levels, which would minimise harmful effects on human health, would entail excessive costs for any of the named pollutants except mercury. For mercury, ambient air concentrations in Europe are below a level where they have adverse effects on human health. No target value for mercury is proposed as not enough is known about the cycle of mercury in the environment.

The European Parliament rapporteur, Hans Kronberger, presented a draft report on the proposal on 12 November 2003. In this report (which was backed by the Parliament's Environment Committee on 21 January 2004), amendments are proposed which would (among others) introduce limit values for arsenic, cadmium, nickel and BaP. The explanatory statement on the amendments refers to the position papers of the Working Groups on arsenic, cadmium and nickel and on PAHs (European Commission, 2000 and 2001), which recommended to set limit values for these substances. It also criticises the arguments for the Commission's reluctance to introduce limit values, as the cost benefit analyses on which this decision is based (Holland *et al* 2001; Entec 2001) do not include all relevant benefits.

The present Policy Brief aims at assessing the likely socio-economic and environmental impacts and consequences of the proposed amendments relating to the introduction of mandatory limit values. The following questions are addressed:

- Is there a case for mandatory limit values (taking into account existing knowledge and information on human health and ecotoxicological risks; exposure and sources; information gaps and uncertainty; the precautionary principle)?
- Are the proposed limit values feasible (taking into account best available techniques)?

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1 COM(2003) 423 final, 16.7.2003.
2 OJ L 296, 21.11.1996.
3 OJ L 163, 29.6.1999.
4 OJ L 313, 13.12.2000.
5 OJ L 67, 9.3.2002.

- What would be the associated costs and benefits (including secondary benefits and taking into account the assumptions, uncertainties and sensitivity analyses in the existing studies)?

These three questions are dealt with in Sections 2, 3 and 4, respectively. Section 5 presents conclusions.

This Brief does not address mercury, because the proposed amendments do not contain limit values for this substance.

Unless indicated otherwise, the information contained in this Brief is based on the Position Papers (European Commission, 2000, 2001) and the Economic Evaluation studies (Holland *et al* 2001, and Entec 2001) that were published within the framework of the preparation of the Commission's proposal.

2 The Case for Mandatory Limit Values

2.1 Human health impacts

The main reason to regulate ambient air concentrations of arsenic, cadmium, nickel and PAHs is their impact on human health (see Table 1). It should be noted that the impacts differ between different compounds containing the metals involved (and, in the case of PAHs, between different types of PAH). The carcinogenic effects can be genotoxic (ie the substance can induce cancer by producing mutations in DNA) or epigenetic (ie the substance can promote cancer by affecting the proliferative capacity of affected cells).

Table 1 Human Health Impacts of Arsenic, Cadmium, Nickel and PAHs

Substance	Carcinogenic effects	Non-carcinogenic effects
arsenic	lung cancer; possibility of arsenic being a genotoxic carcinogen cannot be excluded	increased mortality from cardiovascular diseases, neuropathy and gangrene of the extremities
cadmium	lung cancer (importance as a carcinogen at environmental concentrations not generally accepted)	damage to renal function
nickel	known carcinogen (except in metallic form); possibility of being a genotoxic carcinogen cannot be excluded	effects on the respiratory tract, the immune and defence system, and on endocrine regulation
PAHs	mainly lung cancer (both genotoxic and epigenetic); evidence of skin, bladder and other cancers is less well developed	Not applicable

Table 2 presents the 'unit risk factors' for the four substances, ie the risk of getting cancer from a lifetime exposure to a continuous concentration of the substance of 1 $\mu g/m^3$ or 1 ng/m^3. Based on these unit risk factors (and taking into account other information, such as feasibility and uncertainty on the exact dose-response relationships) the Commission's

Working Groups have proposed limit values, which are also mentioned in Table 2. These limit values are calculated taking an acceptable risk of 10^{-6} (one in a million) as a starting point. For comparison, the WHO guideline values are presented in Table 2 as well. With the exception of cadmium, the WHO guideline values are well below the Working Group recommendations.

