

Technical Note
Cyanide destruction: full-scale operation at Ovacik gold mine

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ABSTRACT

The Ovacik Gold Mine is the first gold mine using the cyanide leaching method in Turkey and has been operating since early June, 2001. The process plant comprises a conventional carbon-in-pulp (CIP) process with a treatment capacity of 300,000tpy ore. Sodium cyanide consumption is approximately 0.5kg/t ore treated. Process tailings are treated in a three-stage chemical destruction circuit using the Inco SO₂/AIR process before being discharged to a lined tailings pond in order to achieve the limits for cyanide and heavy metals set by the Turkish Ministry of Environment. The limit for cyanide in the chemical destruction effluent is 1mg/l, as weak acid dissociable (WAD) cyanide. The circuit was commissioned successfully, under the control of Inco experts, and has since been operating in compliance with all the regulatory environmental requirements. © 2003 SDU. All rights reserved.

Keywords: Cyanide; Gold; Chemical destruction; Tailings pond; Environment

1. INTRODUCTION

The Ovacik Gold Mine is owned by Normandy Madencilik A.S., the Turkish subsidiary of Normandy Mining Limited of Australia. The mine is located about 110km north of Izmir near the west coast of Turkey, some 15km inland from the Aegean Sea.

After obtaining final permits from the Turkish regulatory departments, construction of the process plant, tailings pond and associated infrastructure was started in September 1996 and completed in December 1997. However, the full commissioning of the plant and the chemical destruction circuit was not implemented until June 2001 due to legal issues with the local environmental groups and further thorough review of environmental measures and permit requirements. On behalf of the government, the Turkish Scientific and Technical Research Organisation (TUBITAK) was involved in the review.

A conventional CIP process which utilizes sodium cyanide to extract gold is used at Ovacik. This is the most common process currently used for gold extraction worldwide (McNulty, 2001). After recovery of the gold, the tailings are treated in a three-stage chemical destruction circuit to reduce the concentration of residual cyanide and heavy metals in the effluent tailings stream to the limits set by the Ministry of Environment. The Inco SO₂/AIR cyanide destruction process is used in the first stage to destroy WAD cyanide, while in the second stage heavy metals such as arsenic and antimony are precipitated with ferric. Iron cyanide complexes are precipitated with copper. An independent third stage provides treatment of decant water from the tailings pond for further metal precipitation.

The Inco SO₂/AIR process was selected for Ovacik because of its wide application for slurry treatment and advantages over other methods (Akcil, 2001, 2002, 2003c; Smith and Mudder, 1991; Mudder, 2001; Mudder et al., 2001; Mudder, 1999; Botz, 2001). The process has predominantly been applied to the mining industry and mostly to the treatment of leach tailings slurries. It has been used to destroy cyanide in the tailings of precious metal mines at approximately 80 sites in some 20 countries worldwide. Development and operational benefits of the process are presented by Robbins (1996) and Devuyst et al. (1991).

The Ovacik Gold Mine is the first gold mine in Turkey using cyanide leaching and the Inco cyanide destruction process. As part of Normandy's employment commitment, the mine has recruited local inexperienced operators, unfamiliar with the mine and plant environment. Therefore, experienced

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supervisors were brought to the site from other Normandy mines to train the operators during commissioning. The chemical destruction circuit was also commissioned and operated with 24 hour coverage by Inco experts until local operators were trained and fully competent.

The limits for cyanide and heavy metals set by the Ministry of Environment are given in table 1.

Table 1
Ministry of environment limits for Ovacik tailings

Element	Limit (mg/l)*
CN _{WAD}	1
Cd	1
Zn	5
Cu	5
Pb	2
As	5
Sb	5
Fe	10
Total Cr	2
Hg	0.1

* The cyanide limit is for the chemical destruction effluent before discharge to the tailings pond. Metal limits are for the tailings pond.

The quality of the tailings is checked daily by independent sampling and analysis, by the local health department, in addition to the monitoring program carried out by the mine environmental and production departments.

2. THE INCO SO₂/AIR CYANIDE DESTRUCTION PROCESS

The Inco SO₂/AIR cyanide destruction process uses a mixture of sulphur dioxide and oxygen, in the presence of soluble copper catalyst, to oxidize free cyanide (CN⁻) to cyanate (CNO⁻) as follows:



Sulphuric acid generated during cyanide oxidation is neutralized with lime in the circuit to form gypsum, as follows:



Cyanide weakly complexed with metals such as copper, zinc and nickel are decomposed to free cyanide and metal ions. Once freed of the cyanide, the metals are precipitated as metal hydroxides while liberated free cyanide is oxidized to cyanate according to the reaction (1).

