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Mercury mass balance at a wastewater treatment plant employing sludge incineration with offgas mercury control

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ABSTRACT

Efforts to reduce the deliberate use of mercury (Hg) in modern industrialized societies have been largely successful, but the minimization and control of Hg in waste streams are of continuing importance. Municipal wastewater treatment plants are collection points for domestic, commercial, and industrial wastewaters, and Hg removal during wastewater treatment is essential for protecting receiving waters. Subsequent control of the Hg removed is also necessary to preclude environmental impacts. We present here a mass balance for Hg at a large metropolitan wastewater treatment plant that has recently been upgraded to provide for greater control of the Hg entering the plant. The upgrade included a new fluidized bed sludge incineration facility equipped with activated carbon addition and baghouse carbon capture for the removal of Hg from the incinerator offgas. Our results show that Hg discharges to air and water from the plant represented less than 5% of the mass of Hg entering the plant, while the remaining Hg was captured in the ash/carbon residual stream exiting the new incineration process. Sub-optimum baghouse operation resulted in some of the Hg escaping collection there and accumulating with the ash/carbon particulate matter in the secondary treatment tanks. Overall, the treatment process is effective in removing Hg from wastewater and sequestering it in a controllable stream for secure disposal.

1. Introduction

Mercury (Hg) use in industrialized countries has declined significantly in the last 30 years as the environmental effects of prior discharges of the toxic metal became apparent (Jasinski, 1995; USEPA, 1997; Snopek and Goonen, 2000; Swain et al., 2007). Nevertheless, Hg continues to be used in industrial processes and manufactured products (Floyd et al., 2002; UNEP, 2002) and is found in waste and wastewater discharges from modern society (EC, 2001; Mukherjee et al., 2004; Brooks and Matos, 2005; Hylander and Meili, 2005). Controlling the ultimate fate of Hg in these waste streams and minimizing the ultimate environmental impact of this Hg are an important goal of advanced waste treatment processes. Advanced waste combustion processes typically include the control of Hg in offgases, often adding activated carbon directly to the offgas stream, with subsequent collection of the carbon in a baghouse or other solids removal process (Krishnan et al., 1994, 1997; NRC, 2000). Mercury in wastewater can be removed effectively by conventional treatment processes (Oliver and Cosgrove, 1974; Goldstone et al., 1990; Bodaly et al., 1998), with removal efficiencies of greater than 95% observed at many municipal treatment plants (Balogh and Liang, 1995; Mugan, 1996). The Hg removed during wastewater treatment is found in the sludge residuals, and sequestration of the Hg in this stream is necessary to preclude its dispersal to the environment (Balogh and Liang, 1995). Many larger municipalities throughout the world incinerate dewatered sludge, and Hg control systems for offgases are becoming more common (Malerius et al., 2003; Van den Acker, 2004). In the United States,

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however, the control of Hg in offgas from wastewater sludge incineration has not been widely practiced, and Hg emissions from sludge incineration are a small but measurable component of emissions inventories (USEPA, 1997).

The present study describes a mass balance for Hg in a major municipal wastewater treatment plant that recently installed fluidized bed reactors for sludge incineration and an activated carbon process for control of Hg in the incinerator offgas. It is believed to be one of the first applications of Hg control for a sludge incineration installation in the United States, and serves as an example of the degree to which advanced treatment technologies can effectively control Hg in the wastewater treatment process and sludge disposal/reduction process.

2. Methods

2.1. *Treatment process description and process flow rate data*

Sampling took place at the Metropolitan Wastewater Treatment Plant in St. Paul, Minnesota between January 10 and February 7, 2007. The treatment capacity of the plant is 11.0 m^3/s, and the mean daily influent flow rate during the sampling period was 7.5 m^3/s. A schematic of the treatment process configuration is shown in Fig. 1. Wastewater entering the plant is first pretreated by bar screening and grit removal (not shown). The wastewater then enters primary treatment, where solids are removed by settling. The solids removed there are sent to gravity thickening, where the sludge stream is thickened, increasing the solids content from approximately 0.6% to 5%. Wastewater leaving the primary process flows to secondary treatment, where dissolved organic and fine particulate materials are removed in an activated sludge process. Sludge solids from this process are removed in the final settling process; the greater portion (92%) of these solids is returned to the front end of the secondary process while the remainder is sent as waste to flotation thickening. Cleansed wastewater exits the final settling process, is chlorinated and dechlorinated (not shown), then flows into the Mississippi River.

