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A BETTER, CHEAPER WAY TO REGULATE MERCURY

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Summary: The best way to regulate the release of mercury to our environment is through pollution prevention – placing a declining cap on the use of mercury in products and processes. Such a cap could limit mercury releases to 10% of current levels from intentional uses, and 50% of process emissions by 2010. This approach would be far more effective than EPA's current strategy based on emissions controls, because it achieves dramatically greater reductions in total mercury releases, and reduces the problems of re-releases of mercury from wastes. The proposed level of abatement appears feasible, as major reductions in mercury use have been made in many sectors, and substitutes are available. The cap approach also promises to be much lower in cost than an emissions control strategy because the cost of preventing mercury from entering wastestreams is far less than treating the emissions afterwards. To illustrate, while mercury can be purchased for $3 a pound for use in various products, current regulations would require waste incinerators to spend $200-5400 a pound to remove the mercury from their emissions afterwards. In addition to users, a cap or other controls should be placed on the process emission of mercury from coal-fired plants and other sources, now about 25% of total releases. These steps would implement a pollution prevention approach, and could attain the virtual elimination of mercury releases at a relatively low cost.

I. Introduction and Background

EPA has begun to aggressively regulate emissions of mercury, a bioaccumulative toxic substance, by imposing stringent emissions limits on some of the major emissions sources. These sources are required to adopt treatment technologies that may cost thousands of dollars per pound of mercury reductions. However, other major sources, such as coal-fired power plants, remain completely unregulated. In addition, since mercury is a heavy metal and is not destroyed by treatment, the control technologies simply transfer it to solid and liquid wastes, where re-emission of the mercury may be a problem. An even greater inconsistency is that the use of mercury is only restricted for certain products, leading to its continued use and release to the environment. Arguably, this regulatory system is neither sensible, effective nor fair.

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Mercury is high on EPA's priority list of toxic pollutants, along with other heavy metals such as cadmium and lead, and EPA has recently published a comprehensive Mercury Study and mercury action plan. Mercury is known to cause clinically observable neurotoxicity, such as the former "Mad Hatters" disease, and even death in humans following high levels of exposure. Current concerns focus on exposure to methylmercury, a highly toxic form of mercury that readily enters the food chain. Major epidemics of mercury poisoning have occurred in Japan and Iraq due to high levels of consumption of methylmercury in contaminated fish or grain. More subtle forms of neurotoxicity are associated with prolonged exposure to lower levels of methylmercury, although there is controversy as to the precise level that poses a danger to human health. Currently, EPA estimates that more than one million women and children may be at risk due to methylmercury exposure in the US, primarily from eating contaminated fish, and fish advisories have been posted in 39 states. In addition, recent research, especially in Europe, links mercury potentially to Alzheimer's, Lou Gehrig's and coronary diseases, primarily from dental amalgams. Effects of mercury on the environment include significant reproductive and neurotoxic effects on wildlife, together with effects on plants that inhibit their growth and function.

Certain background information is essential to understand the regulatory context:

(a) Mercury is released to the environment from a wide variety of sources. Intentional uses of mercury have historically led to the majority of U.S. releases, due to the disposal of mercury-containing products such as batteries, paints, dental amalgams and various instruments, as well as mercury used in manufacturing processes. Incidental releases of mercury are caused by the combustion of coal, petroleum and other resources that contain trace amounts of mercury.

(b) Mercury is released from natural as well as human causes, although human causes are estimated to create between 50 and 75 percent of overall atmospheric loading. About 1600 tons of mercury is emitted naturally through aeration from the sea and land, with human-caused emissions resulting both from current uses and re-emissions of mercury from the hundreds of thousands of tons previously released.

(c) Waste incineration results in mercury emissions because waste-streams possess mercury-containing products. If there were no mercury in products, waste incineration would not cause mercury emissions.

(d) Mercury, a metal, is not destroyed through emissions control technologies, nor by incineration. Control technologies collect mercury and then transfer it to a liquid or solid waste that is often landfilled. The mercury in wastes may be ultimately re-released into the environment anyway, although there is considerable scientific uncertainty as to the extent and pathway by which it may do so.

(e) Mercury is in global flux, as it is transported widely through the air. EPA estimates that 40% of mercury deposition in the US is from global sources, with the remainder from domestic sources. However, US anthropogenic emissions add about three times as much mercury to the global reservoir as is deposited from it.

