Defining the Mercury (Hg) Transport Story: Impacts of Legacy Gold Mining in the Burdekin River Catchment, Queensland Australia

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Introduction

The fate, cycling and dispersion of mercury (Hg) within aquatic ecosystems is complex. Mercury (Hg), is a toxic heavy metal and at even low concentrations can pose a threat to biota. The methylation of Hg (CH_3Hg) by sulfate-reducing bacteria allows for Hg to bio-magnify across food chains, accumulate in top predators and subsequently pose a risk to human health. Over 15,000 abandoned (legacy) mine sites reside within Queensland and of these, legacy gold mine sites are primarily located in the Burdekin catchment. Legacy gold mine sites can act as a potential sources Hg released into the environment. Historically, mercury was used as an amalgam in the gold extraction process. Site spoils are often located next to major waterways and tributaries that discharge into the river system. Next to the Murray Darling, the Burdekin River is the second largest catchment in Australia (area of 130,120 km^2) and the single largest source of suspended sediment to the Great Barrier Reef system (GBR), discharging approximately 9234 gigalitres to coastal waters annually. Yearly flood events transport finer suspended sediments downstream, spilling over the Burdekin Falls Dam and out to the GBR, with plumes reaching as far as 500 km north to Cooktown. This study is a collaborative initiative between the UQ and QHFSS that intends to investigate the transport and extent of Hg contamination within the Burdekin River system from abandoned gold mines. By applying a novel Hg DGT sampling approach coupled with highly sensitive analytical tools to examine Hg at low concentrations mechanisms for Hg dispersion within the catchment system can be defined. The following provides a brief overview of the study's progress to date.

Aims & Objectives

The aim of this study is to determine the significance of Hg concentrations in the Burdekin catchment and investigate the potential for legacy mine sites to contribute to Hg contamination.

Objectives

(1) To validate and compare Hg concentrations from 2019 with previous samples collected in 2016 and 2018
(2) Evaluate flooding events, seasonality, and timing of sample collection on Hg dispersion within the Burdekin
(3) Apply a risk assessment approach (ANZG, 2018) and evaluate potential risks to the aquatic and human health

