Reduction of mercury emissions from coal fired power plants

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Policy summary

The biggest source of mercury emissions is coal fired power plants. Several studies show that these emissions in the ECE could amount to about half of the total mercury emissions to air.

In the draft annex V for the HM Protocol that lies before the 48th WGSR in April 2011 the proposal for an emission limit value (ELV) for coal fired power plants (CFPPs) is 30 microgram Hg/m3. Unabated CFPPs can fulfil this ELV.

A CFPP equipped with conventional air pollution abatement techniques that dedust, desulphurise and denox would decimate mercury emissions from the exhaust gases. Electrostatic precipitation (ESP) or fabric filter (FF)), flue gas desulphurisation (FGD) and selective catalytic reduction (SCR) would allow for an ELV of 3 microgram/m3 at no additional cost.

A CFPP not equipped with conventional abatement techniques could also meet an ELV of 3 microgram/m3. Several techniques exist to lower mercury emissions. Additional costs for a CFPP could amount to several million euros. Such costs would lead to a small increase of the price of electric power of about 0.0001 euro / kWh, which is less than one euro annually for a family.

At the 48th session of the WGSR it is up to the Parties in WGSR to decide on an ELV for coal fired power plants. Hopefully, this informal document could guide the WGSR in its decision.

Introduction

Coal fired power plants (CFPP) are the largest anthropogenic stationary sources of mercury emissions in Europe. The USA has developed policies to reduce emissions of mercury from CFPP. The current HM Protocol also addresses the emissions of mercury from CFPP. The Protocol provides information on the Best Available Techniques (BAT) to reduce emissions of mercury. The Protocol does not give a specific emission limit value (ELV) for mercury emissions from CFPP. With the revision of the current protocol new standards aimed at reducing mercury emissions from CFPP could be added to the new HM Protocol.

This paper discusses current mercury emissions from stationary coal fired power plants, possible emissions abatement techniques, costs of mercury abatement, current policies and legislation in the UN ECE region and the proposal for an emission limit value to be added to the HM Protocol.

Emissions of mercury from coal fired power plants

The global mercury emission in 2008 was about 8000 tons, 36% of which (2900 tons) is originating from anthropogenic activities. The main anthropogenic source for mercury emissions is the combustion of fossil fuels. Several estimates of mercury emissions have been reported.

Pirrone

Table 1 gives an overview of the mercury emission per continent from stationary combustion sources in 2008, as presented by Pirrone at the CEM conference in 2009.

Continent	tons Hg
Europe	89
Africa	205
Asia + Russia	905
North America	80
South America	31
Australia and Oceania	113
Total	1423

Table 1: Global emissions of mercury in 2008 from stationary combustion plants (ref. 1)

TNO, MSC-East, CCE

At the 47th meeting of the WGSR in September 2010 CCE has presented a study performed by TNO, MSC-East and CCE to calculate the exceedence of critical loads for new estimates of emissions of heavy metals for different scenarios in the UN ECE region. TNO estimated the emissions of mercury from power plants to be 119 ton/year, for UNECE /Europe in 2010. This is 47% of the total mercury emissions in UNECE- Europe (ref. 28).

E PRTR

Emissions of mercury from CFPP for the EU are also reported to the E-PRTR database. Total reported mercury emissions from stationary sources in 2008 are 37.8 t/a, of which 21.2 tonnes are from CFPP (ref. 14). This is about a quarter of the emissions estimated by Pirrone. It is unclear whether all emissions are reported to E PRTR. CFPP are however the largest stationary source of mercury emissions in E PRTR. The reported emissions per installation can be found at the E-PRTR website, (ref. 14).

Coal consumption

Because of the uncertainty in the mercury emissions an estimate was made on the basis of reported coal consumption for power production. Table 2 gives an overview of the coal consumption burned for the generation of electric power in 2008 (ref. 26). The mercury emission is estimated based on the usual range of mercury content of coal (ref. 4). The mercury emission reduction caused by abatement techniques is not taken into account, so the third column displays the worst case scenario. As a comparison the table also presents the reported mercury emission and the number of power plants of Europe according to the e-PRTR-database 2008.