The cyanide strongly complexed with iron is precipitated as an insoluble ferrocyanide salt by the process. The ferrocyanide forms insoluble metallo-ferrocyanide complexes with available metal ions, as follows:



The cyanate ion (CNO⁻) is not stable and slowly hydrolyses to ammonium and carbonate, as follows:



Gaseous or liquid sulphur dioxide, or soluble sulphite or bisulphite may be used to supply sulphur dioxide. The oxygen requirement of the process is normally supplied by adding large volumes of air. The copper catalyst is provided by copper sulphate addition if it is not already present in the feed solution. The pH range for cyanide destruction is typically 8.0 to 9.5 and is normally controlled by lime or caustic addition.

3. PROCESS DESIGN

Normandy Madencilik engaged Inco Technical Services Ltd. of Canada in 1993 to investigate the suitability of the Inco process for treatment of Ovacik tailings, to achieve the Ministry of Environment criteria. Cyanide destruction and metal precipitation test work was carried out on representative Ovacik ore samples at Inco's principal research laboratory in Canada. The samples were first subjected to cyanide leaching and carbon adsorption tests to obtain representative tailings samples and then treated to achieve a total cyanide of less than 1mg/l. A residual level of less than 0.1mg/l arsenic, and less than 5mg/l antimony, was targeted in compliance with the Ministry requirements.

Test results can be summarized as follows:

- The Inco SO₂/AIR process was successful in achieving the Ministry limits.
- A two-stage tailings treatment was recommended: cyanide destruction in the first stage and arsenic and antimony precipitation in the second stage.
- Additional copper was required to provide the catalyst necessary for the Inco process and to ensure precipitation of the iron cyanide present in the feed solution.
- An optimum pH was maintained with lime or sodium hydroxide.
- An independent third stage for additional antimony removal from tailings return water was recommended.
- The treated slurry continued to post react resulting in a further improvement in effluent quality, therefore, it is expected that any residual cyanide contained in the discharged tailings will be further reduced in the tailings pond.

The flow diagram of the Ovacik chemical destruction circuit is shown on Figure 1.

The chemical destruction circuit was designed to destroy 8.4kg/hr of cyanide in a tailings stream composed of 45% solids (by wt%) and flowing at a rate of 60m³/hr. The slurry and cyanide flows have been calculated using a basis of 900 tonnes of ore processed per day and a maximum concentration of 183mg/l of total cyanide contained in solution.

The first reactor (cyanide destruction tank) has been designed to contact the agitated slurry flow with sodium bisulphite solution and air at a pH of between 8 and 9. Air is sparged into the reactor by one of two blowers, one duty and one stand-by. The pH is adjusted with automatic addition of sodium hydroxide. Copper sulphate, at 150g/l solution concentration, is added to reactor #1 as required.

The second reactor is used to precipitate iron cyanides and heavy metals and has been designed to contact the agitated tailings slurry stream with ferric sulphate and copper sulphate. Ferric sulphate and copper sulphate are added at solution concentrations of approximately 784 and 150g/l, respectively. Similar to reactor #1, the pH is maintained with sodium hydroxide and controlled at about the 7.0 level.

Treated slurry, in compliance with the Ministry requirements, flows to the final tailings pump box from where it is sent to the tailings pond. Decant water from the tailings pond is pumped back to the process water tank for reuse in the process plant. If required, decant water can be retreated in an independent third reactor to further reduce arsenic and antimony. This reactor is designed to contact the agitated decant water with ferric sulphate solution.

Sodium bisulphite and sodium hydroxide are supplied locally by tanker in a solution form at approximately 38% and 50% by wt. concentration and stored in 40m³ and 25m³ storage tanks, respectively.

Ferric sulphate is imported from Europe in 1 ton bags and stored in a reagent area on site. The solution is prepared at a concentration of 784g/l in a 5m³ mixing tank as required and transferred to a 15m³ holding tank from where it is dosed to the chemical destruction circuit. Copper sulphate is supplied locally in 50kg bags in solid form and prepared at a concentration of 150g/l in a 1m³ mixing tank and stored in a 5m³ holding tank.

4. COMMISSIONING AND OPERATION

Full commissioning of the process plant and the Inco cyanide destruction circuit commenced on June 4th, 2001. Prior to commissioning and reagent preparation, full inspection of the plant was conducted in order to identify any deficiencies, as the plant had been on care and maintenance since the end of 1997. Inco personnel were on site prior to commissioning and through the first month of operation in order to check that all the required elements were present to ensure successful operation, identify any problems that might impact upon future operation, confirm process performance, and train local Ovacik personnel to allow them to effectively operate the circuit.

As the Ministry requirement is 1mg/l cyanide in the final treated tailings prior to discharge to the tailings pond, it was decided to use leach tank #1 as a temporary emergency tailings storage reservoir during the commissioning period. If the cyanide level was more than 1mg/l, the tailings were redirected to leach tank #1 until 1mg/l or less was obtained. The material stored in the leach tank was blended with chemical destruction feed for re-treatment.