Table 2 Unit Risk Factors of Arsenic, Cadmium, Nickel and PAHs, Limit Values Recommended by the Working Groups, and WHO Guideline Values

Substance	Unit risk factors	Recommended limit values (annual mean concentrations)	WHO guideline values (**)
Arsenic	1.5 x 10^{-3} per µg/m^3	4 - 13 ng/m^3 (*)	0.66 ng/m^3
Cadmium	1.8 - 4.15 x 10^{-3} per µg/m^3	5 ng/m^3	5 ng/m^3
Nickel	2.4 - 3.8 x 10^{-4} per µg/m^3	10 - 50 ng/m^3 (*)	2.5 ng/m^3
PAHs (B(a)P)	23 - 430 x 10^{-6} per ng/m^3	0.5 - 1 ng/m^3	0.012 ng/m^3

(*) A majority of the Working Group voted for the lower end of the range.
(**) Source: WHO (2001)

Given the evidence on the carcinogenic effects of the substances that the proposed Directive deals with, it seems obvious that human health considerations call for the introduction of limit values. These values should be based on unit risk factors, reflecting the fact that there is no known threshold below which the substances have no impact on human health. It should be noted that the values recommended by the Working Groups are already a kind of compromise, as they take into account feasibility and uncertainty considerations. A purely health oriented and precaution-driven approach would have led to lower values.

2.2 Other environmental impacts

Metal and metalloid compounds can be incorporated by plants and ecosystems either directly via deposition or via uptake from soils. The knowledge of possible effects of arsenic, cadmium and nickel compounds on terrestrial ecosystems is still rather limited. The Working Group on these metals concluded that the available data do not allow the derivation of specific ecological limit values. However, it stated that limit values protective with respect to adverse health effects would generally also cover the protection of terrestrial ecosystems.

For PAHs, it does not appear that there are any quantifiable effects on ecosystems (which does not mean that such effects do not exist).

2.3 Air quality standards as a complement to existing policies and legislation

Several EU laws, international agreements and other policies already have the reduction of the presence of heavy metals and PAHs in the environment as their objective or as a likely side-effect. Among them are:

- the IPPC Directive[6], providing for the application of the Best Available Techniques (BAT) in a number of relevant industries;
- the Large Combustion Plant Directive[7], providing for emission limits for (among others) particulates (to which the pollutants covered by the proposed Directive can be linked);
- the Waste Incineration Directive[8], which specifies emission limit values for various substances, including the metals of concern here as well as particulates;
- the first Air Quality Daughter Directive[9], containing limit values for (among others) particulates and lead, which may require measures that also reduce the concentrations of the pollutants to which the proposed Directive relates;
- several transport and product oriented Directives (for example those containing emission requirements for diesel cars); and
- the UNECE Convention on Long Range Transboundary Air Pollution and its 1998 Protocol on heavy metals, providing for the reduction of mercury, cadmium and lead emissions to 1990 levels and for the application of BAT.

Nevertheless, air quality standards can have an important complementary role to play. The regulation of emissions alone cannot exclude that the simultaneous presence of emissions from various sources may cause adverse effects, even though each of the single sources may meet emission standards. Moreover, in some cases ambient air quality can be significantly affected by pollutants from sources that are not subject to regulations, eg historic industrial sites, transboundary pollution and natural sources, contributing to high background concentrations. In the case of PAHs, the domestic burning of solid fuels (in stoves and open fireplaces) is a very important source of exposure. Here, air quality standards could be a driver for emission standards for heating appliances and for changes in heating behaviour.

Environmental quality standards can also have an impact on innovations, by providing an incentive to develop and apply technologies that are not yet regarded as BAT, so as to be able to meet the standards. Obviously, air quality standards can also function as an 'ultimate remedy' to protect the environment and human health by enforcing the termination of polluting activities if there is no other way of reducing their contribution to air pollution to acceptable levels.