The emission estimated by TNO and Pirrone are well within the range of estimated emissions based on coal consumption.

The USA Department of Energy estimated emissions of mercury from CFPP in the USA to be 48 tonnes in 2005 (ref. 15).

Table 2. Estimated mercury emissions based on coal consumption

Information Source	USA Energy Information administration			e-PRTR 2008	
Region	Coal consumption Mton coal/a	Calculated emission, at 0.05 g Hg/ ton coal ton Hg	Calculated emission at 0.2 g Hg/ ton coal ton Hg	Reported emission ton Hg	number power plants
Europe	1032	52	206	21.2	193
Eurasia	457	23	91	0,50	2
Total Europe + Eurasia	1,489	74	298	21.7	197

Abatement of mercury emissions from coal fired power plants

The mercury content of coal is typically in the range of 0.05-0.2 g/ton (ref. 2). Mercury is volatilized during combustion and converted to gaseous elemental mercury Hg(0). Subsequent cooling of the flue gas and interaction of Hg(0) with other flue gas constituents, such as chlorine and unburned carbon, results in partial oxidation of the Hg(0) to gaseous oxidized forms of mercury Hg(2+) and particulate-bound mercury Hg(P). As a result, coal combustion flue gas contains varying percentages of Hg(P), Hg(2+), and Hg(0). The exact speciation of mercury has a profound effect on the Hg capture efficiency of existing Air Pollution Control Device (APCD) configurations, which has been found to range from 0 to over 90 percent.

Coal washing

Emissions of mercury can be abated by reducing the amount of mercury in the fuel. The mercury content of coal can be lowered by washing the coal before it is fed into the boiler. This process of coal washing is based on solution of pollutants and separation of certain fractions of the coal. Cleaning of coal is applied already as a means to improve the quality of coal, which results in more efficient power production and less wear of the installations in the power plant. In general coal washing can reduce the mercury content of coal but it cannot remove all mercury. Data of cleaning efficiencies reported in the USA show a wide range, from 3 to 78%, depending on the type of coal and the washing process. Mean values are in the range of 20 to 30 % reduction of the mercury content (ref. 27). It is concluded that removal of a part of the mercury is feasible by using coal cleaning methods. In most cases coal cleaning will not entail additional costs, as additional costs for coal cleaning will be compensated by an improved efficiency and reliability of the installation.

Mercury abatement as co-benefit of reduction of NOx, SO2 and dust

For a coal fired power plant the APCD (air pollution control device) normally consists of several abatement techniques. In most cases an ESP is used as a first step in reduction of dust emissions. More and more installations also apply a fabric filter to further reduce emissions of dust. Most installations in the EU and part of the installations in the USA and Canada reduce emissions of SO_2

by applying flue gas desulphurization (FGD) based on wet or semi-dry scrubbers. In many modern power plants also selective catalytic reduction (SCR) is used to reduce emissions of NO_x.

The Hg(P) fraction is typically removed by a particulate control device such as an electrostatic precipitator (ESP) or fabric filter (FF). The Hg(2+) portion is water-soluble and therefore a relatively high percentage can be captured by the wet flue gas desulphurization (FGD) systems. The Hg(0) fraction is generally not captured by existing APCD. However, when an SCR is applied this will promote oxidation of Hg(0) to Hg (2+) and enhance Hg capture in a downstream FGD (ref. 3).

This means that in many current coal fired power plants emissions of mercury are already abated by the existing APCD. The efficiency of the reduction of mercury can be very high, depending on the installation and de the quality of the coal.