II. Current Federal Regulatory Framework

The current regulatory strategy is highly inconsistent, as different sources are treated in dramatically different ways, as shown in the table below. Recent federal regulation of mercury emissions under the Clean Air Act impose stringent requirements on certain major sources, such as municipal waste combustors and medical waste incinerators, but not on others. The regulated sources must reduce their emissions by 90 percent or more, often at considerable expense. However, other major sources of the emissions, notably coal-fired power plants, are not subject to any mercury regulation. (EPA 1998a).

Table 1. Regulation of Major Sources of Mercury Emissions (1994-5 emissions data in Mt/year)

Source	Emissions (Mt)	Reductions Required	Estimated Cost per lb.
Utility boilers			
- Coal	46.9	0	
- Oil	0.2	0	
- Gas	0.0	0	
Munic. Waste Combustors	26.9	90%	$ 211-870
Industrial, residential boilers			
- Coal	20.2	0	
- Oil	9.9	0	
Medical Waste Incinerators	14.6	95%	$2,000-4,000
Hazardous Waste Combustors	6.4	(90%)	($1,043-5,400) (proposed rule)
Chlor-alkali plants	6.5	minor	
Cement plants	4.4	<1%	0
All others	9.0	0	
Total	144.0		

Sources: EPA Mercury Study (MWC, MWI); Utility sources, EPA 1998a; Municipal Waste Combustors, EPA, 1995; Hazardous Waste Combustors, EPA 1996; Chlor-Alkali Plants: 40 CFR 60.52; Cement Plants, EPA, 1998b.

The emissions control technologies contemplated under this approach range from "low technology" practices such as feed control and good combustion practices to higher technologies such as wet scrubbers and activated carbon injection; EPA estimates the latter may cost over $5,000 per pound for some sources, such as hazardous waste combustors. In some cases, the costs are apportioned costs for technologies that control more than one pollutant, and so are not precise, but even in the best of circumstances mercury control is expected to cost hundreds of dollars per pound of emissions reductions. Note that the high cost of mercury pollution control technologies indicate high usage of materials and energy, which results in significant ancillary pollution -- the more expensive controls could result in the emission of hundreds of pounds of traditional pollutants from power generation, such as NO_x and SO_2, as well as CO_2, per pound of mercury abated. In contrast, process changes which get rid of the mercury and preclude the need for the treatment technologies would be both environmentally preferable and less costly.

An emissions-based strategy for mercury is unlikely to be effective for several reasons. First, air emissions only constitute about a third of the mercury currently released to the environment, and imposing stringent limits on point emitters does nothing to clean up the other two thirds. Mercury used in products leads to significant releases from such causes as breakage, spillage and transport, with the remainder discarded as municipal waste. Second, as mercury is volatile, it is unclear how effective extracting mercury from the emissions stream will be in the long term. Mercury is not broken down by treatment, but merely transferred to liquid and solid wastes, including landfills. Although more study is needed, some re-emissions are believed to occur in the short term, and the remainder may be re-released over very long time periods.

Finally, the current regulatory framework turns on its head the whole notion of "polluter pays", as it places obligations to abate emission only on the sources not responsible for the original mercury use themselves. The three groups with major responsibilities to reduce emissions only create emissions because mercury-containing products are discarded in the waste streams which they incinerate. These regulations cannot create incentives for pollution prevention, as they place no obligations on the original users of the mercury to reduce the uses of mercury which lead to the emissions.

The lack of economic incentives to prevent mercury pollution is a serious problem under the current emission-based regulations. Today, mercury can be purchased in bulk for $3 a pound, with only limited restrictions on its use and disposal. This low price creates little economic incentive to reduce its use or disposal. However, waste incinerators must spend hundreds or thousands of dollars to recapture and remove a pound of mercury from their emissions. This makes little sense. Given this huge disparity in cost, eliminating the low-value uses of mercury would be a far cheaper as well as more effective way to reduce mercury pollution.

The persistent nature of mercury highlights a fundamental inconsistency in our environmental law, in that it only addresses pollutants once they are discharged or become wastes. Although such a strategy makes sense for pollutants such as NO_x or SO_2, it does not for a substance like mercury where emissions to air only form a fraction of the releases to the environment. A pollution prevention strategy must instead address the use of mercury. Mercury appears an exceptional example of the adage that an ounce of prevention is worth a pound of cure.