In short, air quality limit values may be an essential complement to emission oriented measures in ensuring the lowest reasonably achievable level of harmful impacts from air pollution on human health and the environment.

3 Feasibility of the Proposed Limit Values

The amendments proposed in the Kronberger report, and backed by the European Parliament's Environment Committee on 21 January 2004, provide for the introduction of the following (yearly averaged) limit values:

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6 Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control. OJ L 257, 10.10.1996.

7 Directive 2001/80/EC of the European Parliament and of the Council of 23 October 2001 on the limitation of emissions of certain pollutants into the air from large combustion plants. OJ L 309, 27.11.2001.

8 Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste. OJ L 332, 28.12.2000.

9 Council Directive 1999/30/EC of 22 April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxides of nitrogen, particulate matter and lead in ambient air. OJ L 163, 29.6.1999.

- arsenic: 6 ng/m^3;
- cadmium: 5 ng/m^3;
- nickel: 20 ng/m^3;
- B(a)P: 1 ng/m^3.

These limit values, which are higher than the WHO guidelines (except for cadmium), but lie within the ranges recommended by the Working Groups (see further Table 2), should be achieved by 1 January 2010. At the request of a Member State, the Commission can extend this deadline in cases where, in the immediate vicinity of certain industrial installations, the limit value cannot be achieved. The Member State should provide the necessary justification for such an extension.

In this section, the possible bottlenecks for achieving each of the limit values will be discussed.

3.1 Arsenic

According to the Economic Evaluation study (Entec, 2001) a limit value of 5 ng/m^3 for arsenic will be achievable for most of the relevant sectors without additional cost (taking into account the need to meet BAT requirements anyway). In the sector of nickel and nickel alloy production, compliance with the limit value will be achieved from investments into nickel emission reductions. In two sectors, namely copper and lead production, the limit value of 5 ng/m^3 is considered unlikely to be achievable for all sites. Presumably, the same will be true for the proposed limit value of 6 ng/m^3.

For the **copper production** sector, the analysis was based on available data for four sites (in Belgium, Germany, Spain and a Nordic country), representing a substantial part of primary and secondary copper production in the EU 15.[10] There were large differences between the four plants in terms of expected achievable air quality by 2010. Whereas the Nordic plant was thought to be able to achieve a 5 ng/m^3 level (by installing bag filters for smelter fugitive gases), at the Spanish site the best achievable air quality by 2010 seemed to be ten times as high: 50 ng/m^3. However, this latter figure was not the result of model calculations, but the reference level in an ongoing feasibility study. No ambient data was available for this Spanish site, hence an assessment of compliance with the potential limit values was not considered possible. The Belgian and German plants should be able to reach a level of about 10 ng/m^3 or less, according to the estimates in the Entec report. In the case of the German plant, reaching a level below 10 ng/m^3 was not thought to be feasible, unless it shut down the smelter.

In the **lead production** sector, model calculation data were available for three sites (in Belgium, Germany and France). The German plant was expected to be able to meet a limit value of 5 ng/m^3 under a ‘business as usual scenario’ (including investment plans to comply with existing legislation), while the Belgian and French ones probably were not (although in the French case, the predicted arsenic concentrations in 2010 after additional investment range from 1 to 15 ng/m^3). The information presented in the Entec study does not allow a detailed assessment of the reasons for these differences. At the Belgian site, it seems that fugitive emissions from the large area (10 ha) on which primary and secondary raw materials

[10] Information from the EU-25’s largest copper producing country (Poland) was not included in the analysis.

are stockpiled play an important role. Roofing this entire area was not considered to be feasible.

In short, the proposed limit value for arsenic seems to be achievable by 2010 for all relevant sectors, with a small number of possible exceptions in the sectors of copper and lead production. In both sectors there is at least one plant which is expected to be able to comply. Therefore, a more detailed analysis of the reasons why compliance by the other plants would be impossible seems to be justified.