Reported levels of emissions and reduction

Table 3 presents data on mercury emission from existing power plants that are reported in section 4.3.3.3 of the EU BAT Reference document for Large Combustion Plants (ref 25). Measurements of three coal fired power plants equipped with an ESP and FGD show that mercury concentrations in the stack gases are below 5 microgram/ Nm^3. Measurement of mercury levels behind an ESP at 37 installations show a mean concentration level of 4.9 microgram/ Nm^3.

Table 3. Reported mercury emissions from current coals fired power plants, emission concentration in microgram/Nm3

	APCD applied				
Information Source	Raw gas	ESP	ESP + FGD	ESP + SCR + FGD	AC FF
BREF LCP (ref. 25)		5 [2)] (0.3 - 35)	< 5 [1)]		
Wang (ref.22)	3 - 27 [3)]	3 - 25	2 - 7	1,2	9
DOE/NETL (ref . 29)	5 - 20				

1) BREF LCP, Table 4.41

2) BREF LCP, Table 4.43

3) Wang, table 3

APCD: Air Pollution Control Device

ESP: Electro Static Precipitator to reduce emission of Particulate Matter

FGD: Flue Gas Desulphurisation to reduce emission of SO2

SCR: Selective Catalytic Reduction to reduce emission of NOx

AC FF: Activated Carbon injection and Fabric Filter

Data on mercury concentrations in the raw gases are not provided in the EU BREF for LCP. Emission concentrations can be estimated based on the assumption that the efficiency of reduction of mercury by an ESP is in the range of 30 to 50 % (ref 25). Mercury concentrations in the raw gas upstream of the ESP are estimated to be in the range of 2 to 3 times the level of 4.9 microgram/ Nm^3, being 10 to 15 microgram/ Nm^3. This is in line with the emission levels measured in China by Wang et al (ref. 22).

The reported data show that in most cases the emission concentrations of mercury in the stack gases of existing coal fired power plants already are below 30 microgram/ Nm^3 without specific mercury abatement techniques. Application of ESP and FGD will reduce the concentration of mercury further to levels in the range of 5 - 10 microgram/ Nm^3. The use of an ESP to control dust emissions is common practice in Europe and most installations are also equipped with FGD to control emissions of SO_2. Many installations will achieve emission levels below 10 microgram/ Nm^3 and for most new installations emissions will be below 5 of even 3 microgram/Nm^3.

It can be concluded that most current coal fired power plants in Europe will meet the proposed emission standard of 30 microgram/ Nm^3 without making any additional provisions against mercury emissions.

Effects of EU legislation on emission abatement techniques

In the European Union emissions of coal fired power plants have to be reduced according to the LCP Directive (2001/80/EC). In two years time the new Industrial Emissions Directive (2010/75/EU) will replace the LCP. The IED sets limit values for emission of NO_x on a lower level than the LCP. Therefore all of the new installations and many of the existing installations have to be equipped with SCR to reduce NO_x. The impact of the use of a combination of techniques that are designed to reduce other pollutants, i.e. to reduce SO_2, NO_x and particulate matter (PM), can be estimated based on information in the BREF for Large Combustion Plants (section 4.5.7). This approach is in line with the above mentioned mechanisms. The BREF Large Combustion Plant gives the following conclusions on the use of BAT (ref. 25).

- A fabric filter or ESP removes about 50% of the mercury from the flue gas.
- A FGD removes 50% of the residual mercury emission. This means that when an ESP and FGD are installed at a LCP the residual mercury emission is 25% of the mercury in the coal.
- A residual emission of 10% can be achieved by combining an ESP/FGD with a Selective Catalytic Reduction (SCR) for the abatement of NO_x.
- When firing sub-bituminous coal or lignite the reduction rate of an APCD can be considerably lower and ranges from 30 - 70 %. This is caused by the low amount of unburned carbon on the fly ash resulting in lower adsorption of elemental mercury. In practice this is balanced by the lower mercury content in sub bituminous coal and in lignite. The concentration of mercury in the stack gases are in the same order of magnitude for coal and lignite.