Throughout the commissioning period, process parameters were varied to observe the effect on overall performance. A sulphur dioxide ratio of approximately 5kg SO₂/kg CN_{WAD} was found to be effective in achieving the required effluent quality. Adding excess sulphur dioxide negatively affected the process. The large excess reduces the available oxygen, (which is evidenced by the measured concentration of dissolved oxygen), and also slows the catalytic activity. During commissioning there was some evidence that excess sulphur dioxide resulted in residual sulphite which produced elevated readings when using the picric acid procedure.

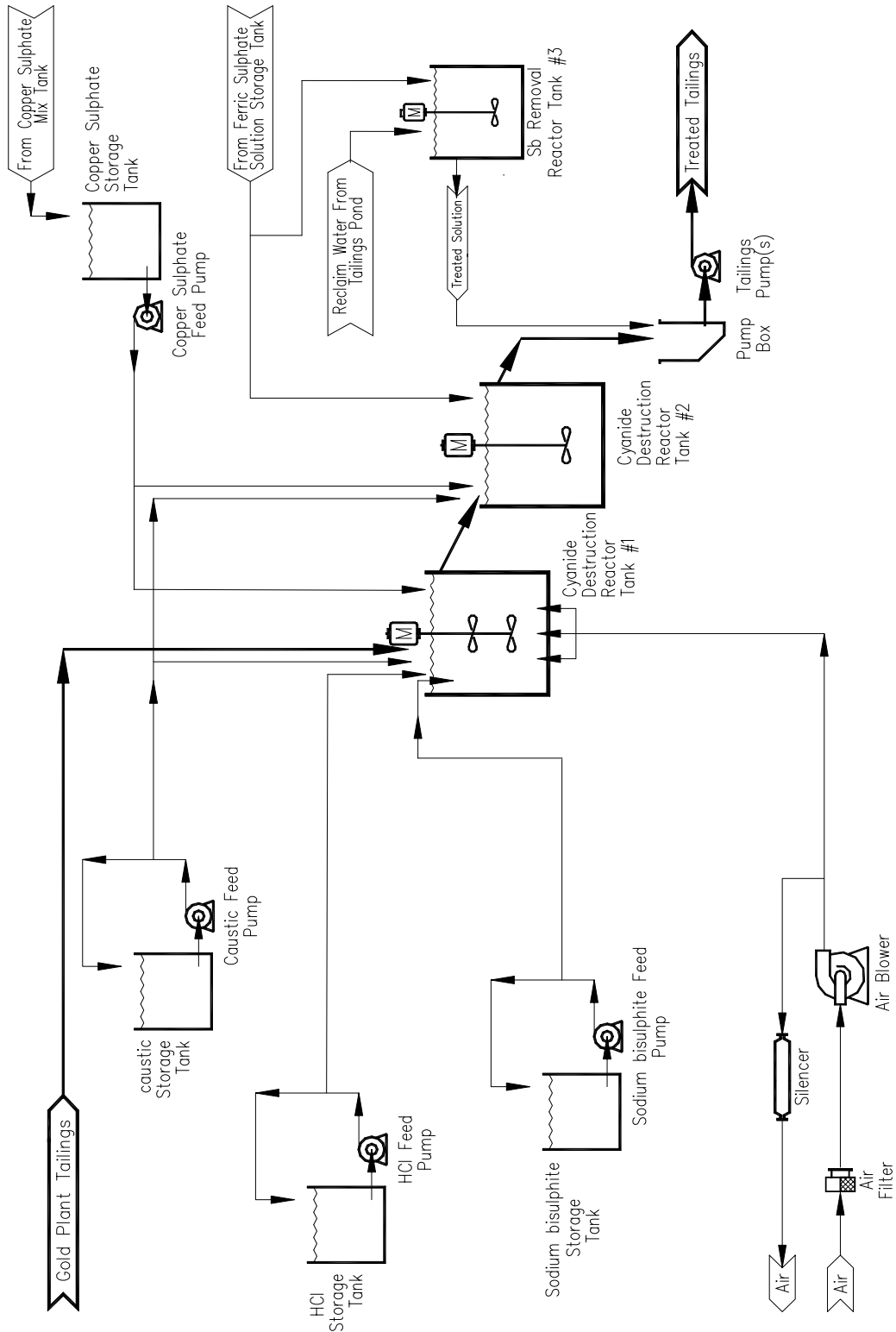


Figure 1. The flow diagram of the Ovacik chemical destruction circuit

The operating pH levels were optimized and the copper sulphate addition adjusted in each reactor to minimize effluent cyanide concentration. During the commissioning, it was decided to install a hydrochloric acid addition line to reactor #1 in case of difficulty in reducing pH by the sodium bisulphite (e.g. due to excess lime added in the mill circuit). Hydrochloric acid rather than excess sodium bisulphite was used for pH control when feed pH was high.