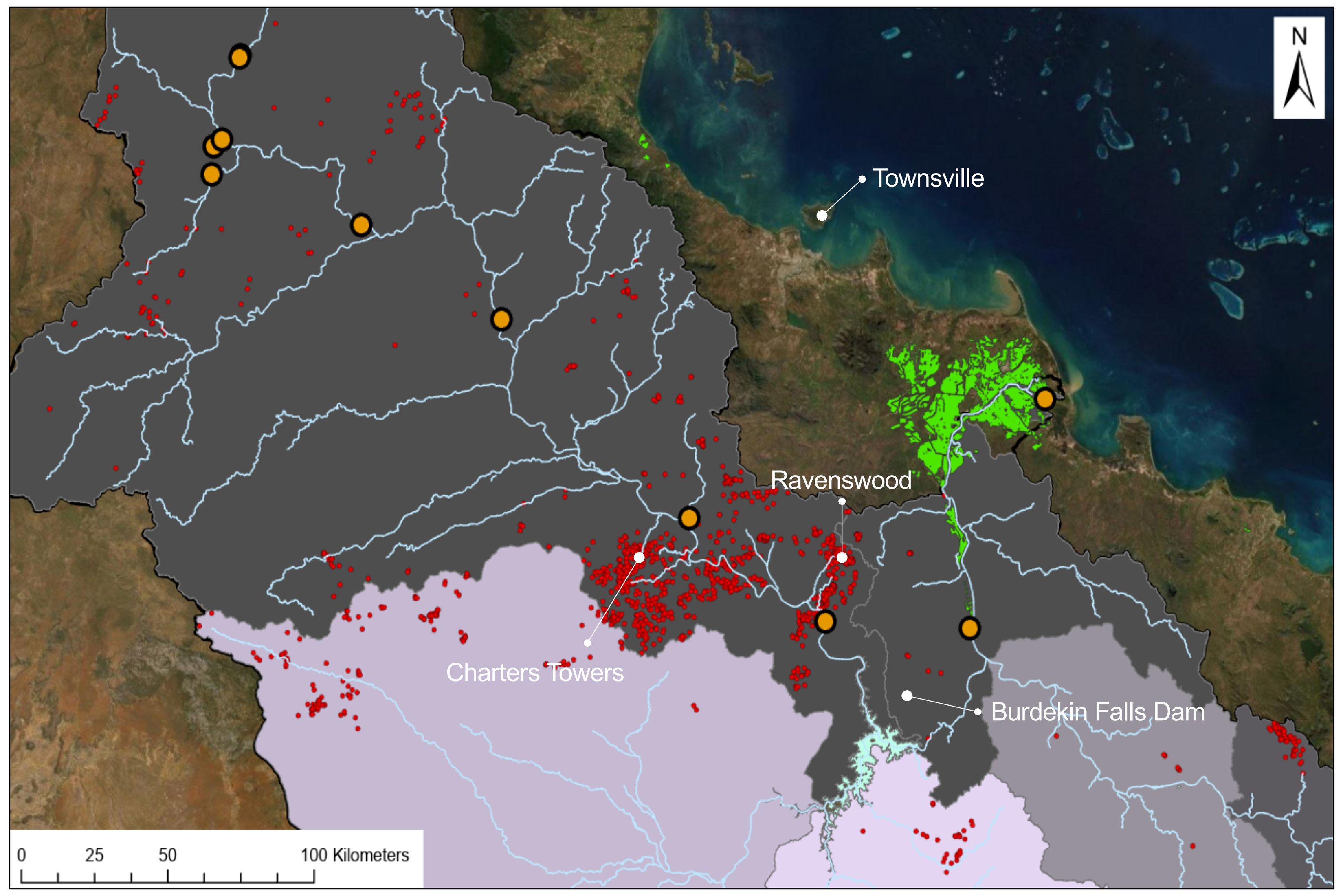

Figure 1: 2019 sample collection locations in the upper and lower Burdekin catchment (yellow points). The figure demonstrates major tributaries of the Burdekin River system, legacy gold mine sites (red) and sugar cane (120 km^2) (green area). Note that organo-mercury fungicides such as Shirtan were applied to sugarcane roots to prevent root rot until its removal in 2020. The use of these fungicides allow sugar cane areas to act as an additional point source of Hg release into the Burdekin.

Methods

Sample site selection is based on the location of historical gold mining operations. Water (250 mL < 0.45μm filtered and 500 mL unfiltered samples), (800g) sediment and Diffusive Gradients Thin Films (DGT) samples (total of 18 from 6 sites) were collected in November 2019. At low concentrations in water the Hg DGT can measure Hg that is truly in solution (Figure 3). Hg absorbs onto the binding gel in the DGT representing Hg concentrations that are in the labile size fraction (<10 nm) and accumulates over the period of DGT installment (3-4 days) (Figure 3 & 4) . Post deployment of the binding gel is carefully removed and analyzed for Hg in the laboratory.

Laboratory analysis utilizes the Agilent 8800 ICP-QQQ instrument at the QHFSS laboratory to analyze for (1) lead isotopes, (2) heavy metals, and (3) rare earth elements in water and sediment digests. This particular model of the ICP-MS instrument is designed to detect low concentrations and can minimise interreferences when analyzing complex sample matrixes such as in saline or seawater samples. Standard water analysis, and sediment will also be analyzed for organic carbon, % moisture, particle size distribution, Hg and methyl-mercury (CH_3Hg). These sample techniques were chosen due to the Hg DGT's ability to sample in-situ concentrations of Hg and subsequent measurement over a given time period using the ICP-MS enhanced ability to detect low concentration values, which are expected for this study.

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Figure 2: On the left the Lake Dalrymple, held in by the dam is depicted in the dry season and on the right in the wet season, where fine suspended sediments overflow the Dam wall. Lake Dalrymple has the storage capacity of 1,860,000 ML (equivalent to 4 times the volume of the Sydney Harbour) Figures are retrieved from ABC, 2019.

To Date, no one has used Hg DGT's to measure Hg contamination in the Burdekin and used Pb isotopes coupled with Hg DGT to pinpoint the source for Hg contamination.

Expected Outcomes & Significance

Significance:

To date, no research study has used DGT's to measure Hg concentrations and used Pb isotopes coupled with Hg DGT to pinpoint the source for Hg contamination in the Burdekin River. An important outcome of this project is the development and application of this methodology. The study provides an additional foundation to validating a new approach for investigating heavy metal contaminants such as Hg at low concentrations.

Expected Outcomes:

(1) The goal is for this approach to be used by government or private sector organizations that aim to quantify the impact of a contaminant in a river system.
(2) Using Hg as a model, this project sets a president for future applications of measuring other toxic heavy metals or contaminants.