3.2 Cadmium

According to the Entec study (Entec, 2001) a limit value of 5 ng/m^3 for cadmium will be achievable for most of the relevant sectors without additional cost (taking into account the need to meet BAT requirements anyway). In three sectors, namely copper, zinc and lead production, the limit value of 5 ng/m^3 is considered unlikely to be achievable for all sites.

In the **copper production** sector, the same four plants were examined as for arsenic and the mentioned limit value could be achieved for most of these as a side effect of investments into arsenic reductions (see further Section 3.1). In the case of the Nordic plant, even a level of 0.5 ng/m^3 was considered to be achievable. For the German plant, an emission level of around 10 ng/m^3 in 2010 was predicted (the range under a 'business as usual scenario' being estimated between 1.3 and 14.2 ng/m^3). For this plant, reaching a level below 10 ng/m^3 was not thought to be feasible, unless it shut down the smelter. In the case of the Spanish plant, 25 ng/m^3 was used as the reference level in an ongoing feasibility study. No ambient data was available for this Spanish site, hence an assessment of compliance with the potential limit values was not considered possible.

In the **zinc industry** the limit value of 5 ng/m^3 was expected to be achievable for the three plants for which model calculations were done. For several other sites however, where measured ambient concentrations were much higher (up to 107 ng/m^3), the limit value was considered not to be achievable. The Entec report did not underpin this statement by means of model calculations.

In the **lead production** sector, model calculation data were available for the same three sites as in the case of arsenic (see Section 3.1). Once again, the German plant was expected to be able to meet a limit value of 5 ng/m^3 under a 'business as usual scenario' (including investment plans to comply with existing legislation), while the Belgian and French ones probably were not (although in the French case, the predicted cadmium concentrations in 2010 after additional investment range from 1 to 15 ng/m^3). As in the arsenic case, the information presented in the Entec study does not allow a detailed assessment of the reasons for the differences.

It can be concluded that the proposed cadmium limit values are generally feasible. In a limited number of cases in the non-ferrous metal industry the limit value may cause problems. Due to a lack of detailed information, the exact nature and magnitude of these problems cannot be assessed. It seems likely that the exemption procedures that will be required under the proposed Directive (as amended) could fill this information gap.

3.3 Nickel

In the case of nickel, the proposed limit value of 20 ng/m^3 was not among the values analysed in the Entec study. However, in most sectors a value of 10 ng/m^3 appeared to be achievable without additional costs. In the iron and steel industry, nickel and nickel alloy production and the petroleum refining sector additional investment costs (beyond BAT) would be involved in achieving this value. For the zinc and lead industries as well as for the shipping sector insufficient data were available to assess the feasibility of the limit value. In two sectors, namely iron and steel and copper production, the limit value of 10 ng/m^3 was considered unlikely to be achievable for all sites.

In the **iron and steel** sector (electric arc steelmaking) the limit value of 10 ng/m^3 appears to be achievable in principle, but the Entec report doubted whether the compliance technique (significant stack height increase) would be acceptable to planning authorities in all cases. Whether these stack height increases would also be needed to achieve the proposed limit value of 20 ng/m^3 is not clear.

In the **copper production** sector, the analysis was based on the same four plants as in the previous sections and it was found that the limit value of 10 ng/m^3 could be achieved for the Nordic plant, whereas the Belgian plant could reach a level below 30 ng/m^3. In the case of the Spanish plant, 50-100 ng/m^3 was used as the reference level in an ongoing feasibility study. No ambient data was available for this Spanish site, hence an assessment of compliance with the potential limit values was not considered possible.

To summarize, although the proposed 20 ng/m^3 limit value itself has not been analysed, it seems likely that it will be achievable in the majority of cases. In some sectors, it would require investments beyond BAT, and in the iron and steel sector it might require the acceptance of high stacks. A few derogations could be needed in the copper production sector.

