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Hydrogen cyanide in ambient air near a gold heap leach field: Measured vs. modeled concentrations

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Abstract

To extract gold from low-grade ores, a solution of sodium cyanide is trickled over pads of crushed ore. During this operation, small quantities of hydrogen cyanide gas may escape to the ambient air. To assess these emissions, we collected air samples at monitoring stations located on opposite sides of a gold heap leach field at distances ranging from 1100 to 1500 ft from the center of the field. Hydrogen cyanide was detected in 6 of 18 ambient air samples at concentrations ranging from 0.26 to 1.86 parts per billion (ppb). Ambient air samples collected at residential properties located within 2600 ft of the leach field did not contain detectable concentrations of cyanide (detection level of 0.2 ppb). We used site-specific data and two steady-state air dispersion models, ISCST3 and AERMOD, to predict ambient air concentrations of cyanide at the sampling points. The ISCST3 model over-predicted the measured 8-h concentrations of hydrogen cyanide by a factor of 2.4, on average, and the AERMOD model under-predicted the air concentrations of hydrogen cyanide by a factor of 0.76, on average. The major sources of uncertainty in the model predictions were the complex terrain of the area and the uncertainty in the emission rates of cyanide from the leach field. The measured and predicted concentrations of cyanide in the air samples were not at levels that would pose a human health hazard for acute or chronic exposures. Published by Elsevier Ltd.

Keywords: Air monitoring; ISCST3; AERMOD

1. Introduction

In the United States, cyanide heap leaching is the most commonly used method of extracting gold and other precious metals from low-grade ores (USEPA, 1994a; USDOE, 2002). Crushed ore is piled on an impervious geosynthetic liner. An alkaline solution (pH 9–11) of sodium cyanide is then trickled over the surface of the leach pad using agricultural drip irrigation tubes. As the cyanide solution percolates through the crushed rock, the cyanide forms a soluble complex with the gold. The pregnant solution is collected at the bottom of the leach pad and treated to recover the gold. Following rejuvenation, the solution is reused for additional gold extraction.

The pH of the leaching solution is optimally maintained at pH 10.5 to maintain the cyanide in an anionic form. However, small amounts of hydrogen cyanide may be formed as the result of reactions between the cyanide solution and mineral acids in the ore and carbon dioxide in air. To investigate the

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public health impact of these hydrogen cyanide emissions, we measured the concentrations of hydrogen cyanide in ambient air near an active heap leach field. The facility was a gold mining and cyanide heap leach operation in Colorado. We measured ambient air concentrations of cyanide near the leach field and on residential properties located about $\frac{1}{2}$-mile from the leach field.

In addition, we used two air dispersion models to predict ambient air concentrations of hydrogen cyanide for the time periods the samples were collected. The results predicted by the air dispersion models were compared to the analytically measured concentrations.

2. Methods

2.1. Air sampling and analysis

Ambient air samples were collected at five locations as depicted in Fig. 1: (1) 1200 ft northwest of the leach field [NW-1], (2) 1100 ft southeast of the leach field [SE-1], (3) 1490 ft southeast of the leach field [SE-2], and (4) at two residential properties on the edge of the nearby town [RES-1 and RES-2]. These private residences were located about 2600 ft southeast of the leach field. The distances were measured from the monitoring station to the center of the leach field. The exact locations of the sampling points were determined using a Global Positioning System (GeoExplorer 3®; Trimble, Sunnyvale, CA). At the time of the sampling, the predominant wind directions were crosswind or upwind to sampling station NW-1, and crosswind or downwind to the other sampling stations (Fig. 2).

We collected air samples for six consecutive 8-h periods over a 2-day period using a personal sampling pump that operated at a flow rate of about $1\,L\,min^{-1}$. Before and after each sampling event, we measured the airflow rate through the collection apparatus using a primary standard meter (Gilian Gilbrator®; Sensidyne, Clearwater, FL). The sampling pump was connected to an impinger apparatus containing 15 ml of 0.1 N potassium hydroxide (KOH) to trap the cyanide (NIOSH Method 7904) (NIOSH, 1994). The intake port on the impinger was attached to a tripod stand about 3-ft above ground level.

At the end of an 8-h sampling period, the KOH solution in the impinger was transferred to a glass vial. The impinger was rinsed with 2 ml of 0.1 N KOH, and the rinsate was added to the sample vial. The samples were sent by overnight mail to DataChem Laboratories (Salt Lake City, UT) for analysis. The laboratory analyzed the samples using NIOSH Method 6010 (NIOSH, 1994). In this method, cyanide reacts with a barbituric acid-pyridine reagent to produce a reaction product that is measured spectrophotometrically. The detection level for cyanide in the air samples was about 0.2 parts per billion (ppb). No cyanide was detected in the field blank samples collected at the sampling locations. The cyanide concentrations in the air samples are reported as parts per billion (ppb) hydrogen cyanide ($1\,ppb = 1.12\,\mu g\,m^{-3}$).

Before testing, we obtained the written, informed consent of the owners of the private residences, as well as that of the facility management where we conducted the air monitoring.

2.2. Air modeling

To predict the concentrations of hydrogen cyanide at the monitoring points, we used two air dispersion models, ISCST3 and AERMOD. The ISCST3 model was run with a commercial interface, ISC-AERMOD View (Version 4.8.5) (Lakes Environmental Software; Waterloo, Ontario, Canada). AERMOD was developed as a next-generation model to ISCST3, and it incorporates more complex algorithms and concepts, such as planetary boundary layer theory, and advanced methods for handling complex terrain.

Both of the models are steady-state, plume dispersion models that were developed for the U.S. Environmental Protection Agency (EPA) to support regulatory air modeling programs. These models were specifically developed to simulate air pollution resulting from emissions from industrial sources. The models can simulate the impact of an areal source of contaminant release, such as emissions from a heap leach field. The models use meteorological data averaged over 1-h periods of time to estimate 1-h steady-state concentrations of air contaminants.

A meteorological station located 1800 ft south of the heap leach field supplied local meteorological data for the models. Ambient air temperatures during the sampling period (October 2000) ranged from 40 to 58°F. Winds were variable, and the average hourly wind speed varied from 5 to 19 $miles\,h^{-1}$. No precipitation fell during the sampling periods. Meteorological data from the Denver Stapelton International Airport for upper atmospheric