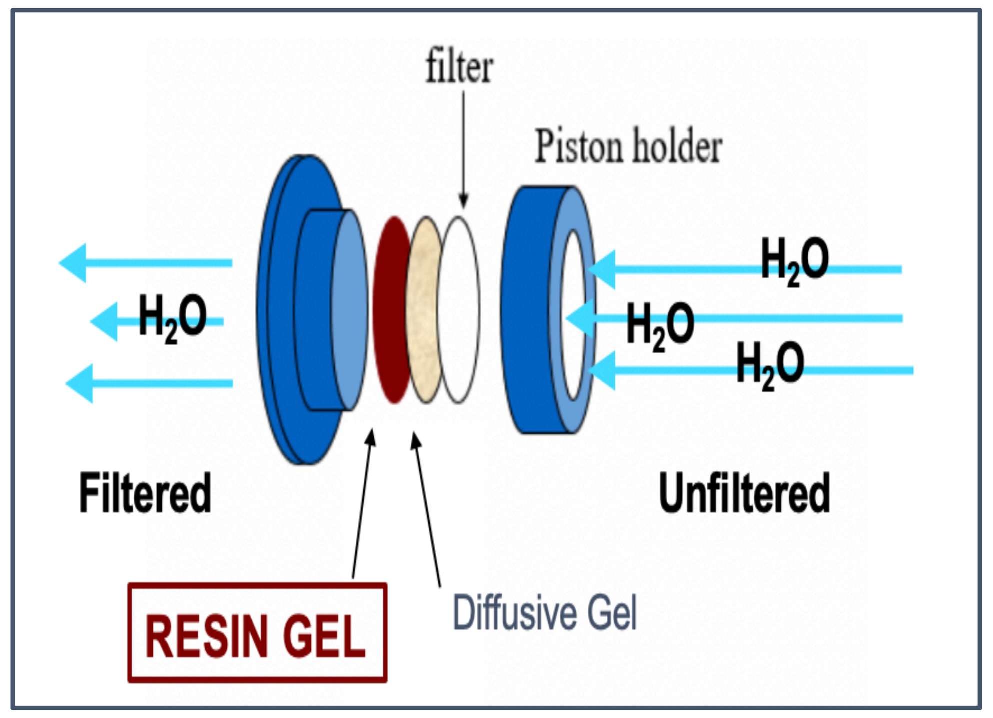

Figure 3:DGt schematic depicting the process by which Hg is collected. Water enters through a membrane which separates out major particulate matter. It is than further filtered through a diffusive gel, reducing the presence of colloids and other undissolved matter. Major Hg compounds that are in the labile size fraction are absorbed onto a thiol resin gel.

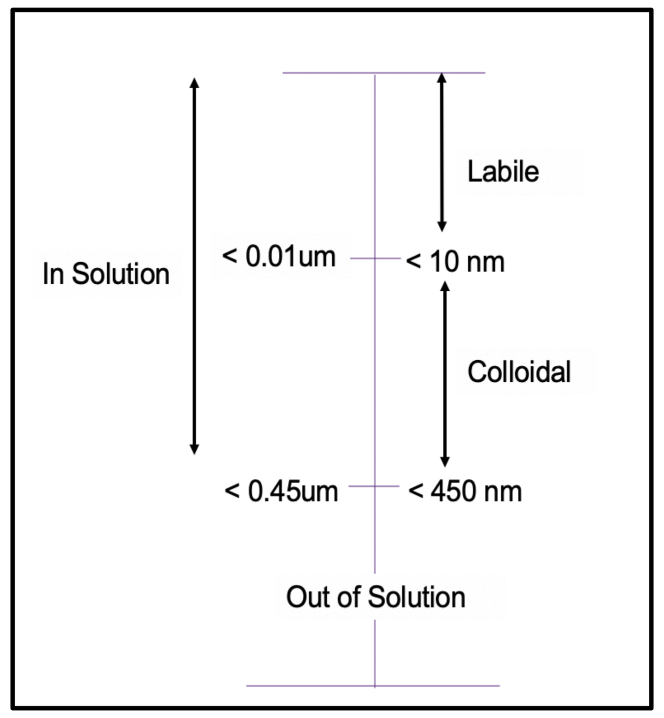

Figure 4: Schematic identifying size fraction ranges in solution.

Figure 5: Depiction of DGT deployment strategy.

Figure 6: Example of DGT sample site, captured 26 November 2019

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