Marine Pollution Bulletin 73 (2013) 306–313

Contents lists available at SciVerse ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

# Trace metals associated with deep-sea tailings placement at the Batu Hijau copper–gold mine, Sumbawa, Indonesia

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ARTICLE INFO

*Keywords:*
Copper
Arsenic
Mercury
Deep sea tailings placement

ABSTRACT

The Batu Hijau copper–gold mine on the island of Sumbawa, Indonesia operates a deep-sea tailings placement (DSTP) facility to dispose of the tailings within the offshore Senunu Canyon. The concentrations of trace metals in tailings, waters, and sediments from locations in the vicinity of the DSTP were determined during surveys in 2004 and 2009. In coastal and deep seawater samples from Alas Strait and the South Coast of Sumbawa, the dissolved concentrations of Ag, As, Cd, Cr, Hg, Pb and Zn were in the sub μg/L range. Dissolved copper concentrations ranged from 0.05 to 0.65 μg/L for all depths at these sites. Dissolved copper concentrations were the highest in the bottom-water from within the tailings plume inside Senunu Canyon, with up to 6.5 μg Cu/L measured in close proximity to the tailings discharge. In general, the concentrations of dissolved and particulate metals were similar in 2004 and 2009.



## 1. Introduction

The Batu Hijau copper–gold mine is located on the southwest corner of the island of Sumbawa in the province of West Nusa Tenggara, Indonesia (Fig. 1). The mine is operated by PT Newmont Nusa Tenggara (PTNNT) and processes ore at a rate of approximately 130,000 t/d. The open-pit mine is at an elevation of 450 m above sea level. Crushed ore is processed through a grinding circuit and flotation-based concentrator for copper and gold extraction. The tailings slurry from the operation consists of finely ground rock that is disposed of by a deep-sea tailings placement (DSTP) facility. This method of disposal was determined to have several advantages over on-land disposal and was approved by the Government of Indonesia (ANDAL, 1996). The tailings, which typically comprise approximately 60% solids, are conveyed by gravity in a pipeline from the process plant to the outfall discharge point at the head of a steep submarine canyon (the Senunu Canyon) located 3.2 km off shore at 110 m depth. From the point of discharge, the tailings, flow down the steep off-shore canyon as a bottom-attached density current and are ultimately deposited in the deep oceans at depths in excess of 3000 m.

The use of DSTP for mining operations is not uncommon in Indo-Pacific archipelagic nations, and has also been used by mines in the northern hemisphere (Apte and Kwong, 2004; Jones and Ellis 1995; Poling et al., 2002; SAMS, 2010) (Supplementary Table S1). The existing DSTP facilities of PTNNT deposit tailings at depths of between 1000 and 3000 m, which are considerably deeper than a number of past marine disposal operations that have deposited at depths of between 80 and 500 m (e.g. Island Copper, Kitsault – Canada; Atlas Copper – Philippines; Black Angel – Greenland; Minahasa Raya – Indonesia). The justification for selecting DSTP for tailings management is usually based on the challenges in maintaining on-land tailings storage facilities in high rainfall, mountainous and seismically active terrain and the proximity to deep oceanic canyons. The DSTPs are engineered to ensure that tailings density, seabed gradients and oceanographic currents and upwelling characteristics at the pipeline exit point minimise material rising into the surface waters. The Batu Hijau copper/gold mine is one of the larger examples of DSTP in the world and deposits tailings at the greatest depth.

The discharged tailings slurry contains elevated concentrations of a range of metals that have the potential to impact on the marine environment. However, the dilution in the receiving environment is predicted to result in concentrations being below those predicted to cause effects to aquatic biota (ANZECC/ARMCANZ, 2000). The present study investigated the water-borne and benthic sediment metal concentrations in Senunu Canyon, the South Coast of Sumbawa Island, and Alas Strait, which separates Sumbawa and Lombok Islands. Depth profile sampling was performed at a range of locations to allow comparison of dissolved metals near the discharge point with those in the surrounding environment and with internationally accepted water quality guidelines.

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0025-326X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpolbul.2013.04.013