The performance of the circuit was negatively affected when the feed cyanide load (kg CN/hr) increased due to transfer of barren solution from the elution circuit to the CIP adsorption circuit. Transfer of cyanide containing barren solution to adsorption tank #1 increased both the cyanide concentration and flow rate to the chemical destruction circuit causing potential upset conditions in the circuit. Any change in the feed flow rate or composition of the feed required an adjustment to reagent addition rates in order to keep the required level. The cyanide level was kept below 1mg/l by diligent monitoring and adjustment of the reagent additions to sufficient levels. Diversion of barren solution from adsorption tank #1 to the front of the leach circuit resulted in a more controlled feed, smoother operation and reduction of reagent consumption in the chemical destruction circuit. As barren solution contains cyanide, sodium cyanide addition to the leach circuit was cut or reduced during transfer resulting in reduction of sodium cyanide consumption in the plant.

Due to very low level of arsenic and antimony both in the feed and in the discharge, treatment of decant water through reactor #3 has not been required so far.

Total operating cost of the chemical destruction circuit is approximately \$0,91 per ton of ore treated. Main cost areas for the circuit are given in table 2.

Table 2
Chemical Destruction Circuit Operating Costs

Cost	%	\$/t
Labour	17	0,15
Power	13	0,12
Sodium bisulphite	33	0,30
Copper Sulphate	23	0,21
Ferric Sulphate	12	0,11
Other	2	0,02
Total	100	0,91

In conclusion, the cyanide destruction circuit at Ovacik was commissioned successfully and is operating at design conditions, reducing the level of cyanide in the tailings effluent to the required 1mg/l or lower at the discharge to the tailings pond. WAD cyanide in the feed varied between 48 and 134, with an average of 83mg/l.

5. PROCESS CONTROL

The Inco SO₂/AIR cyanide destruction circuit is operated and monitored by the Production Department. The operators control the circuit to make sure that the tailings from the system are in compliance with the regulatory requirements before discharge. This necessitates that operators closely monitor the flow rate and composition of the feed as well as the quality of the effluent in order to allow timely adjustment of the addition rates of reagents to the reactors, in response to changes. It is also part of the operators' duties to check air blowers, reagent dosing pumps, air and reagent supply to the reactors.

Operators take samples from the feed and discharge streams every two hours for WAD cyanide, iron and copper determination so they can ensure that the process is operating effectively and can take quick corrective action should there be any indication of the start of a process upset.

WAD cyanide is measured by the operator in the plant laboratory, using the picric acid method prescribed by Inco. It is a quick, easy and accurate method and can be carried out by a trained operator. In the picric acid procedure, cyanides that are weakly complexed with metals are liberated using DTPA or EDTA. This cyanide, along with free cyanide contained in the solution, reacts with a buffered picric acid solution causing a colour change. The intensity of the colour development is proportional to the amount of cyanide that is present in the solution. By using a colorimeter to compare the samples to known standards, operators obtain accurate cyanide analyses. This method is used only for control of the circuit operation and not for environmental monitoring and reporting which is done separately by the environmental department using different methods as explained below.

The WAD cyanide concentration in the feed is used to calculate the cyanide load and required sodium bisulphite flow rate. The WAD cyanide in the effluent is measured to verify compliance with the requirements. If the WAD cyanide in the effluent is high, the operator immediately begins troubleshooting.

Internal operating procedures have this level set at 0.6mg/l which gives the operators sufficient time to react and correct an imbalance in the system.

In addition to two-hourly cyanide determination by the picric acid method, a cyanide sensing probe installed in reactor #1 provides an on-line indication of reactor performance. It gives continuous mV output, which becomes increasingly negative as the cyanide concentration increases within the reactor, providing quick, early indication of potential problems.

Iron and copper are analyzed using atomic absorption by an on-site contractor laboratory. These measurements enable the operators to optimize copper addition for iron cyanide precipitation, while providing sufficient catalytic effect in reactor #1.

The operators check the circuit regularly to ensure that the following process requirements are satisfied:

- The pH in both reactor #1 and #2 is maintained within the desired operating range by sodium hydroxide addition.
- The sodium bisulphite dosage is set above the minimum requirements.
- The oxygen transfer is sufficient for the sodium bisulphite addition rate.
- Catalytic activity is maintained.
- Sufficient copper and ferric sulphate addition is maintained.

Of the five reagents mentioned, the operator only adjusts the flows of sodium bisulphite, copper sulphate and ferric sulphate. The flow rate of compressed air remains constant and sodium hydroxide is automatically controlled.