The same levels of efficiency are reported in studies that were performed in the USA and China (ref 27, ref. 22).

Estimated effects of full implementation of BAT on mercury emissions

If coal fired power plants apply the most effective techniques to reduce emissions of SO_2, dust and NO_x, the emissions of mercury will also be reduced. These techniques are regarded as Best Available Techniques (BAT) and for EU Member States application of BAT is mandatory under the current IPPC Directive and under the new Industrial Emissions Directive.

If the raw gas concentration is estimated to be below 30 microgram/ Nm^3 and the overall efficiency of a combination of ESP, FGD and SCR is estimated to be 90%, the resulting emission concentration of mercury in the stack gases will be below 3 microgram/ Nm^3. This level is obtained without application of specific mercury abatement techniques.

All six coal fired power plants currently in operation in the Netherlands use ESP, SCR and FGD. Three new coal fired power plants that are constructed in The Netherlands, will be equipped with FGD, SCR and a fabric filter, but no specific mercury abatement techniques. In the environmental permits for RWE, Electrabel and E-ON it was stated that emissions of mercury will be below 3 microgram/ Nm^3, as a yearly average at 6% O2. ,).

Current level of emission abatement in Europe

In the current situation in the EU still many large combustion plants do not apply the full range of abatement techniques, in particular SCR is not common yet. As explained above it can be expected that emissions of mercury from these installations in the current situation will already be below 10 microgram/ Nm^3 without additional mercury abatement techniques.

If these plants will apply SCR or specific mercury abatement the levels of mercury emissions can be reduced to less than 3 microgram/ Nm^3. As data about the number of CFPP that do not apply SCR or FGD are not available an estimate of the potential reduction of mercury emissions cannot be made.

In the USA about one-third of US power generating capacity was equipped with SO_2 scrubbers in 2005. The US EPA expects that in 2015 two-thirds of the installations will equipped with FGD (ref. 16).

Specific abatement techniques for mercury reduction

At the Power Plant Air Pollutant Control “Mega” Symposium in 2008 several new methods have been presented for the reduction of mercury emissions up to removal efficiency of 90%.

Activated Coal Injection (ACI) upstream of the ESP/FF increases the Hg(P) portion that can be removed by the ESP/FF from the flue gas. When brominated active coal is injected the Hg(2+) portion also increases which improves the performance of the FGD for the removal of mercury (ref 4). The use of activated coal as adsorbent will reduce the emission of mercury to levels in the range of microgram/Nm^3. For the Toxecon process, based on injection of activated carbon, emission levels were established in the range of 0.5 to 3 microgram/ Nm^3 (Ref. 17).

Besides activated coal other adsorbents are commercially available that will increase the Hg(P) portion and improve the emission reduction rate of the ESP/FF. (ref. 5 , 6, 7, 8).

The use of activated coal can have a negative impact on the quality of by-products of the flue gas cleaning, such as fly ash and gypsum. Instead of the injection of adsorbents fixed structures of adsorbents can be used for mercury removal. The general concept of this technology is to install a fixed sorbent structure such as gold coated plates (MerCAP™), a carbon honeycomb, or a bed of sorbent material directly downstream of a particulate collection device such as an ESP. By using a fixed bed the by-products will remain uncontaminated, the sorbent can be collected and possibly regenerated, the sorbent can oxidize mercury that is not adsorbed thus creating enhanced mercury capture in a wet scrubber, and the fixed bed can capture additional fine particulate that would otherwise be emitted (ref. 9).

The oxidation of elemental mercury can be increased by injection of chloride- or bromide compounds upstream of the SCR. Thus the FGD emission reduction rate will also be increased. This technique can also be combined with sorbent injection (ref. 10, 11, 12). Several suppliers offer brominated products that will reduce mercury emissions, e.g. Geobrom offered by Chemtura and the Vosteen process (ref. 18, 19).

