Report

AQUA METROLOGY SYSTEMS

SafeGuard™ H2O Bench Test Report

Removal of Ionic Mercury from Power Plant Wastewater

15 September 2018

This report summarizes results of the Aqua Metrology Systems' SafeGuard™ H2O intelligent Hg(II) remediation system bench test study and details the system's ability to remove ionic mercury in power plant wastewater.

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Background

Aqua Metrology Systems (AMS), a leader in real-time analytical solutions, developed the first fully automated, online multi-stream metrology commercially available to monitor challenging wastewater streams. As a result, AMS has been providing power plants with accurate and reliable online monitoring capabilities to control Total Selenium (Se) and Arsenic (As) in Flue Gas Desulphurization (FGD) wastewaters since 2010.

In late 2017, AMS applied their technical know-how and experience with challenging wastewater streams to develop a low cost remediation treatment approach based on contaminant removal using an electrogenerated stannous ion reagent. The SafeGuard™ H2O system addresses a range of trace metal contaminants including dissolved mercury (Hg^{2+}) vis-á-vis a process that is relatively simple, efficient and cost effective alternative when compared to traditional, lengthy, challenging and expensive processes.

The SafeGuard H2O system features both low capital and operating costs, making it an economical and attractive remediation system. The system can operate in batch or continuous flow mode and is scaleable to large and small volume treatment volumes.

Introduction

FGD wastewater typically contains different mercury species requiring treatment prior to discharge to remove soluble and highly toxic ionic mercury (Hg^{2+}), contaminants of primary concern. The most commonly used FGD wastewater treatment process is based on mercury precipitation reactions. These multistep, high footprint and lengthy processes require extensive engineering infrastructure and high capital investments. Moreover, mercury precipitation processes have low selectivity, resulting in a high reagent demand that results in significant costs of treatment.

A dissolved mercury removal approach based on its reduction by stannous chloride has been investigated by Department of Energy Savannah River site (B. Looney "Ultralow Mercury Treatment Using Chemical Reduction and Air Stripping" 2003). In this treatment approach dissolved ionic mercury has been successfully removed from contaminated surface water. The two-step process initially involves mercury reduction into insoluble elemental mercury (Hg^0) form, followed by elemental mercury air stripping that reduces dissolved mercury levels down to the parts per trillion (ppt) range. This reaction is well understood in that stannous chloride is widely used as a reducing agent for dissolved mercury reduction in cold vapor mercury analysis (EPA Method 245.1). It should be stressed, that stannous reagent specifically addresses dissolved mercury specie in the solution and provides high selectivity of remediation process.
Ionic mercury reaction by stannous chloride is described by equation (1):

$$Hg^{2+} + Sn^{2+} = Hg^0 + Sn^{4+} \qquad (1)$$

This reaction is spontaneous and practically instant. Under optimized conditions the reaction can be driven to completion within minutes or even seconds. The subsequent air stripping of the resulting dissolved mercury out of the solution is also fast and complete.

However, commercially available stannous reagent solutions (stannous chloride/sulfate) are highly unstable, corrosive reagents that make them impractical for high volume wastewater treatment.

The proprietary approach developed by AMS is based on electrolytic stannous reagent generation on demand. As a result, SafeGuard H2O is free from the drawbacks of using a traditional stannous chloride reagent. In fact, freshly generated stannous ion using tin metal precursor provides very accurate reagent dosing. This reagent poses no environmental and health risks. Finally, SafeGuard H2O provides a cost effective alternative to highly challenging and expensive existing mercury treatment process.

SafeGuard™ H2O System Design and Operation Principle

The configuration of bench scale SafeGuard H2O (Figure 1) stannous reagent dosing system is shown in Fig 1. The system design is simple, straightforward and comprises of two key components:

- Galvanostat and control system
- Stannous ion electrolytic generator

The principle of operation for the SafeGuard H2O (Figure 2) is based on controlled electrolytic reagent generation. Treated water is pumped through a reagent generator electrically connected to Galvanostat. Galvanostat is pre-set to maintain certain electric current and generate stannous reagent *in situ* for further injection into contaminated water stream.