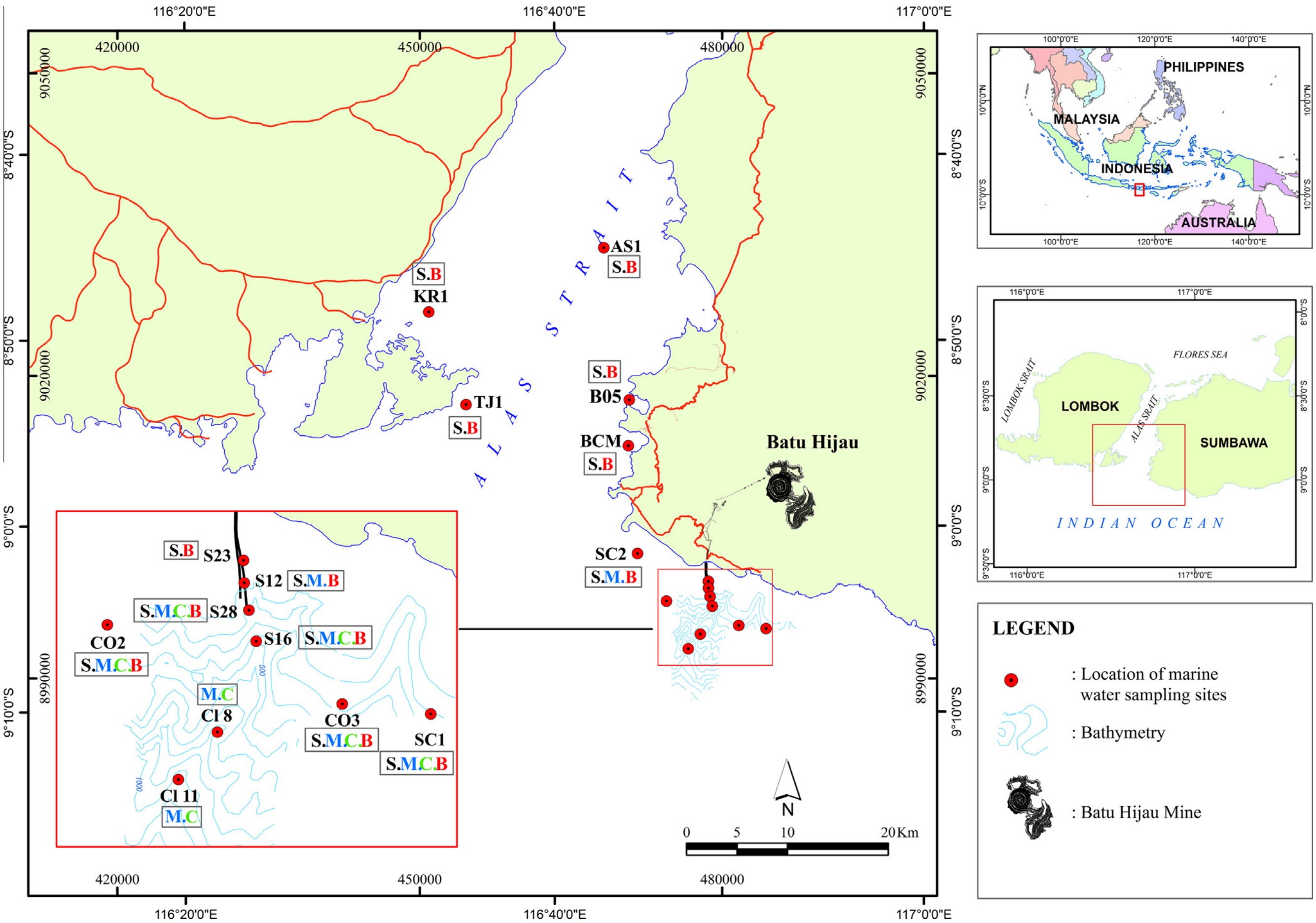


**Fig. 1.** Location of the sampling sites in the water off Sumbawa Island, Indonesia.

## 2. Methods

### 2.1. Field site

This study involved two water sampling surveys undertaken in October 2004 and April 2009 in the area shown in Fig. 1. The study area included five reference sites in Alas Strait, between the islands of Sumbawa and Lombok, that were sufficiently distant (20–40 km) to not be impacted by the DSTP. There were twelve sites on the south-western side of Sumbawa, within 4–8 km of the DSTP, and six sites in the Senunu Canyon (sites with code "S") within 1.5 km of the DSTP.

### 2.2. Water sample collection and treatment

High purity deionised water (18 MΩ/cm, Milli-Q, Millipore) was used in all equipment washing procedures and for the preparation of metal standards. One-litre low-density polyethylene (LDPE) (Nalgene) bottles were used for sampling waters for all metals other than mercury and 1-L fluorinated ethylene propylene (FEP) (Nalgene) bottles were used for sampling waters for mercury analyses. The LDPE bottles were cleaned rigorously before use, using a three-stage sequential washing procedure. This involved soaking bottles and caps in 2% detergent solution (Extran) for at least 2 h, then soaking in 10% $HNO_3$ (Merck, Analytical Reagent grade) for at least 24 h, and then soaking in 1% high purity nitric acid (Merck Tracepur) for at least 48 h, with at least five rinses with Milli-Q water between each step. The 1-L FEP bottles were cleaned by soaking in 50% analytical grade (AR) nitric acid for 48 h, and then soaking in 10% ultra-pure grade hydrochloric acid (Merck Tracepur) for at least 72 h, and then soaked in Milli-Q water for at least 48 h, with at least five rinses with Milli-Q water, between each step. Each bottle was stored inside two polyethylene sealable bags for transport to and from the field.

Samples were collected from between 2 and 4 depths at each site using acid-washed (10% $HNO_3$ v/v) Niskin® samplers. The Niskin® was suspended at the sample depths of 3, 50, and 120 m below the surface and approximately 10 m above the sea floor (varied depending on site) for approximately 10 min to rinse the sampler with sample before triggering the device to obtain the sample. Ultratrace sampling techniques were employed in the field similar to those described by Ahlers et al. (1990). Two people were involved in the sampling operation and both wore powderless vinyl gloves (Bioclean 100, Nitritex Ltd). One person operated the Niskin sampler by releasing the pressure valve and releasing the tap to dispense the sample. The second person handled the LDPE and FEP bottles, which involved removing bottles from zip-lock bags, removing the lids and filling with the sample that was dispensed from the Niskin sampler, closing the lid, and replacing the bottle back into two zip-lock bags. For purposes of quality assurance/quality control (QA/QC) during sampling of waters, at least 10% site duplicates and 10% field blanks (air blanks) were collected.

Following collection, samples were stored in ice-filled cooler boxes until return to the laboratory. The samples were then filtered (Angel et al., 2010a; Hatje et al., 2003) within 8 h of collection using acid-washed (10% $HNO_3$, Tracepur, 24 h) polycarbonate filter