Assessment of Young Dong tributary and Imgok Creek impacted by Young Dong coal mine, South Korea

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Introduction

The Young Dong coal mine site is located in northeastern South Korea, close to the city of Samcheok. It ceased operation in 1995 and remediation was done on the site to stabilize waste piles and route water through the site. The remediation mainly focused on stabilizing a site that has considerably steep slopes with an overall elevation gain of approximately 100 m. An attempt to treat acid rock drainage (ARD) from the adit was made by filling the adit with a large amount of limestone and constructing a concrete bulkhead at the opening. However, water issuing from the adit is still considered ARD in that it contains extensive mineral acidity in the form of dissolved iron and aluminum. In addition to the challenges of the steep terrain and high mineral acidity, treatment options are limited by the fact that the quantity of flow from the adit is highly variable over the seasons and sometimes reaches 2.0 cubic meters per min (m^3/min). The Young Dong tributary flows into Imgok Creek, and it is one of the most highly ARD impacted streams in Korea, with the major ARD source being the Young Dong tributary (Yu and Heo 2001). The primary impact is an elevated level of iron in the stream water, which results in substantial deposition of iron hydroxide and other precipitates downstream of the confluence of

Imgok Creek and the Young Dong tributary (Kim and Chon 2001). The most abundant precipitate in Imgok Creek was identified as schwertmannite (Yu et al. 1999). The most significant consequence of these deposits is the obvious polluted appearance of the stream, which is of great concern to the local population. It was not clear whether elevated levels of toxic metals such as Zn, Cd, Cu, Ni, and Pb are present in the precipitates and the degree to which they impact the aquatic ecosystem of Imgok Creek. A better understanding of the current chemical conditions of the Young Dong/Imgok Creek tributary is needed to design the size and remediation process that will be successful in improving water quality in Imgok Creek.

The objectives of this paper are to report on the findings from a preliminary site assessment of the water and sediment chemistry of the confluence of the Young Dong tributary and Imgok Creek. ARD and sediments in the Young Dong tributary were examined to estimate metals loads in the Young Dong Tributary and to evaluate existing downstream impacts on Imgok Creek water quality. Sediments were sampled and subjected to water-based leaching procedures (Wildeman et al. 2007) to evaluate potential impacts on water quality following remediation due to the release of sediment-associated metals by re-suspension, dissolution, and/or desorption. The potential for pos-remediation stream contamination by existing sediments will determine how quickly Imgok Creek will recover following remediation of the Young Dong site.

Water quality considerations

In order to evaluate the impact of the Young Dong coal mine, the measured water quality must be compared to some benchmarks. We have chosen to use the Korean Water Quality Criteria (KWQC) as primary benchmarks (Korean Ministry of Environment 2010) for both water collected from the site and leachate from the water extractions of the sediments. Different KWQC are recommended in order to protect either human or ecosystem health. There are considerable differences in the levels of target elements that depend on these two different objectives of KWQC. It is, therefore, necessary to consider the principal aims of the recommendations prior to discussion of the site-specific results. KWQC for inorganic elements related to freshwater or mine drainage are shown in Table 1. KWQC are structured by the type or usage of water. The main purpose of KWQC is to protect human health and the ‘‘drinking water’’ KWQC represents the lowest concentration of target elements in the media. Although this provides a benchmark for comparison, the unlikely use of Young Dong water as a drinking water source makes it more stringent than necessary. The ‘‘stream’’ KWQC is also implemented to protect human health and has a shorter list of inorganic elements. The ‘‘discharge’’ KWQC, with the highest pollutant discharge permission levels, is for discharge from mine adits located in otherwise clean areas. For this KWQC, discharge water includes any water that comes out of any facilities for water treatment. Two additional benchmarks are given in Table 1, the first being USEPA criteria to protect aquatic life (US Environmental Protection Agency 1986). These levels have been established on the basis of available acute or chronic aquatic toxicity data for the pollutants, and the value given is that for water with a hardness of 100 mg $CaCO_3$/l. Thus, meeting these levels should result in a safe and sustainable aquatic environment for biota. Finally, Table 1 includes the USEPA standards (US Environmental Protection Agency 2002) established by the Resource Conservation and Recovery Act (RCRA), which are given for the concentration of metals in leachate produced by the Toxic Characteristic Leaching Procedure (TCLP; EPA Method 1311). Exceeding these criteria will result in the classification of the waste as hazardous and will require special disposal procedures. This benchmark was chosen as a ‘‘worst case’’ for classifying the sediments collected from the site. In the respect that Korea is in the process of changing from human health to aquatic toxicity KWQC in streams, the comparison between the numerical standards used in the two countries will be made in the discussion. One significant difference between the more stringent Korean and USA criteria stand outs; Cu and Zn are much lower in USA aquatic life standards than in Korean drinking water standards.

Materials and methods

In March 2008, an extensive sampling event at the Young Dong area was conducted. Water was collected at twenty-two sites including the adit, eighteen sites along the Young Dong tributary, and three sites on Imgok Creek. Subsequently, over the next 5 months, follow-up sampling trips to make field measurements and to collect water samples were made. During the March 2008 sampling, sediments were collected at four of the sampling sites. The focus of this paper is to report on the impact of the Young Dong tributary on Imgok Creek and therefore results are only given for water samples for five key sites, and sediments chemistry for the Imgok Creek site directly below the confluence (Fig. 1). Details and results of all sampling events are contained in a report to MIRECO (Wildeman et al. 2008).