III. A Better Way to Regulate - Capping the Use of Mercury in Products and Processes

A better way to regulate mercury would be through pollution prevention, either through imposing a tax on mercury or placing an overall cap on the consumption and release of mercury. Since taxes may not be politically feasible, this article discusses the cap approach in terms of the two different sources of mercury releases to the environment. This chapter treats the intentional use of mercury, now about 350 metric tons (Mt) per year, and the following chapter treats the 132 Mt released unintentionally from processes such as the combustion of coal and other raw materials that contain trace amounts of mercury.

A. Capping the Intentional Use of Mercury

The cap approach is especially compelling as applied to the intentional use of mercury. It would be more effective environmentally, as it is the only way to capture the use of mercury in products, which lead to the majority of mercury releases. Costs of the prevention approach are also lower, as if use is limited, there is then no need to control mercury emissions from waste combustion, saving waste combustors an annual expense estimated at well over $50 million.

Currently, as shown in the tables below, 346 Mt of mercury is used for industrial purposes. Under EPA's Action Plan for Mercury, some reductions are expected from a negotiated 50% reduction in use by the chlor-alkali industry and a number of voluntary recycling programs. However, a total cap on mercury use could be feasiblely set for 100 metric tons (Mt) in the short term, and lowered to levels as low as 30 Mt or even zero over a number of years, far below current or expected levels of mercury use or release. A cap would be more effective than the emissions approach because it addresses all sources of mercury releases, and avoids the problem of re-releases of mercury.

Table 2. Mercury Use Under Emissions and Cap Approach for Intentional Uses (Mt mercury)

		1997	2003	2010
Emission approach:	- consumption	346	250?	200?
Cap approach:	- consumption cap	346	100	30

The method to achieve the cap would be to impose a ceiling or cap on the use of mercury in the United States, and set declining benchmarks over a number of years to give businesses adequate time to comply. The overall level of the ceiling would be reduced toward the eventual goal of complete elimination or very low usage, say by the year 2010. The above cap figures are based on the phaseout of mercury by the chlor-alkali industry, and reductions of 10% annually by other sectors. We note that while the cap should ultimately reach a very low number, it arguably need not reach absolute zero, since there are some natural mercury emissions. Setting a cap at a low amount would leave some room for very high priority uses of mercury, and considerably ease the economic cost of imposing a cap.

One issue is whether to impose the cap on mercury use at the consumer, seller or producer level. The easiest approaches may be to place the cap on the few entities that produce mercury, or the limited number that distribute and sell it. Allowances representing the cap amount would be distributed to these entities based on their past level of production or sale, or else auctioned to them. Importers should be included, as there is significant import and export of mercury -- net imports were 300 Mt in 1996 and 20 Mt in 1997. USGS 1998b.

This method may be especially simple to apply to mercury producers. Since 1990, no mine in the US has produced mercury as a principal product, and only a small amount is produced in association with gold at several mines. Nearly all the mercury in the US is now produced by three firms that recycle mercury from secondary sources, such as spent products and liquid mercury from chlor-alkali plants. Therefore, only a few entities would need to be involved.

Some consideration under any regulatory approach needs to be given to the disposition of the significant existing stockpiles of mercury. These are the stocks contained in older chlor-alkali manufacturing plants, those held by commercial brokers, and in the National Defense Stockpile. Each of these stockpiles are estimated to consist of 3,000 to 4,000 tons of mercury. The disposition of this stored mercury is a difficult problem, and research is needed to identify more effective ways to permanently stabilize or store these mercury stockpiles.

B. Increased Environmental Benefits under the Cap Approach

The cap approach on intentional uses would result in substantially lower total releases of mercury to the environment. Under the emissions control approach, EPA estimates that continuing use of mercury in products to be over 150 tons, resulting in significant environmental releases. Although the fate of mercury used in products is highly uncertain and requires more research, some preliminary US studies in Florida and Minnesota show that 10% can be lost by product breakage and transport before entering a landfill, and more could be released from the landfill depending on the type of waste disposed, and such parameters as temperature, moisture and bioactivity in the landfill. A thorough Swedish study estimates that 40% of the mercury in thermometers is released, 10% to air, 10% to water and 20% to land. This loss of mercury from products is therefore a continuing major problem under an emissions approach.