3.4 Benzo(a)pyrene

The Economic Evaluation report for PAHs (Holland *et al* 2001; hereafter: AEA/TNO report) shows that for industry the envisaged limit value of 1 ng/m^3 for BaP is generally feasible, with the exception of the direct surroundings of cokeries. The limit value is also exceeded near aluminium plants using the Söderberg process. However, the report stated that it appears likely that there will be no Söderberg plant left in the EU 15 by 2010, and that the aluminium industry in the new Member States will probably follow a similar trend.

The main concern regarding feasibility of the limit value in industry lies therefore with **cokeries**. For coke plants, no additional emission reduction measures beyond BAT are known. The AEA/TNO report therefore only mentions two other options: relocation (which would reduce population exposure, but would not be undertaken solely as a PAH control measure) and closure of the plant (which would shift the activity, and associated environmental problems, to a non-EU location). The report also shows, however, that the range of measured B(a)P concentrations near cokeries is quite large. For example, Dutch data indicate concentrations of 0.2 to 0.5 ng/m^3 in the direct proximity of a coke plant (page 18 of the AEA/TNO report). Further research would be needed to find out if such low levels could be achieved at other cokeries as well.

The AEA/TNO report estimates that 43 per cent of the rural and 27 per cent of the urban population in the EU (and a number of Accession Countries) is currently exposed to B(a)P concentrations above 1 ng/m^3 (but below 5 ng/m^3) due to the **residential combustion of solid fuels** (in combination with background concentrations). While it would probably be technically feasible to reduce these concentrations to levels below 1 ng/m^3 (eg by using optimised stoves or switching to other fuels), it may be difficult in practice to change household behaviour so as to achieve this.

For **traffic**, which currently contributes to B(a)P levels slightly exceeding 1 ng/m^3 in a limited number of cases, a range of technical, management and policy options is available. These measures would primarily be taken for other purposes than PAH emission control (eg other emissions, such as CO_2 and particulate matter; congestion reduction).

In short, the proposed limit value for B(a)P is in principle achievable, with the probable exception of sites close to cokeries. In practice, the feasibility of achieving the limit value in areas where solid fuels are used for domestic heating may also be questionable.

4 Costs and Benefits of Compliance with the Proposed Limit Values

In this Section, the available information on costs and benefits of achieving the limit values will be discussed. Section 4.1 looks at the findings in the two Economic Evaluation studies, the underlying information and assumptions. In Section 4.2, the role of secondary and other benefits is discussed.

4.1 The results of the Economic Evaluation studies

4.1.1 Arsenic, cadmium and nickel

Table 3 shows the estimated costs and benefits of achieving limit values for arsenic, cadmium and nickel. The figures are based on the Entec report (Entec, 2001), taking into account the statements made in that report concerning the uncertainty ranges: plus or minus 50 per cent for costs (in the case of nickel only plus 50%), and plus or minus one order of magnitude for the benefits. For arsenic, the Entec report provides cost and benefit estimates of meeting a limit value of 13 ng/m^3 only. For nickel, the costs and benefits of achieving 20 ng/m^3 are calculated here as the arithmetic mean of the values for 10 and 30 ng/m^3 presented in the Entec report.

Table 3 Costs and Benefits of Compliance with Limit Values for As, Cd en Ni (€ mln per year)

	Costs		**Benefits**	
	Best estimate*	**Range**	**Best estimate***	**Range**
Arsenic (13 ng/m^3)	17 **	8 - 28.5	0.19 - 0.90	0.019 - 9
Cadmium	22	10 - 36	0.07 - 0.31	0.007 - 3.1
Nickel	283	128.5 - 310	0.115 - 0.73	0.0115 - 7.3

* With a 4% discount rate.
** Plus costs for the lead sector (for which data to quantify costs were lacking).