The operators measure and read the circuit parameters every two hours and record them on the circuit log sheet. These variables are pH in reactors #1 and #2, dissolved oxygen in reactor #1, copper sulphate flow rate to reactors #1 and #2, sodium bisulphite flow rate to reactor #1, ferric sulphate flow rate to reactor #2, cyanide sensing probe reading in reactor #1, WAD cyanide, copper and iron concentration in the feed and discharge.

The process control of the circuit requires good communication between the operators of the chemical destruction circuit and other plant circuits (e.g. milling, leach-adsorption, elution and reagent make-up), as changes in the upstream circuits can affect the performance.

6. ENVIRONMENTAL MONITORING

The quality of the final treated tailings effluent and water in the tailings pond is monitored by the mine Environmental Department and reported to the regulatory departments monthly (Normandy, 2001).

WAD cyanide is measured daily on the composite samples taken from the tailings effluent and from the decant water which represents the tailings water stored in the pond. Samples for metal analysis are taken from four different points of the tailings pond in order to be representative. Arsenic and antimony are determined daily and chromium, nickel, copper, lead, iron, mercury, cadmium and zinc are determined weekly.

All the samples are filtered through a 0.45 micron membrane filter and preserved with sodium hydroxide for cyanide and with nitric acid for metal analysis. The WAD cyanide is determined at the on-site laboratory using a method which involves distillation for one hour with the sample buffered at pH 4.5 using an acetate buffer and collection of the released hydrogen cyanide in a sodium hydroxide scrubber solution. The collected cyanide is quantified by UV spectrophotometry.

Figure 2 shows the WAD cyanide assay results of the tailings effluent and decant water samples since June. As seen in the figure the required cyanide levels of 1mg/l in the discharge and tailings pond has been achieved at all times over the first five months of operation.

Table 3 shows weekly antimony, arsenic, iron, cadmium, chromium, copper, mercury, magnesium, zinc, nickel and lead analysis in the tailings pond since commissioning. All the metals have remained below the Ministry of Environment limits.

The Bergama Health Department also visits the site daily and takes samples from tailings effluent and return water for analysis of WAD cyanide and from the tailings pond for analysis of arsenic and antimony. The samples are independently analysed by the Governmental laboratory in Izmir.