In comparison, the cap approach would clearly reduce total mercury releases by an order of magnitude, and also reduces air emissions. Under the current emissions approach, even if only 150 tons of mercury were to continue to used, this results in at least 15-20 tons of emissions even with controls on incinerators, counting emissions from breakage, transport and incineration. In contrast, if a cap were placed on mercury consumption, total use is reduced to the cap amount of 30 tons, and emissions are estimated at 3 tons from breakage and transport, and another 4 tons from waste incineration - 7 tons, which is half to a third as much. If total mercury use, breakage or re-emissions from landfills turns out to be higher than the minimum estimates above, the benefits from the cap approach are even greater.

C. Lower Costs under the Cap Approach

A major cost savings of the cap approach on intentional uses is that by virtually eliminating mercury from the waste-stream, it avoids the need for mercury controls on waste incinerators and combustors, saving an otherwise perpetual annual cost. EPA estimates the cost of mercury controls to be $11-46 million per year for municipal waste combustors and a significant part of the $143-256 million annual control cost for medical and hazardous waste incinerators. In addition, the cap approach avoids the need for the costs for special landfill controls for mercury, and the considerable expense and effort required by the numerous voluntary recycling programs associated with regulatory approaches that do not restrict use.

A cap on mercury consumption appears entirely practicable, as it takes advantage of a trend that is already underway in our economy. Mercury is still sold, at approximately $3 a pound in bulk, and used in many products. USGS 1998. However, industrial consumption of mercury has been declining rapidly, from 1503 metric tons (Mt) of mercury in 1988 to 346 Mt in 1997, as shown in the following table. EPA in its Mercury Study concluded that, “in general, the data suggest that industrial manufactures that use mercury are shifting away from mercury except for uses for which mercury is considered essential." Analysis shows that very few uses are actually essential, and that a cap approach is a sensible and cost-effective way to proceed.

Table 3. Trends in Industrial Mercury Consumption in the United States (in metric tons (Mt))

	1988	1992	1997
Batteries	450	10	6
Chlorine	350	200	160
Paints	200	0	0
Wiring	175	80	57
Chemicals	80	25	*
Instruments	70	80	24
Dental	50	40	40
Lamps	25	55	29
Lab	20	25	*
Other	50	90	30
Total	1,503	605	346

* included in Other

Source: USGS, Minerals Yearbook 1997; Center for Clean Air Policy, 1998.

Much of the reductions in mercury use to date can be attributed to legislation to eliminate mercury in paint additives and batteries. EPA banned the use of mercury in paints in the early 1990s, and a combination of federal and state legislation has caused mercury use for batteries to decline from 250 tons in 1989 to only 6 in 1994. In addition, a combination of public pressure and state and local programs to reduce mercury use has also led to steady declines in many other categories of mercury consumption.

The data presented below show that these significant decreases in use can be attributed to cleaner technologies and substitutes for mercury, which have allowed industry to reduce mercury use by about 10% per year. This trend would be encouraged to continue if appropriate pollution prevention-oriented regulations were put into place, such as a declining cap on mercury use.

Batteries. Since 1992, several states have restricted the mercury content of batteries, and a federal law to restrict mercury use in batteries went into effect in 1996, the Mercury-Containing and Rechargeable Battery Management Act. The small amount of mercury now being used is largely for button cell batteries, where the amount used per battery is declining. In addition, as of 1996, all mercury-containing batteries must be disposed of in special landfills.

Chlorine production. Approximately 14 plants still use the mercury-cell process to produce chlorine and caustic soda, and in 1997 consumed 160 Mt of mercury, almost half the total. Although these plants comply with a 1975 federal rule regarding mercury emissions, the fate of much of the 160 MT is unknown, and is not captured by existing monitoring methods. These older plants are a minority (12%) of the industry, and are being converted to the newer, more efficient and mercury-free membrane process whenever new capital investment is required. The chlorine industry has voluntarily agreed to halve their mercury use within the next few years. Arguably, these plants should be totally phased out by 2010, a step already taken by some countries.[2] Each mercury-cell plant, however, may contain 300 tons of mercury, so when these older plants are replaced by alternative technologies, the mercury will have to be disposed of as hazardous waste. Under US law there is no approved disposal method for mercury, and only recovery or recycling is allowed. The cost of reducing the mercury consumed by these plants would be the cost of accelerating the investment in newer and more efficient plants, or of phasing out these plants if demand were lacking.

