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关于水泥窑排放水银的问题(1)

Cement Kiln Mercury (Hg) Emission Issues

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引 言 Introduction

There is a growing level of concern about mercury emissions from cement kilns and interest in the industry on developing cost effective options for controlling these emissions. Cement plants have a wide range of mercury inputs and resulting emissions because of the wide variety of raw materials and fuels used in the process. Further the current level of mercury emission control at cement plants varies from 0% to as high as 95% using existing particulate control systems. This is the first in a new series of GCI TechNotes that will examine this issue.

由于人们对水泥窑排放水银的关注日益高涨，工业界才有兴趣发展节约且有效的办法来控制这些排放. 水泥厂因为在生产过程中使用的生料和燃料中可能含有不同程度的水银，因此会排放水银. 而且当前一些水泥厂对水银排放的控制程度由 0%至最高的 95%不等，使用的是微粒控制系统. 在新的一系例 GCI 工艺摘要中，这是探讨这个问题的第一篇。

Mercury emissions are regulated based on concern for mercury entering the food chain and bioaccummulating to significant levels that could impact people eating fish. The following is a brief review of the factors that impact this issue including the basic chemistry of mercury and mercury compounds, emission modeling issues and emission control factors. References at the end provided details on the health effects of various forms of mercury.

水银排放的监控是基于人们的关注水银会进入我们的食物链，长时期的积累在生物系统里，对一些吃鱼的人会有影响. 以下是对那些影响的因素作一个简短的复审，包括水银的基本化学作用和水银的化合物、排放模型分析的问题与排放控制的因素. 参考的资料附于本文的底部，提供了关于不同形式的水银对健康的影响。

水银的形式与其在环境中的结局 Mercury Forms and Fate in the Environment

There are four forms of mercury that have the potential to form from the cement kiln system. These are elemental mercury, mercuric chloride, mercuric oxide and mercuric sulfide. Table 1 provides a summary of some data regarding these forms.

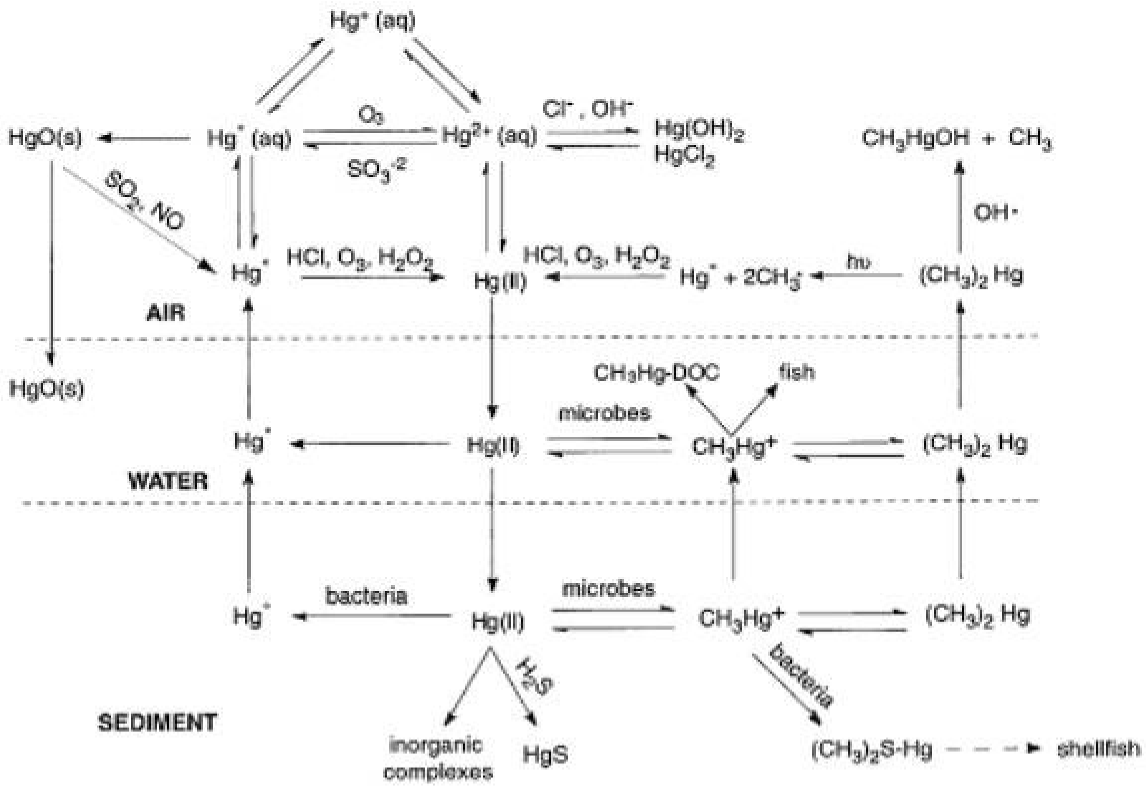
水银在水泥系统里有可能形成以下四种形态；水银的原体、氯化汞、氧化汞及硫化汞。表一提供这些形态的扼要数据。