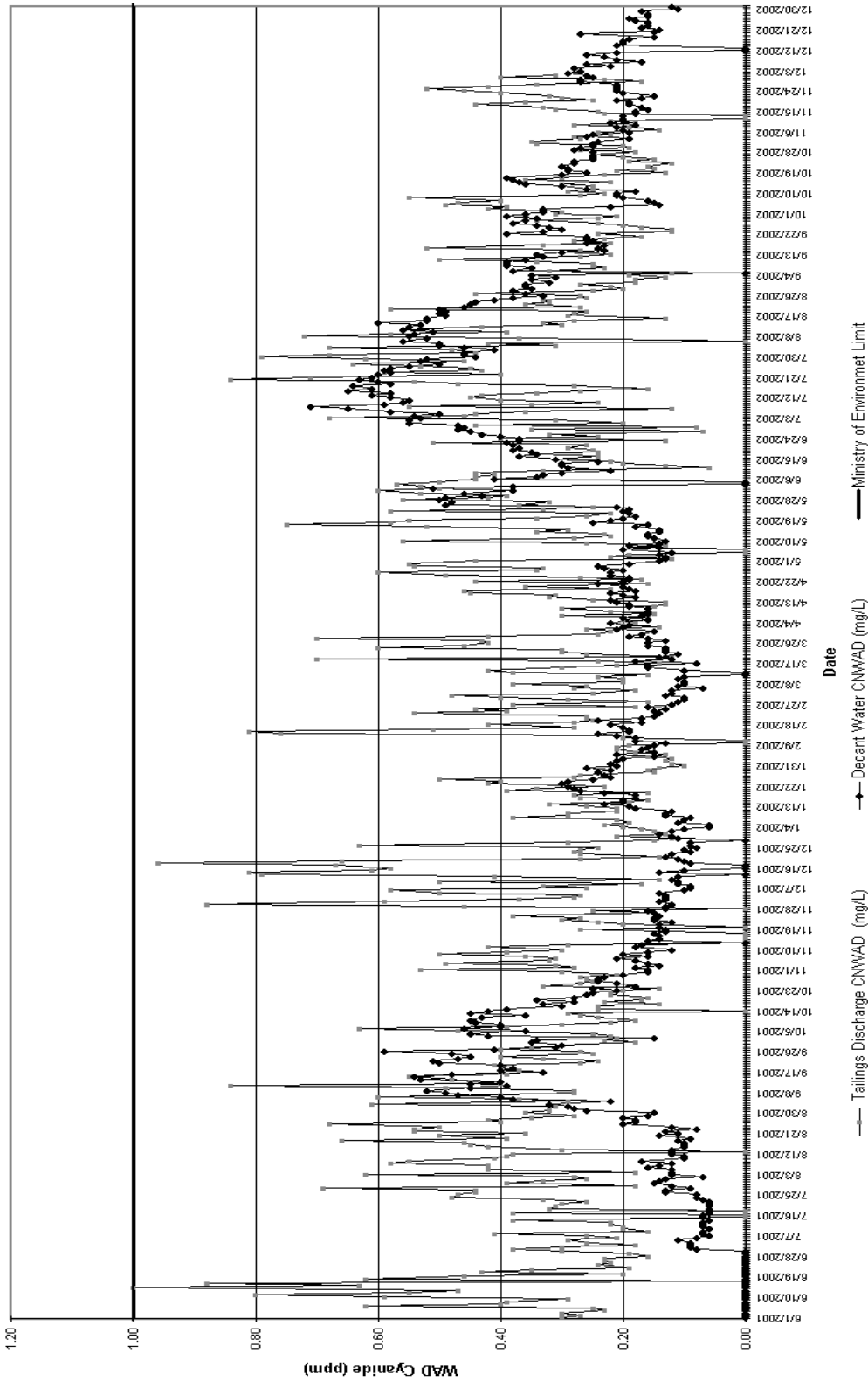


Figure 2. WAD cyanide in tailings discharge and decant water

Table 3
 Weekly tailings pond metal analysis (Normandy Madencilik A.S., 2001; 2002)

Date	Sb	As	Fe	Cd	Cr	Cu	Hg	Mg	Zn	Ni	Pb
06.06.2001	<0.5	<0.5	0.04	<0.01	<0.01	<0.001	<0.001	-	<0.001	<0.05	<0.05
13.06.2001	<0.5	<0.5	0.2	<0.01	<0.01	<0.001	<0.001	-	<0.001	<0.05	<0.05
20.06.2001	<0.5	<0.5	0.25	<0.01	<0.01	0.036	0.002	-	0.016	<0.05	<0.05
27.06.2001	<0.5	<0.5	-	<0.01	<0.01	-	<0.001	-	-	<0.05	-
04.07.2001	<0.5	<0.5	<0.03	<0.01	<0.01	0.1	0.0014	12.5	0.011	<0.05	<0.05
11.07.2001	<0.5	<0.5	<0.03	<0.01	<0.01	0.11	0.00247	14.8	0.013	<0.05	<0.05
18.07.2001	<0.5	<0.5	<0.03	<0.01	<0.01	0.14	0.00234	12.5	0.007	<0.05	<0.05
25.07.2001	<0.5	<0.5	0.03	<0.01	<0.01	0.15	0.00272	11.3	0.006	<0.05	<0.05
02.08.2001	<0.5	<0.5	0.06	<0.01	<0.01	0.2	0.00242	11.1	0.027	<0.05	<0.05
08.08.2001	<0.5	<0.5	0.05	<0.01	<0.01	0.23	0.00126	11.6	0.007	<0.05	<0.05
15.08.2001	<0.5	<0.5	0.11	<0.01	<0.01	0.2	0.0017	13.3	0.005	<0.05	<0.05
22.08.2001	<0.5	<0.5	0.04	<0.01	<0.01	0.26	0.00222	16.2	<0.005	<0.05	<0.05
29.08.2001	<0.5	<0.5	0.08	<0.01	<0.01	0.38	0.00211	14.2	<0.005	<0.05	<0.05
05.09.2001	<0.5	<0.5	0.1	<0.01	<0.01	0.66	0.00176	15.0	<0.005	<0.05	<0.05
12.09.2001	<0.5	<0.5	0.08	<0.01	<0.01	0.75	0.00175	14.1	<0.005	<0.05	<0.05
19.09.2001	<0.5	<0.5	0.06	<0.01	<0.01	0.7	0.00154	14.5	<0.005	<0.05	<0.05
26.09.2001	<0.5	<0.5	0.05	<0.01	<0.01	0.69	0.00402	15.1	<0.005	<0.05	<0.05
03.10.2001	<0.5	<0.5	0.05	<0.01	<0.01	0.75	0.005	15.9	<0.005	<0.05	<0.05
10.10.2001	<0.5	<0.5	0.03	<0.01	<0.01	0.83	0.00628	16.6	<0.005	<0.05	<0.05
17.10.2001	<0.5	<0.5	0.1	<0.01	<0.01	0.74	0.0118	17.8	<0.005	<0.05	<0.05
24.10.2001	<0.5	<0.5	<0.06	<0.02	0.001	0.63	0.0013	17.7	<0.01	<0.1	<0.1
31.10.2001	<0.5	<0.5	<0.03	<0.01	<0.01	0.45	0.027	16.9	<0.005	<0.05	<0.05
07.11.2001	<0.5	<0.5	<0.03	<0.01	<0.01	0.49	0.0036	18.1	<0.005	<0.05	<0.05
14.11.2001	<0.5	<0.5	<0.03	<0.01	<0.01	0.48	0.0182	19.2	<0.005	<0.05	<0.05
21.11.2001	<0.5	<0.5	<0.03	<0.01	<0.01	0.33	0.0137	19.2	<0.005	<0.05	<0.05
28.11.2001	<0.5	<0.5	<0.03	<0.01	<0.01	0.31	0.00643	18.0	<0.005	<0.05	<0.05
05.12.2001	<0.5	<0.5	<0.03	<0.01	<0.01	0.29	0.00316	17.1	<0.005	<0.05	<0.05
12.12.2001	<0.5	<0.5	<0.03	<0.01	<0.01	0.31	0.00526	18.5	<0.005	<0.05	<0.05
19.12.2001	<0.5	<0.5	<0.03	<0.01	<0.01	0.27	0.00478	16.9	<0.005	<0.05	<0.05
26.12.2001	<0.5	<0.5	<0.03	<0.01	<0.01	0.23	0.0045	15.6	<0.005	<0.05	<0.05
Limit	5.0	5.0	10.0	1.0	2.0	5.0	0.1	-	5.0	-	2.0