Dentistry. Substantial amounts of mercury are still used in the commonly used silver amalgam fillings, which are up to 50% mercury. Although our laws place no prohibition on placing mercury directly into one's teeth, they require that it be treated as a toxic substance when taken out. Underscoring this extreme inconsistency is that anyone with more than four amalgam fillings is expected to exceed the World Health Organization's recommended limits for mercury exposure. Although it has been argued that the superior nature of silver amalgam fillings compensate for the damage caused by the mercury, others argue that the mercury in dental fillings could be a major causal or contributing factor in several illnesses. Recent research, especially in Europe, has linked mercury to Alzheimer's and Lou Gehrig's diseases, heart conditions and chronic fatigue, and some countries are beginning to halt the practice of using silver amalgam fillings. Although mercury is expected to continue to be used in fillings in the U.S., due in part to resistance by the American Dental Association to even research these issues, increasingly effective non-mercury substitutes may be developed and used in the future.

Flourescent lamps. Fluorescent lamps contain small amounts of mercury. Although the mercury content of fluorescent lamps has declined 53% from 1989 to 1995, and is expected to decline further, sales of fluorescent lamps, which are energy-efficient, has been growing by 4% per year. Although a small percentage of lamps are recycled, most are discarded to waste-streams.

While it is difficult to be precise, the costs of capping and reducing mercury use in the above fields appears modest. The total value of the mercury used in the United States is about $2 million, and industry has been able to reduce mercury use by 10% a year in recent years. The costs of requiring industry to continue these reductions appears to be orders of magnitude less than the alternative, which is the tens of millions of dollars that EPA estimates that incinerators must spend annually for mercury controls once the mercury-bearing products are discarded into wastestreams. Even if the costs of control technologies are assessed at minimum values, there appear to be enormous savings in a pollution prevention approach to mercury control.

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[2] Sweden and other Nordic countries have agreed to phase out mercury cell chlor-alkali plants by the year 2010. Swedish EPA 1991. This is also suggested in the UNECE protocol on heavy metals (UNECE, 1997, Annex II para. 59).

IV. Process Emitters of Mercury - Coal-fired Boilers, Cement and Other Sources

To be effective, a regulatory system should include both the end-users of mercury and the sources which emit mercury through incineration of raw products. The great majority of the latter emissions come from coal-fired power plants, but oil-fired plants, the cement industry and other more minor sources also contribute. These sources emit mercury because their combustion processes release the trace amounts of mercury that occurs naturally in the coal, soil or earth.

Table 4. Process Emissions/Releases of Mercury (Mt, 1994-95 data)

	Emissions	Other releases	Total releases
Coal-fired boilers	66	48*	114
Oil-fired boilers	10		10
Natural Gas boilers	0		0
Cement manufacturers	4		4
Pulp and Paper manufacturers	2		2
Geothermal Power	1		1
All others	1		1
Total	84	48*	132

Source for emissions: EPA Mercury Study, Vol. 1 p. 3-6.

* Estimated by subtracting mercury emissions from the total mercury content of coal (estimated at 14 pounds mercury per trillion Btu, using USGS averages of 15.4 pounds for Appalachian coal and 12.6 pounds for Powder River Basin coal (other fields vary from 5 to 36 pounds). Finkelman (USGS), 1998.)

The 132 Mt of mercury released from these process sources represent about 25% of all U.S. mercury releases, and 60% of direct emissions to the air; coal-fired plants contribute about 80% of this total. EPA has however not imposed any mercury regulations on the principal sources of these emissions from coal- and oil-fired plants, citing the very high cost of end-of-pipe controls (tens of thousands of dollars per pound) in its recent Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units. However, reducing mercury releases from these sources is perfectly feasible, as there are pollution prevention options that can be used, such as switching to low-mercury coal and to natural gas and renewable energy sources.

Emissions from all the other non-fuel process sources were only 8 Mt in 1996, and come from cement kilns, pulp and paper manufacturers, geothermal power, and a few other industries. All these minor industrial sources face considerable difficulties in reducing process emissions of mercury, which should be taken account of in setting the cap amount.

A. The Cap Approach for Process Sources

A mercury cap can be applied to process sources, and is feasible because pollution prevention technologies are available for coal-fired power plants, by far the principal source. A cap approach is the best method to reduce mercury because it promotes pollution prevention, but is not as dramatically superior to emissions limits as was the case with intentional users.

A key consideration in designing a cap for process sources is whether to cap their total mercury releases, or only their emissions to the air. Because these sources do not create the problem of breakage and leakage of mercury from products, it is possible to consider either a cap on total mercury releases, or a cap on emissions. Under either approach, a cap would be set on the total mercury allowable, and allowances allocated or auctioned to sources.