These estimates suggest that the costs of achieving the limit values probably outweigh the benefits, although the upper part of the benefits range and the lower part of the cost range for arsenic overlap slightly. However, as the Entec study clearly states, the quantified benefits only cover reduction in cancers due to exposure to arsenic, cadmium and nickel. Other potential benefits to be gained by implementing the limit values include:

- reduced adverse health effects due to reductions in exposure to other metals;
- reduced mortality and morbidity effects due to reductions in exposure to PM_{10};
- reduced adverse impacts on ecosystems and crops; and
- reduced occupational exposure to carcinogenic metal pollutants (potentially important where better control is achieved over fugitive emissions).

It is therefore concluded that the quantified benefits may be significant underestimates of the total benefits. In Section 4.2 we will address the relevance of these additional or secondary benefits.

It is also important to note that the benefit figures in Table 3 are based on estimates for the value of preventing a statistical fatality (VPF), ranging from € 0.9 million to € 4.4 million per VPF (with a 'best estimate' of € 1.8 million). The Entec report points out, however, that the size of the population that will experience health benefits may not be large. In such cases, the relevance of estimating benefits using VPF is limited, because VPF is based on small changes in risk over large populations. The willingness to pay by a smaller population to reduce the risk of a fatality may exceed the VPF figures.

4.1.2 PAHs

Table 4 presents the cost and benefit estimates of achieving the 1 ng/m^3 for B(a)P, as reported in the AEA/TNO study.[11]

Table 4 Costs and Benefits of Compliance with the Proposed B(a)P Limit Value (€ mln per year)

	Costs		**Benefits**	
	Best estimate	**Range**	**Best estimate**	**Range***
Cokeries (conversion to new plant)	unknown, but € mln		up to 48	
Residential	not specified	250 - 370**	150	6 - 8,800
Traffic	not specified		7.1	0.3 - 920

*Including variations in risk factors
** Assuming annual costs to be 10% of investment costs

From Table 4 it can be concluded that the available information does not allow any firm statements on the net benefits of introducing the limit value for B(a)P. Nevertheless, at least for the residential sector (using solid fuels for heating) substantial health benefits can be achieved and they are likely to be in the same order of magnitude as the costs.

In the AEA/TNO study, a considerably lower value for preventing a statistical cancer is used than in the Entec study: the range is from € 0.47 million to € 2.7 million, with a 'best estimate' of € 0.72 million. In these estimates, it is assumed that 90 per cent of the cases of lung cancer are fatal and 10 per cent are recoverable. They also take into account factors such as age and the time lag between exposure and effect (using a discount rate).

11 The estimates for the Söderberg smelters have not been included because, as stated above, it is unlikely that in the medium term any of this type of aluminium smelters will remain operational in the EU.

The AEA/TNO report identified a number of secondary benefits, but also 'disbenefits' that could result from introducing a PAH limit value. The secondary benefits include mainly reduced emissions of other pollutants, such as particles, NO_x and greenhouse gases, as well as improved energy efficiency. The secondary 'disbenefits' are related to the specific measures taken to ensure compliance with the limit values. For example, in the case of relocation of cokeries the material consumption for building the new plant is identified as a possible secondary disbenefit.

4.2 Secondary and other benefits

The quantified benefits in the studies discussed above relate only to the value of preventing cancer due to atmospheric pollution by arsenic, cadmium, nickel and PAHs. However, as indicated, there may be several other benefits (and possibly also 'disbenefits') associated with the introduction of limit values for these substances. Broadly speaking, these secondary benefits may include the following types:

- avoided damage to ecosystems, crops, etc, due to the reduction in exposure to the targeted pollutants;
- avoided non-environmental damage (eg in terms of improved occupational health and safety) due to the reduction in exposure to the targeted pollutants; or
- avoided damage due to a reduction in non-targeted pollutants, resulting from the measures taken to achieve compliance with the limit values.