Water sample collection

Water samples were grab-samples collected according to the methods practiced by the United States Geological Survey (Shelton 1994). Samples were filtered on a site into polypropylene 50 ml test tubes (VWR Scientific), using 0.45 micron filters (Millipore Supor) and were acidified to below pH 2.0 using nitric acid (Fisher Trace metal grade). Elemental analysis was performed using inductively coupled plasma-atomic emission spectrometry_(ICP-AES, Perkin Elmer, ICP-OES 3000) analysis. Conversion of the S data to sulfate (SO_4) is accomplished by multiplying the value by 3 (the ratio of 32:96). Sample alkalinity was determined by titration with dilute sulfuric acid to the Bromcreosol Green/Phenyl Red end point using a digital titrator (HACH). Sample pH was determined on site using field portable pH meters that were calibrated on site using pH 4 and 7 buffers. Results are only given for water samples collected at the same time and location as the sediments samples.

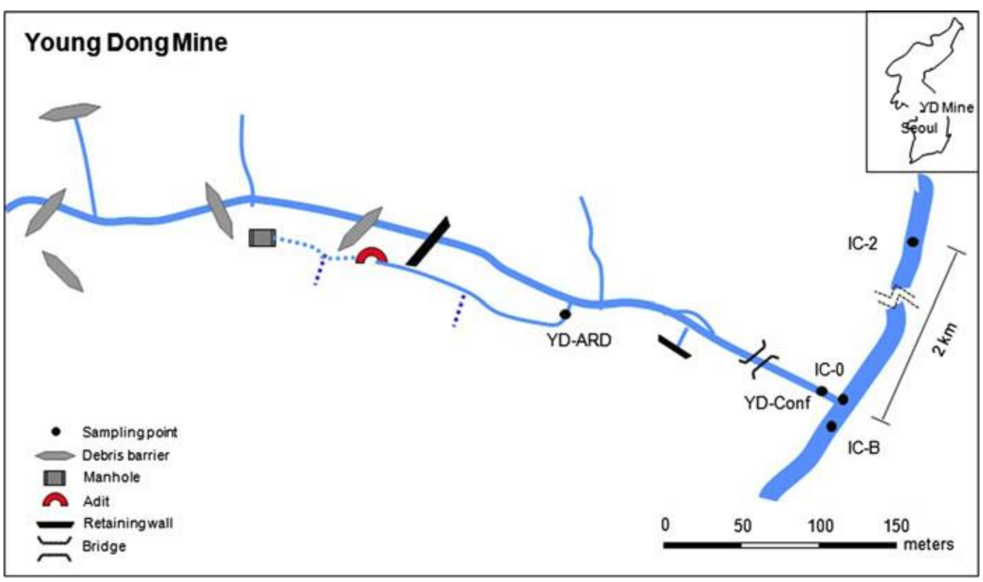

Fig. 1 Sampling map for sites near the mine site on the Young Dong tributary of Imgok Creek

Sediment sampling and analysis

During the March 2008 sampling event, sediments were taken at the Young Dong tributary and Imgok Creek using the composite method developed by Smith et al. (2000). This composite sample was prepared by taking small scoops of sediment using 250 ml plastic beakers and combining them in a single large plastic bucket. At least 30 samples were taken per composite over a 10–50 meter reach of stream. Sediment samples were taken in four locations:

1. IC-B, on the Imgok Creek just before the confluence of Young Dong tributary (background site)
2. IC-0, on Imgok Creek just below the junction with the Young Dong outflow,
3. YD-ARD, on the channel that conveys the ARD to the main Young Dong tributary,
4. YD-Conf, on the Young Dong tributary just before it discharges into Imgok Creek.

All sediments were wet sieved in the field to below 10 mesh. Prior to further processing, they were airdried at room temperature for 1 week at the laboratory. After dryness, sediment subsamples were leached by several methods described in the following section.

The three different test methods used to evaluate the leaching potential of metals from the sediments are summarized in Table 2 (Hageman and Briggs 2000; Hageman et al. 2005). The first two tests are based on extraction with deionized water and have been developed by Colorado School of Mines (CSM) and the US Geological Survey (USGS) to provide simple and inexpensive methods to assess mine wastes (Wildeman et al. 2003, 2007). Hageman et al. (2005)

found that the major source of variation in leaching results arises in the sampling of heterogeneous waste piles, even though the recommended 30 sample composite method of sampling was used (Smith et al. 2000). The third test is a modification of the EPA Toxicity Characteristic Leaching Procedure (TCLP) (EPA Procedure 1311) and is also used because it closely resembles the sequential leaching step that releases carbonate minerals (Tessier et al. 1979; US Environmental Protection Agency 2002). Because the Colorado Division of Minerals and Geology (CDMG) uses a higher ratio of solids to water and is a longer leaching procedure than the US Geological Survey Field Leach Test (USGS-FLT), the concentrations of leached constituents are usually higher. Samples were also acid digested using aqua regia for total elemental content. After 0.45 lm filtration, all leachate samples were acidified with nitric acid and then analyzed by ICP-AES.