A cap on total mercury would be environmentally preferable, and would cap the total amount of mercury contained in the feedstocks used by these plants – for coal, the mercury contained in the coal as mined. This is environmentally preferable because unlike an emissions approach it would require reductions in the overall amount of mercury, including that released to liquid and solid wastes in the sludges from coal cleaning and other control technologies. It would also force more fundamental process changes to reduce mercury than an emissions reduction approach.

However, if the mercury released to water and solid wastes from coal plants could be stabilized to the point they are not likely to re-enter into the environment, a cap on emissions only, which would be less costly, could be considered. Evidence to date suggests that since the coal cleaning process separates out the heavier particles, much of this particle-bound mercury may not re-volatilize. There is little data, however, to evaluate the re-emissions of mercury from the slurries and sludges from emissions scrubbing, which could be significant.

Depending on which approach is taken, a declining cap on mercury released from process sources should be established as defined in the following table. Note that the baseline figures in the table adopt EPA estimates of rising mercury emissions by coal-fired power plants. The costs and benefits of the techniques to achieve these reductions are described in the following sections.

Table 5. Mercury Releases Under Cap Approach for Process Sources (Mt)

		1995	2003	2010
Current approach:	- process releases	132	140?	150?
	- process emissions	84	90	96
Cap approach:	- total mercury cap	132	105	75
	- emissions cap	84	66	48

This table does not consider potential sources of process mercury emissions from the use of automotive oils and fuels, and metal smelting processes, as these are not currently estimated by EPA. However, if in the future they are determined to be significant, they would need to be included to the cap amount, and realistic declines incorporated.

B. The Benefits of the Cap Approach Applied to Process Emitters

The benefits of the cap approach are clearly superior to the current approach taken by EPA to do nothing about the mercury emitted or discharged by coal and oil-fired plants. EPA 1998a. The cap approach gets real reductions in mercury, and as described below at reasonable costs.

The more complex issue is whether the cap approach should be applied to the total process mercury releases of these sources - 132 Mt in the table above - or only on their air emissions. There are significant difference between these two approaches, as the cap on emissions would allow the use of emissions control technologies, rather than require more fundamental process changes. Such emissions control technologies may include enhanced coal cleaning and flue gas scrubbing, which may reduce 50% or more of mercury in emissions, but would then simply transfer it to solid or liquid wastes. In contrast, a cap on total process mercury would force reductions through prevention, such as by switching to lower mercury coal and converting from coal to natural gas or other energy sources, thereby reducing total mercury releases. The total cap is the better pollution prevention option, and a cap on emissions is justified only if it can be shown that the mercury released to water and solid wastes from emissions control technologies can be sufficiently stabilized to not re-enter the environment

C. The Costs of the Cap Approach Applied to Process Sources

EPA has thus far declined to regulate most process sources as it is generally very expensive to apply treatment technologies to their mercury emissions, as the mercury concentrations are so low. EPA's Mercury Study estimated the cost of known end-of-pipe treatment technologies to be as high as $70,000 per pound of mercury for coal plants, though it is possible some technologies will be found that are much cheaper. Therefore, the most practical way to reduce their emissions is through switching to cleaner fuels or raw materials. Such process changes may be very difficult for cement plants, which must incinerate limestone to make cement, and the other industrial sources, but fortunately fuel switching and repowering options are practical for the principal source, coal-fired combustion facilities. These prevention options are discussed below for the different categories of sources.

Coal-fired thermal plants. Significant options exist to reduce the mercury releases from coal-fired power plants and process boilers. These include the use of low-mercury coal in the short term, and switching to natural gas, which has virtually no mercury, or more advanced energy technologies in the longer term.

Switching to lower- mercury containing coal and prompting more selective mining of existing beds is a near-term option for complying with a mercury cap. There is much variability in the mercury content of different coal fields: Appalachian coal contains 15.4 pound of mercury per trillion Btu, and Powder River Basin coal contains 12.6 pounds per trillion. Other fields vary from a low of 5 to a high of 36 pounds. The cost of switching to lower-mercury coal however is difficult to predict. In comparison, the Acid Rain Program, which prompted a shift to low-sulfur coal, resulted in far lower costs of compliance than predicted, with a third of companies complying without suffering cost increases. Ellerman, 1997. The same may or may not be true of switching to lower-mercury coal, although there is an existing trend towards using the lower-mercury Powder River coal.