When coal with low chlorine content is combusted, the amount of elemental mercury that is oxidized on the SCR catalyst is small and therefore the emission reduction rate may be insufficient. In those cases coal blending with high chlorine coal types is a cost effective measure to reduce the mercury emission (ref. 13).

Conclusion on available techniques for reduction of mercury

The possibilities for mercury abatement depend on the characteristics of the situation. A distinction can be made between new installations, existing installations equipped with conventional emission abatement techniques (ESP and FGD), existing installations with additional SCR, and installations that apply specific mercury abatement techniques.

- New coal fired power plants: if the abatement techniques on a new CFPP are optimized for reduction of mercury the emission concentration can be lowered to 3 microgram/ Nm^3or less.
- Existing coal fired power plants with conventional abatement techniques: if an existing coal fired power plant is equipped with techniques to abate emissions of PM and SO_2 the emissions of mercury are expected to be in the range of 3 to 10 microgram/ Nm^3.
- Existing coal fired power plants with conventional abatement techniques and with SCR: if an existing coal fired power plant is equipped with techniques to abate emissions of PM and SO_2 and with an SCR to reduce the emissions of NO_x the emission of mercury is expected to be in the range of 3 to 5 microgram/Nm^3.
- In other cases for existing plants the emissions of mercury can be abated by using available techniques based on the injection of a sorbent, e.g. activated carbon. Emission levels below 10 microgram/Nm^3 can be achieved in general and levels below 3 microgram/ Nm^3 for the best performing of these techniques. New abatement techniques based on the use of bromine are currently being developed and tested and will become available soon.

Costs and cost-effectiveness of mercury abatement

In general it can be stated that abatement techniques that are aimed specifically at mercury reduction can be expensive because of the low mercury concentrations in off-gases and the volatility of metallic mercury, Hg(0). This also goes for dedicated mercury abatement at CFPP. However, because the APCD on coal fired power plants already captures a large part of the emissions the reduction of mercury on CFPP can be very cost-effective compared to other sources of mercury emissions.

Costs per installation and cost-effectiveness of mercury abatement can vary over a wide range for different situations and installations. The costs depend on the emission levels that have to be attained and on specific characteristics of the installations. A distinction can be made between existing and new installations.

New installations

In a new coal fired power plant, equipped with SCR, FGD and fabric filters, the emissions of mercury can be reduced to levels below 3 microgram/ Nm^3 without additional costs for mercury abatement. Reduction efficiencies depend on the input of mercury and on the design and operation of the installation, but can go up to 90%.

New installations in the EU will have to meet the ELVs for SO_2, NO_x and dust in the new Industrial Emissions Directive. This implies in most cases the use of an SCR. So in general it can be stated that new CFPP in the EU can reach emission levels for mercury of 3 microgram/ Nm^3 without additional costs.

New installations in the rest of the UN ECE region will have to meet the ELVs for SO_2, NO_x and dust in the Gothenburg Protocol. The ELVs in the current Gothenburg Protocol for new installations imply already the use of FGD and SCR. After revision of the Protocol the ELVs are expected to be lower than in the current Protocol, therefore also in these situations mercury emissions will be at levels of 3 microgram/ Nm^3 without additional costs. *Existing installations*

The use of flue gas desulphurisation and of a catalytic reduction of NO_x are important characteristics for the reduction of mercury. Many existing installations are already equipped with FGD and SCR. These installations can reach emission levels in the range of 3 to 5 microgram/ Nm^3 without additional costs.

Installations that are not equipped with SCR will have to take additional measures to reduce mercury emissions to levels below 3 microgram/ Nm^3 . The costs depend on the situation. The most used technique is based on the injection of activated coal. If the installation is already equipped with a fabric filter this will be a relatively economical solution. A value of 11.000 $/lbs Hg, about 19.000 euro/kg, was reported for the Toxecon process (ref. 17). For an installation with an annual emission of 100 kg of mercury the costs are estimated at 2 million euros.