continued

Date	Sb	As	Fe	Cd	Cr	Cu	Hg	Mg	Zn	Ni	Pb
02.01.2002	<0.5	<0.5	0.04	<0.01	<0.01	0.29	<0.001	16.6	<0.001	<0.05	<0.05
09.01.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.29	<0.001	16.8	<0.001	<0.05	<0.05
16.01.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.32	0.0981	16.9	<0.005	<0.05	<0.05
23.01.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.55	0.0116	17.3	<0.005	<0.05	<0.05
30.01.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.59	0.0103	17.4	0.007	<0.05	<0.05
06.02.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.55	0.00193	18.3	<0.005	<0.05	<0.05
13.02.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.55	0.00366	18.5	<0.005	<0.05	<0.05
20.02.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.52	0.0018	16.4	<0.005	<0.05	<0.05
27.02.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.53	0.00348	16.1	<0.005	<0.05	<0.05
06.03.2002	<0.5	<0.5	0.03	<0.01	<0.01	0.57	0.003	16.4	0.007	<0.05	<0.05
13.03.2002	<0.5	<0.5	0.03	<0.01	<0.01	0.47	0.0007	15.4	<0.005	<0.05	<0.05
20.03.2002	<0.5	<0.5	0.06	<0.01	<0.01	0.46	0.00093	15.4	0.01	<0.05	<0.05
27.03.2002	<0.5	<0.5	0.10	<0.01	<0.01	0.44	0.0009	15.9	0.028	<0.05	<0.05
03.04.2002	<0.5	<0.5	0.05	<0.01	<0.01	0.50	0.0008	16.6	0.011	<0.05	<0.05
10.04.2002	<0.5	<0.5	0.10	<0.01	<0.01	0.49	0.00078	15.4	0.022	<0.05	<0.05
17.04.2002	<0.5	<0.5	0.09	<0.01	<0.01	0.52	0.00064	14.6	0.013	<0.05	<0.05
24.04.2002	<0.5	<0.5	0.09	<0.01	<0.01	0.51	0.0007	13.5	0.028	<0.05	<0.05
01.05.2002	<0.5	<0.5	0.04	<0.01	<0.01	0.59	0.00082	15.6	0.014	<0.05	<0.05
08.05.2002	<0.5	<0.5	0.05	<0.01	<0.01	0.50	0.00057	15.1	0.03	<0.05	<0.05
15.05.2002	<0.5	<0.5	0.04	<0.01	<0.01	0.49	0.00037	16.3	0.015	<0.05	<0.05
22.05.2002	<0.5	<0.5	0.06	<0.01	<0.01	0.45	0.00043	14.1	0.02	<0.05	<0.05
29.05.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.50	0.00035	14.8	0.015	<0.05	<0.05
05.06.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.44	0.00028	15.2	0.006	<0.05	<0.05
12.06.2002	<0.5	<0.5	0.03	<0.01	<0.01	0.40	0.00021	14.3	0.021	<0.05	<0.05
19.06.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.43	0.00022	14.2	0.009	<0.05	<0.05
26.06.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.56	0.00019	15.6	0.012	<0.05	<0.05
03.07.2002	<0.5	<0.5	0.06	<0.01	<0.01	0.78	0.00022	15.8	0.008	<0.05	<0.05
10.07.2002	<0.5	<0.5	0.04	<0.01	<0.01	0.95	0.00017	16.4	<0.005	<0.05	<0.05
17.07.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.86	0.00014	16.0	0.008	<0.05	<0.05
21.07.2002	<0.5	<0.5	0.03	<0.01	<0.01	0.74	0.0003	17.9	<0.005	<0.05	<0.05
Limit	5.0	5.0	10.0	1.0	2.0	5.0	0.1	-	5.0	-	2.0