In the longer term, a far more environmentally preferable option would be if power companies switched their generating capacity entirely to natural gas or other technologies with virtually no mercury. Modern combined cycle natural gas power plants can generate electricity at just over 3 cents per kilowatt hour, considerably lower than new coal plants and generally half a cent to a cent more than even the old coal plants that have paid off their capital costs. In addition, natural gas power provides major benefits in reducing pollution from sulphur dioxide, nitrogen oxides, particulates and carbon dioxide wholly apart from its mercury benefits. This incremental cost of repowering with gas appears to be reasonable, as long as time is given to allow plants to incorporate this action in their investment cycle. Many argue that these old coal-fired plants are overdue to switch to natural gas due to the many pollution reduction benefits this would create, in which case the net social costs of the change would be low or zero.

Oil-fired thermal plants are a fairly small source, contributing 10 Mt mercury in emissions. As with coal, switching to natural gas is a long-term option, but would not be expected to produce as many ancillary benefits in reducing other pollutants as replacing coal-fired plants.

Other process sources have lower emissions, in total estimated at 8 Mt in 1996. *Cement plants* emit 4Mt of mercury by incinerating limestone, which contains trace amounts of mercury, and other materials in their kilns. Another 4 Mt of emissions in total are derived from *pulp and paper manufacturers*, *geothermal power*, *smelting*, and a few other industries. All these industries face considerable difficulties in reducing process emissions of mercury, which should be taken account of in setting the cap amount. However, some pollution prevention options exist, such as in the cement industry, reducing the use of mercury-containing waste products, lowering the clinker content of Portland cement and using more blended cements.

V. Legislation Creating the Cap

It is likely that legislation would be needed to create the caps on mercury consumption and release recommended in this article, at either the federal or state level. Normally, the authorities of the federal EPA or state pollution control agencies do not extend to regulating the use of products, but instead their emissions or waste releases. Although the Toxic Substances Control Act may be able to be used, it may not cover all aspects of a desired program, and it may be more practical to seek legislative authority. Examples of laws that restrict the use of a substance in products are legislation phasing out the use of lead in gasoline (42 USC §7545(c)), phasing out ozone-depleting substances, and that limiting the use of mercury in batteries, mentioned above.

The federal or state law imposing the cap on mercury should:

a) impose a cap both on the sale, production, or consumption of mercury, and a second cap on the process sources that release mercury, that decline over time;
b) create a system for distributing the allowances under the cap amount, either through an auction mechanism, allocating them to existing users/producers, or some combination;
c) establish a trading system if desired, especially if the allocation method is used;
d) create strict monitoring and reporting requirements, together with a system of penalties and fines for non-compliance.

There are several important design issues in creating this system. One is whether to impose one cap or two, separating the intentional consumers of mercury and those making process releases. On the one hand, it would be economically efficient to create one cap, as this would equalize the economic burden among all sectors. However, an important economic benefit of the proposed cap approach is the cost savings from avoiding the need for mercury controls on waste incinerators. This requires that mercury levels for intentional uses be capped at very low levels, as these are the uses leading to discarded mercury in wastestreams. Since a combined cap could not assure this result, it appears that two caps are necessary. Another reason to adopt two caps is that it would allow the policy option of adopting a total mercury cap for intentional consumers, and an emissions cap for process sources.

Another issue is allocation of allowances to the regulated entities. Traditional pollutant cap programs allocate allowances to existing sources based on their past discharges. This may be politically most expedient, but creates problems for new entrants, and may be perceived to be inequitable as it rewards the dirtiest sources. A better way to allocate allowances would be to auction the allowances, or create a more equitable allocation system, such as one based on current use or discharges, instead of past data. For process sources, allocations should also be output-based wherever possible, such as on electricity output instead of energy input, thereby rewarding efficiency.

It also makes sense to allow recipients of allowances to trade their allowances freely between themselves under either the consumption cap or the process sources cap. For consuming sources, trading allows private firms to exchange these mercury allowances between themselves so the highest priority uses of mercury can be made. For process sources, trading allows those most able to make the reductions to do so, saving costs, and allows those most able to make reductions to benefit from doing so quickly. In either case, the environmental benefits are absolutely guaranteed by the cap, and it makes little sense for government to have to decide each year which particular user groups or sources most deserve allowances. Importantly, under either cap the potential releases of mercury would be very small and widely dispersed through the economy, creating no fear that trading may lead to localized effects.