If a power plant has no emission abatement techniques installed the costs of mercury reduction can be relatively high. The total costs of a fabric filter and a system for injection of activated carbon based on the Toxecon process were estimated to be 62.000 $/lbs, or 106.000 euro/kg mercury abated (ref. 17). The costs per installation are estimated at 10 million euros. In the USA DOE/NETL estimated the cost effectiveness of mercury abatement to range from 3.810 to 166.000 $/lbs Hg, or 6.500 to 300.000 euro/kg mercury (ref. 20). The lower values in the range are costs for installations that are already equipped with abatement techniques. In that case the costs of abatement mainly consist of the costs of the used sorbent. The high values are for installations that have to add an additional fabric filter to remove the sorbent from the off-gases. The costs per installation are estimated to range from 6 million to 30 million euros.

In 2006 TNO estimated the cost effectiveness of additional specific mercury abatement on coal fired power plants without FGD or SCR at 128.000 euro/kg mercury removed.

The emission of mercury for a large, 1000 MW power plant without SCR is estimated to be in the magnitude of 100 kg/year. If reduction of 1 kg of mercury costs 10,000 euro the additional yearly costs for abatement of mercury emissions are in the range of 1 million euros. This is in the same order of magnitude as the costs for reduction of SO_2 or NO_x. A modern power plant can produce about 7000 to 8000 GWh of electrical energy yearly. This means that additional mercury abatement can lead to an increase of the price of electric power of about 0.0001 euro / kWh, which is less than one euro annually for each family.

Attribution of costs

It is important to notice that adding an adsorbent injection to a coal fired power plant will have several co-benefits next to mercury reduction. Other pollutants, like heavy metals and POPs, will also be reduced. If the costs of a fabric filter are apportioned to only the mercury reduction, this will result in a less favourable cost effectiveness for mercury abatement.

Total costs for the UNECE region

It is assumed that in the next 15 years all CFPP in Europe will be equipped with abatement techniques that will remove NO_x, SO_2 and PM from the off-gases. This is based on the ELVs in the new Industrial Emissions Directive in the EU and on the upcoming revision of the Gothenburg Protocol. These installations will have mercury emissions with concentrations that are far lower than 30 microgram/ Nm^3. In many cases emissions will be in the range of 3 microgram/ Nm^3.

The proposed ELV of 30 microgram/ Nm^3 for mercury in the revised Heavy Metals protocol will be met without any additional costs for mercury abatement.

If a lower ELV than 30 is applied in the new Heavy Metals protocol the costs of abatement depend on the height of the ELV. If the ELV is set at 3 microgram/ Nm^3 most of the new installations and part of the existing installations will meet this level without extra costs. A part of the installations that are not equipped with SCR will have to take additional measures to remove mercury from the stack gases to meet an ELV of 3 microgram/ Nm^3. Costs for these installations can go up to annually 10 million Euro per installation or more, as was explained above.

The additional costs for mercury abatement in UN ECE Europe depend upon the number of installations that have to take additional measures for mercury reduction. In a worst case estimate, if half of all installations i.e. 100 installations, will have to apply these measures costs can go up to more than 1 billion Euros.

It is important to notice that there is a strong synergy between abatement of mercury and NO_x . Mercury abatement for installations with FGD but without SCR can be an incentive for the application of SCR. The investment and running costs for mercury abatement can cover part of the costs of an SCR. This will reduce mercury emissions and will also reduce emissions of NO_x. This will induce a reduction of the environmental load from power production at relative low costs because of the co-benefits for NO_x and mercury of the use of SCR in combination with FGD.

Current policies and legislation in the UN ECE region

The USA has issued the Clean Air Mercury Rule (CAMR) in 2006, aimed at reducing mercury emissions from power plants from 48 t/a in 2005 to 15 t/a in 2018. On February 21, 2011 the US EPA issued a final regulation for emissions of mercury from coal fired power plants (ref. 30). This regulation sets ELVs for mercury emissions for new and for existing coal fired boilers. The ELVs for the mercury concentrations emitted by new and by extisting installations are set at levels of about 3 mg/ Nm^3 and about 5 mg/ Nm^3 respectively.