From a methodological point of view, it is obvious that the first type should be included in any cost-benefit analysis (CBA) of an environmental policy measure. For the second and third type this is less obvious, because it is conceivable that there are other, less expensive options to achieve the same result. Therefore, if non-environmental benefits and benefits from reductions in other pollutants are included in the CBA, the scope of the analysis should in principle be broadened so as to include all other measures that would bring about these secondary benefits as well. For practical purposes, however, one can safely include all three categories of secondary benefits in a CBA, assuming that the unit values of benefit categories (eg the value of preventing a statistical fatality) will reflect the order of magnitude of the cost involved in reaching the same result by other means.

On the basis of the available information, it is impossible to quantify the secondary benefits from introducing limit values for arsenic, cadmium, nickel and benzo(a)pyrene, even in terms of order of magnitude. Tentatively, one might expect the avoided damage to ecosystems and crops to be relatively small, as atmospheric concentrations contribute relatively little to the total load of these substances. Occupational health and safety, on the other hand, might be a very important benefit category. The same could be true for traffic safety as a side benefit of traffic reduction measures leading to PAH reductions. The non-targeted pollutants that could be reduced as a side-effect of the measures taken under the proposed Directive are particulates and lead, as well as CO_2. Substantial benefits might be expected here as well.

Apart from the secondary benefit categories mentioned above, there are other unquantified benefits that could result from introducing air quality limit values. These include the 'technology forcing' impact that such standards may have, by stimulating research and the development of technology that is currently not considered as BAT.

Given the lack of information on the size of secondary benefits, a direct comparison of the estimated costs and benefits will necessarily lead to biased conclusions.

5 Conclusions

Human health considerations are the main justification for the introduction of mandatory limit values for ambient air concentrations of arsenic, cadmium, nickel and PAHs. All these pollutants have the potential to cause cancer, and most of them are probably genotoxic carcinogens (implying that there is no safe lower threshold for exposure). A 'unit risk' approach is therefore called for, deriving limit values from a given level of risk that is considered to be acceptable. The limit values that were proposed by the Commission's Working Groups were based on this approach. They are (with the exception of cadmium) less stringent than the WHO guidelines, reflecting feasibility and uncertainty considerations that the Working Groups took into account.

Several pieces of legislation, conventions and policies are already in place that will contribute to decreases in the ambient air concentrations of the pollutants considered here. Nevertheless, air quality standards have in important complementary role to play. Mandatory limit values may be an essential additional tool in ensuring the lowest reasonably achievable level of harmful impacts from air pollution on human health and the environment.

The air quality limits proposed in the Kronberger report (and endorsed by the European Parliament's Environment Committee) are within the ranges recommended by the Working Groups. On the basis of the available information, it can be concluded that these values are achievable for most of the relevant sources. The main possible exceptions include:

- a small number of non-ferrous metal plants (with respect to the metals); and
- an unknown number of cokeries (with respect to B(a)P).

In addition, the B(a)P limit value might be difficult to attain in practice with respect to residential solid fuel use, although it should be technically feasible.

A direct comparison of the costs and benefits involved suggests that for the metals the quantified benefits are significantly lower than the costs, whereas for PAH they are in the same order of magnitude. However, the estimates are based on a very limited amount of available information. Moreover, uncertainties are large, resulting in very wide ranges for the estimates. The relevance of the method used to value reductions in cancer incidence is questionable, as this method is based on small changes in risks for a large population (while the population involved here is small). Last but not least, the quantified benefits do not take into account any secondary or other benefits, resulting in an underestimation of which even the order of magnitude is unknown. All in all, the direct comparison of the estimated costs and benefits will necessarily lead to biased conclusions.

Given the large uncertainties and information gaps, a precautionary approach seems to be advisable. The introduction of mandatory limit values based on unit risk factors would fit well in such an approach. Temporary exemption possibilities for the small number of situations where the limit values cannot be achieved at reasonable cost could be justifiable.

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