Thickened sludges from the gravity (GTS) and flotation (FTS) thickening processes are stored separately, and mixed just prior to centrifugal dewatering. The dewatered sludge cake (28–30% solids) is then pumped into fluidized bed incinerators for combustion. Residual water streams from gravity thickening (GTO), flotation thickening (FTO), and centrifugation (centrate) are returned to liquid treatment: GTO to primary treatment, and FTO and centrate to secondary treatment.

A schematic of an incineration process train is shown in Fig. 2; three identical trains operate in parallel at the Metropolitan Plant. Dewatered sludge cake is pumped into the incinerator, where it burns in the fluidized bed at temperatures around 770 °C. Residual ash and offgas flow out the top of the incinerator and through heat exchange and recovery equipment. Activated carbon for Hg removal is added to the stream at this point, then both the carbon and the ash are removed in the baghouse. A multi-stage wet scrubber cleans the baghouse exit gas, and a wet electrostatic precipitator polishes the offgas further, prior to its discharge up the stack. Ash and carbon residuals from the baghouse are removed from the plant and landfilled. Spent water exiting the wet scrubber is returned to liquid treatment, entering prior to secondary treatment.

Data for process flow rates were collected from the Metropolitan Plant's process information data system. Mass flow rates of Hg in various process streams were calculated by multiplying the measured Hg concentration in a given stream by the appropriate flow rate of that stream. Thus, the concentration of Hg in the daily influent composite sample (ng/L) was multiplied by the influent flow rate for that day (m^3/s) to

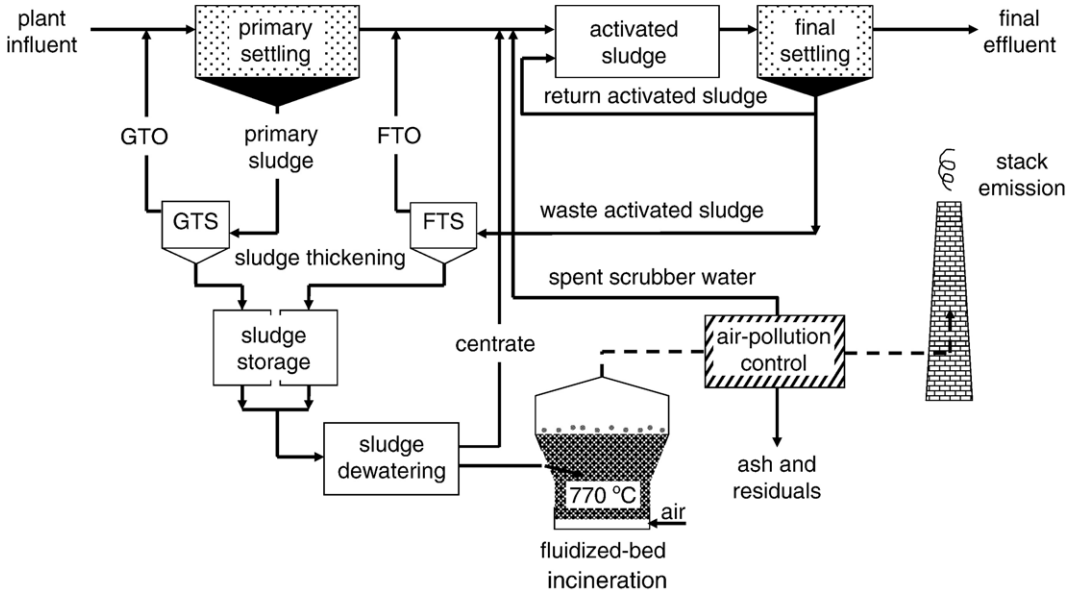

Fig. 1 – Schematic diagram of the process configuration at the Metropolitan Wastewater Treatment Plant, St. Paul, Minnesota, USA.