表一　水银的形态　Table Mercury Forms

合成物 **Compound**	水银 **Mercury**	氯化汞 **Mercuric Chloride**	氧化汞 **Mercuric Oxide**	硫化汞 **Mercuric Sulfide**
公式 **Formula**	**Hg**	**$HgCl_2$**	**HgO**	**HgS**
熔点 ˚C **Melting**	-39	276	500（分解）	584（升华）
沸点 ˚C **Boiling**	357	302	N/A	N/A
水溶性 **Solubility**	低 **Low**	高 **High**	不溶 **insoluble**	不溶 **insoluble**

Figure 1 from the Toxicological Profile for Mercury prepared by the Agency for Toxic Substances and Disease Registry, USDHHS, shows how various mercury compounds can be transformed in the environment.

下面图里的水银毒型是从美国的有毒物质与疾病登记处（Agency for Toxic Substances and Disease Registry, USDHHS）得来的，显示不同的水银合成物能转变到环境中。



Source: Stein et al. 1996.

Figure 1. Transformation of Mercury in Air, Water and Sediment

上面图一 显示水银在空气中、水中和沉淀物中的转变

模型分析的问题 Modeling Issues

Clearly the form of mercury found in stack emissions can have a significant impact on the fate of mercury in the environment and therefore have a potential impact on human health and the environment. Many of the existing programs for modeling emissions make worst case assumptions regarding the form of the mercury as it is emitted as well as the transformation path that the mercury takes once it is released to the environment. It is therefore critical that any modeling take into account the actual molecular form and valence state of any mercury that is emitted and make realistic assumptions regarding transformation of mercury emitted to the environment.

很明显从烟囱排放出的水银，对水银在环境里的结局有重大的影响，因此对人们的健康和环境有潜在的危险. 很多现有的程序对排放的模型分析，得出一个最环的假设关于排放出来的水银的形态，及其一旦被释放入环境之后的转变途径. 因此，非常重要的是在进行任何模型分析时有必要把任何水银被排放之后的实际分子形态与价态(Valence State) 考虑在内，然后对水银排放入环境之后的转变做一个真实的假设。

"Evaluating the Consequences of Mercury Emissions from a Point Source" by Zemba, Gossman, Woodford, and Chrispell provides an excellent analysis of the faults on this sort of modeling when applied to a cement plant.

"Evaluating the Consequences of Mercury Emissions from a Point Source"一书［由 Zemba, Gossman, Woodford, and Chrispell 编写］对这种模型分析应用在水泥厂子时的错误，提供一些卓越的分析。

控制的问题 Control Issues

In much the same way that the form of the mercury can impact emission modeling it can also impact emission control technologies and their efficacy. Traditionally used methods such as activated carbon capture (ACC) have primarily been used on municipal waste combustors where mercury concentrations in the gas stream are relatively high and where there is a significant presence of chlorine in the gas stream – both of which enhance carbon adsorption of mercury. To the extent that any control technology is used it is important that the mercury not be transferred from one medium to another in a way that does not result in its real removal from the global mercury cycle.

差不多同样地水银的形态能影响到排放模型分析，也能影响到排放的控制技术和他们的功效. 传统使用的办法，如用活性炭吸附，那曾经是当初使用于焚烧城市废物的焚烧炉，因为那里的气流中有较高的水银浓度，而且还呈现高度的氯气 – 两者都增强炭的吸收能力. 在某种程度上使用任何控制技术，重要的是不要让水银由一个中介转至另外一个中介，那种做法不会真正达到把它从全球的水银循环里驱除的目的。

结 论 Conclusion

Clearly the "best" environmental fate for mercury is to sequester it in the form of the insoluble oxide or sulfide in an environment where it is unlikely to be altered by microbes or bacteria. This has the potential to remove the mercury from the global mercury cycle. The cement manufacturing technology has that potential but each kiln system is different because of different raw materials, fuels and other process conditions. Control technology that might work on one kiln will not necessarily work on another. Strategies to convert mercury in the process to insoluble and low volatile oxide and sulfide forms that allow the exiting particulate control systems to capture the mercury are likely to be the most cost effective.

很清楚，水泥在环境中最好的结局是把它隔离开，在一个环境里使它成为不容于水的氧化物或硫化物， 而在那里不大可能会被微生物或细菌所改变. 这样会有可能把它从全球的水银循环里驱除出去. 水泥制造的技术有这种可能性，但是每个水泥窑的系统都不同，因为使用的生料、燃料与工艺的条件都不同. 使用的控制技术在一个水泥窑也许能行，而用在另一个水泥窑时未必能行. 以不溶于水的，低挥发性的氧化物和硫化物的形态来转变水银，让现有的微粒控制系统来捕捉水银，这可能是最经济的办法。

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