In the EU the LCP directive (2001/80/EC) has no specific ELVs for mercury. The LCP Directive will become part of the new Industrial Emissions Directive (IED). The draft of the IED does not give ELVs for mercury emissions, but it gives ELVs for SO_2, NO_x and PM. For the large power plants these ELVs are 200, 200 and 20 mg/ Nm^3. To meet these ELVs specific abatement techniques have to be applied for at least the reduction of SO_2 and dust. For new installations the ELVs will be set at 150, 150 and 10 mg/ Nm^3. This is more or less on the same level as the proposals for the option 2 for revision of the Gothenburg Protocol. These emission levels imply the use of additional NO_x reduction. This will lead to reductions of mercury emissions with an efficiency of about 75%, or about 90% if an SCR is used, as explained above. The remaining emissions of mercury after emission abatement will be in the range of several microgram/Nm^3.

It is unclear whether individual EU Member States have legislation or policies in place aimed at mercury reduction from CFPP. Germany has announced a proposal for an ELV of 3 microgram/ Nm^3 (ref. 23). In environmental permits for three new installations in The Netherlands the ELVs are set at 2.4 or 2.8 microgram/ Nm^3 as yearly average (ref. 24).

Proposal for revision of the HM Protocol (ECE/EB.AIR/WG.5/2010/10)

In the proposal to the WGSR, ECE/EB.AIR/WG.5/2010/10, in chapter G, paragraph 12, an ELV for mercury from power plants is proposed of 30 microgram/ Nm^3. This ELV can be met by applying abatement techniques that are already mandatory to meet the new European Emission Directive IED. These techniques are also necessary to meet the expected ELVs in the revised Gothenburg Protocol, when option 1 or option 2 for the revised ELVs is applied.

Further reduction of mercury emissions can be accomplished by applying lower ELVs for mercury, e.g. a value of 3 microgram/ Nm^3. If abatement techniques are designed to meet also the ELV for mercury this will not lead to higher costs. If an existing installation, applying SCR, FGD and a fabric filter, does not meet an ELV of 3 microgram/ Nm^3 additional measures in the shape of injection of a sorbent or addition of a halogenated compound is necessary. The costs of these measures will be relatively low compared to costs of mercury abatement at other stationary sources like steel plants or cement kilns.

Conclusion

Coal fired power plants are by far the largest source of mercury to air. When coal fired power plants meet the emission limit values for NO_x, SO_2 and PM in the European Industrial Emissions Directive or the emission limit values according to option 2 in the proposal for revision of the Gothenburg Protocol, the emissions of mercury will be reduced to concentration levels that are far below 30 microgram/ Nm^3. Expected emission levels for most power plants are in the range of 3 microgram/ Nm^3.

The proposed ELV for the revised Heavy Metals Protocol can be met by most installations without taking additional measures. This means that an ELV of 30 microgram/ Nm^3 for mercury emissions from power plants in practice will not result in a reduction of mercury emissions from coal fired power plants. Coal fired power plants still would contribute about 50% of the total mercury emissions in Europe.

BAT to reduce mercury emissions is the application of SCR, in combination with FGD. If an SCR is not applied BAT for the reduction of mercury is based on sorbent injection, which can reduce emission concentrations by 90%. In this way an emission limit value of 3 microgram/ Nm^3 for coal fired power plants can be reached. .

The costs of additional sorbent injection on coal fired power plants that meet the emission standard of 3 microgram are estimated to be in the magnitude of 10,000 euro/kg mercury abated. For a large power plant of 1000 MW the costs would be 1 to 10 million euro or 0.0001 to 0.001euro/kWh produced.

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