Finally, the legislation should be made consistent with existing requirements for EPA to establish MACT emissions limits under the Clean Air Act for mercury emissions. If the cap limits are sufficiently stringent, as proposed in this article, then the cap approach should replace these limits for waste incinerators and combustors, as these controls would be unnecessary, given the reductions in mercury use. The remaining major emissions source would be coal-fired boilers, where both the total cap suggested here and emissions controls may be compatible.

VI. Going Global With the Cap Approach

Another compelling reason to adopt a cap approach on mercury use and process releases is that it is readily adapted to a global program. Ultimately, mercury pollution must be controlled globally, as emitted mercury travels great distances, and may be subsequently deposited on lands and waters far from the source locale. For example, it is estimated that 40% of deposition in the United States comes from this global reservoir.

The concept of a cap on mercury consumption may be the only effective way to abate mercury on the global scale. One problem noted above is that controlling emissions does not address the problems of breakage of mercury-containing products, and of re-release of the mercury after it is transferred from the air to liquid or solid wastes, which is likely to be far worse in other countries that have weaker landfill controls. In addition, few countries, especially in the developing world, would have the resources to adopt an emissions approach, which may cost hundreds or thousands of dollars per pound of mercury abated. In contrast, provided the political will is present, a cap program would be both effective and reasonably simple to administer, especially if applied to the very few global producers of mercury.

A global cap might be set at an increment over the natural emissions rate which the environment could tolerate, such as 25% of natural emissions, or 400 Mt on a global level. This would cause significant reductions, as an estimated 2,600 metric tons of mercury are emitted every year from human causes globally (EPRI 1997) In addition, the mining of mercury still goes on, with approximately 3,000 Mt produced yearly, 1,500 Mt from the Almaden y Arrayanes mining complex in Spain, and another 611 Mt from the Khaydarkan mining complex in Kyrgyzstan. As in the US, the cap could most easily be imposed on the few producers, together with measures aimed to address continuing emissions from coal-fired plants and similar process emitters.

A global reduction in mercury use could best be addressed if a global agreement is reached to adopt a mercury cap. However, only a few other countries have major domestic programs addressing mercury, and so this discussion needs to begin on a regional or global scale. Relevant regional discussions include that for North America under the Commission for Environmental Cooperation, and the recent international agreement between European and North American countries, the Protocol to the 1979 Convention on Long-range Transboundary Air Pollution on Heavy Metals, which is expected to be ratified in the next few years. The cap approach should be advocated in the context of these agreements - perhaps 130-150 Mt by 2010 for North America and 250-300 Mt if Europe is included. Also, the United Nations Environment Programme is conducting discussions for an international treaty to regulate persistent organic pollutants, although it currently does not address inorganic substances such as mercury. Advantage should be taken of these discussions to initiate a regional or global cap on total mercury use and release.

VII. Conclusion

There are few substances on earth where a pollution prevention strategy makes more sense, as compared to end-of-pipe controls, than mercury. A cap approach to mercury use and release is advocated as it both lowers total releases and prevents potential re-releases of mercury, compared to other strategies. Because it restricts all releases of mercury to the environment, it promises to lower the amount of mercury in the environment, unlike the emissions approach. It is also considerably less costly and fairer, in contrast to the current regulation which impose heavy burdens on some sources while allowing others to continue unregulated. This cap-and-reduce method could usefully be applied to the **use** of other toxic substances in our economy as well, such as lead, perchloroethylene (PERC) and ultimately substances such as chlorine.

The following table summarizes the stringent cap amounts suggested in this article for both intentional uses of mercury and process sources of mercury releases. Although a combined cap is possible, political and technical considerations likely require a separate cap for each group. Together, these limit mercury to 205 tons by the year 2003, and 105 tons by the year 2010. At that point they could be re-evaluated to see if further reductions are reasonable.

Table 6. Total Mercury Under Emissions and Cap Approach (Mt mercury)

		1997	2003	2010
Intentional uses				
Emissions approach:	- consumption	346	250?	200?
Cap approach:	- consumption cap	346	100	30
Process Sources				
Current approach:	- process releases	132	140?	150?
Cap approach:	- total mercury cap	132	105	75

Current evidence shows that it is feasible in our economy to substitute for mercury use, and if given adequate time and incentive, industry could do so in a cost-effective manner. A mercury cap approach would provide the correct incentives, and lead to the virtual elimination of one of the most significant toxic materials in our society at reasonable cost.

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