continued

Date	Sb	As	Fe	Cd	Cr	Cu	Hg	Mg	Zn	Ni	Pb
31.07.2002	<0.5	<0.5	0.06	<0.02	<0.02	0.69	0.00013	20.5	0.01	<0.1	<0.1
07.08.2002	<0.5	<0.5	0.03	<0.01	<0.01	0.67	0.0001	19.3	<0.005	<0.05	<0.05
14.08.2002	<0.5	<0.5	0.05	<0.01	<0.01	0.81	0.00019	23.0	<0.005	<0.05	<0.05
21.08.2002	<0.5	<0.5	0.04	<0.01	<0.01	0.70	0.00013	24.9	0.012	<0.05	<0.05
28.08.2002	<0.5	<0.5	<0.06	<0.02	<0.02	0.47	0.00017	25.9	<0.01	<0.1	<0.1
04.09.2002	<0.5	<0.5	0.06	<0.02	<0.02	0.41	0.00015	26.1	0.02	<0.1	<0.1
11.09.2002	<0.5	<0.5	<0.06	<0.02	<0.02	0.51	0.00014	26.2	0.02	<0.1	<0.1
18.09.2002	<0.5	<0.5	<0.06	<0.02	<0.02	0.32	0.00013	26.7	<0.01	<0.1	<0.1
25.09.2002	<0.5	<0.5	0.04	<0.01	<0.01	0.41	0.00015	26.4	<0.005	<0.05	<0.05
02.10.2002	<0.5	<0.5	<0.06	<0.02	<0.02	0.44	0.00013	30.1	0.01	<0.1	<0.2
09.10.2002	<0.5	<0.5	<0.06	<0.02	<0.02	0.47	0.00024	29.2	<0.01	<0.1	<0.1
16.10.2002	<0.5	<0.5	<0.06	<0.02	<0.02	0.33	0.00016	34.2	<0.01	<0.1	<0.1
23.10.2002	<0.5	<0.5	<0.06	<0.02	<0.02	0.37	0.00013	32.3	<0.01	<0.1	<0.1
30.10.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.25	0.0002	28.1	<0.005	<0.05	<0.05
06.11.2002	<0.5	<0.5	0.03	<0.01	<0.01	0.16	0.00014	22.5	<0.005	<0.05	<0.05
13.11.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.21	0.00025	28.5	0.006	<0.05	<0.05
20.11.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.26	0.00035	32.2	<0.005	<0.05	<0.05
27.11.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.24	0.00012	31.1	<0.005	<0.05	<0.05
04.12.2002	<0.5	<0.5	<0.1	<0.02	<0.02	0.29	0.00022	31.2	0.01	0.014	<0.1
09.12.2002	<0.5	<0.5	0.06	<0.01	<0.01	0.24	0.0001	26.7	<0.005	<0.05	<0.05
11.12.2002	<0.5	<0.5	<0.06	<0.01	<0.01	0.27	0.00019	28.1	<0.005	<0.05	<0.05
18.12.2002	<0.5	<0.5	0.06	<0.01	<0.01	0.21	0.00027	27.0	0.006	<0.05	<0.05
19.12.2002	<0.5	<0.5	0.07	<0.01	<0.01	0.23	0.00026	29.2	<0.005	<0.05	<0.05
25.12.2002	<0.5	<0.5	<0.03	<0.01	<0.01	0.21	0.00048	30.1	<0.005	<0.05	<0.05
Max.	<0.5	<0.5	0.25	<0.02	<0.02	0.95	0.0981	34.2	0.03	<0.1	<0.2
Limit	5.0	5.0	10.0	1.0	2.0	5.0	0.1	-	5.0	-	2.0

7. CONCLUSIONS

The Ovacik Gold Mine went through a prolonged and thorough permitting process. Being the first gold project in Turkey using the conventional cyanide leaching method, environmental measures taken at the mine, especially with respect to the cyanide management system, have been put through long and exhaustive reviews by the relevant government departments (Akcil, 2003 a, b). Development and operation of the mine has also been examined with great care by both local and national communities. The successful operation of the mine and in particular the management of cyanide at Ovacik is crucially important to the future development of the gold mining industry in Turkey, an industry of significant economic opportunity and benefit for the country. Ovacik was successfully commissioned and to date has been operating in full compliance with the regulatory requirements. This is attributed to the dedication of Normandy personnel and the assistance of Inco specialists. The cyanide is routinely destroyed to less than 1mg/l before discharge to a lined tailings pond and metal levels in the pond are well below limits. In addition to the independent monitoring by local government departments, all the site environmental monitoring programs and process control systems are in place to ensure safe disposal of the tailings without any environmental impact both in the short and long term.

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