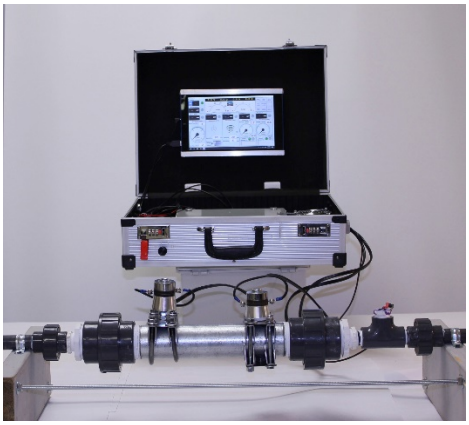

Figure 1: SafeGuard™ H2O stannous reagent dosing system

SafeGuard™ H2O Dissolved Mercury Removal Strategy

The SafeGuard H2O treatment approach to ionic mercury removal from FGD wastewater is demonstrated in Figure 2.

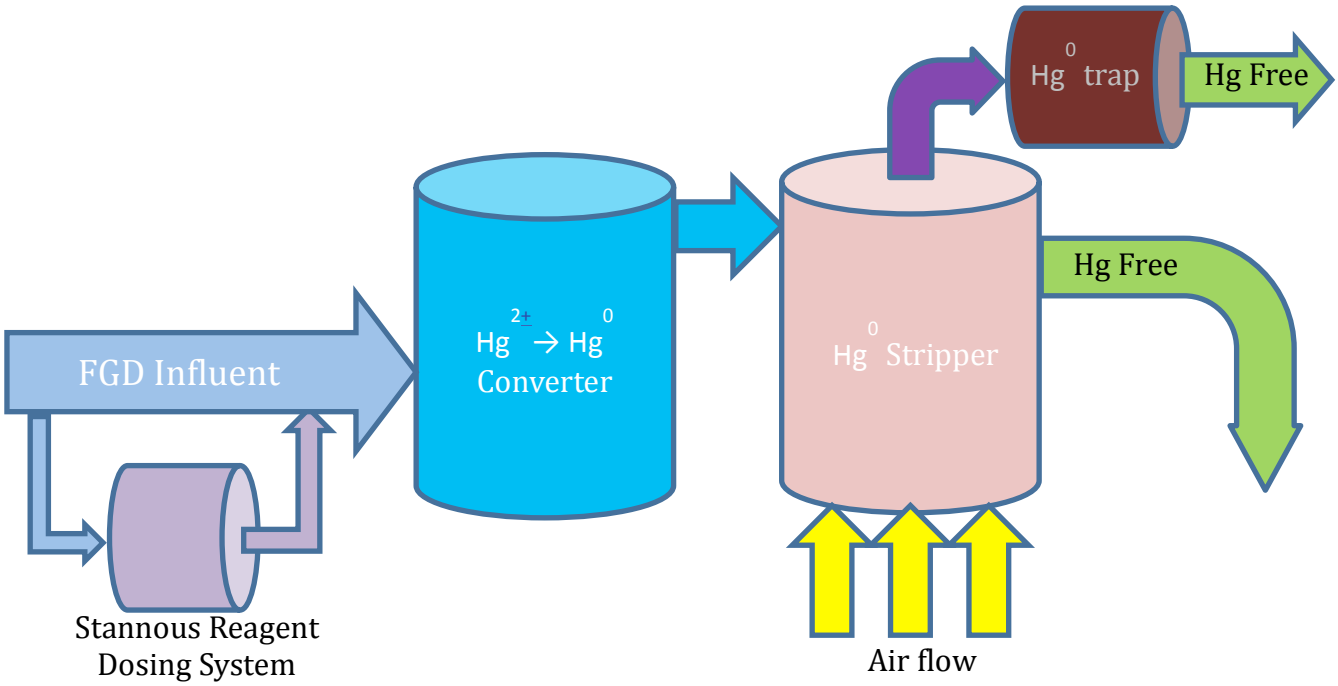

Figure 2: SafeGuard™ H2O dissolved mercury removal process diagram

Generally, dissolved mercury removal process can be divided in three main steps:

- **Reagent generation step** during which desired amount of stannous reagent is generated in by-pass stream and re-injected into treated FGD wastewater;
- **Conversion step** during which dissolved ionic mercury species are reduced by stannous reagent into insoluble elemental mercury form;
- **Stripping/trapping step** in which elemental mercury formed during conversion step is removed from the solution by air flow and trapped by mercury trapping module.

Mercury Removal From Typical FGD Wastewater

SafeGuard H2O dissolved mercury removal performance from typical FGD wastewaters (Figure 3) is summarized in Tables 1-2.

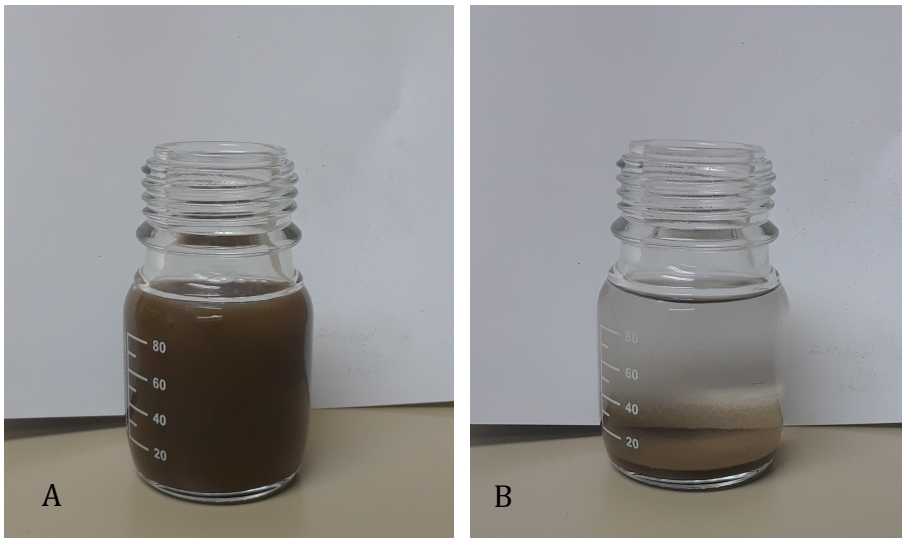

Figure 3: FGD wastewater sample: agitated (A), settled (B) FGD sample treatment results

Settled (clarified) FGD sample treatment results using different stannous reagent dose are summarized in Table 1.

Table 1: Settled FGD wastewater sample mercury treatment results

Sample	Stannous dose, ppm	Hg (total), ppb	Hg (dissolved), ppb	Removal,%
Settled	NA	5	4.6	NA
Settled	1	NA	0.1	98
Settled + 100 ppb	1	NA	1.7	98.3
Settled + 100 ppb	2	NA	0.1	99.9

Table 2: Unfiltered FGD wastewater sample mercury treatment results

Sample	Stannous dose, ppm	Hg (dissolved), ppb	Removal,%
Unfiltered	NA	6±2	NA
Unfiltered+100 ppb	1	16	84
Unfiltered+100 ppb	2	<2	98
Unfiltered+100 ppb	4	<2	98

Summary

1. Dissolved ionic mercury can be efficiently removed by electrogenerated stannous ion from both unfiltered and settled FGD blowdown wastewater in batch and flow manner.

2. Dissolved mercury remediation process is fast and applicable and can be complete within 30 minutes or less.

3. No sample preparation, such as pH, ORP adjustment is required to achieve high mercury removal efficiency.

Appendix A:

Potential SafeGuard™ H2O system implementations for power industry

Figure 4: SafeGuard H2O™ treatment system implementations: FGD blowdown (A); coal ash ponds (B)