WCDE 00386–01 | Revision 161115

RISK MANAGEMENT FOR CYANIDE HANDLING

Case study

Lyndia Stacey[1]

Information contained in this case study is for the sole use as a teaching aid specific to the application of risk management processes. Operating and technical details are intentionally vague and incomplete to prevent use in other real life applications or scenarios.

A mining company uses ore extraction, milling and smelting to produce main end products of nickel and copper. To extract and separate these base metals from the ore, cyanide solution (NaCN) is used in the concentrator process [1]. The company receives NaCN in the form of briquettes which are concentrated, solid forms of NaCN that are 98% pure, Figure 1. They resemble charcoal briquettes used in BBQs (Figure 2) in both form and weight. Each NaCN briquette weighs approximately 14 grams, is 3.4 cm in length, 3.2 cm wide and 1.5 cm thick. Mill technicians follow Standard Operating Procedures (SOPs) to mix these briquettes with high pH water. In recent years, four minor incidents occurred regarding the cyanide mixing tank. These included a spill and minor damage to equipment; there were no injuries. As a result, an opportunity to improve this procedure was identified.

In order to understand the issues related to the NaCN system, a risk assessment was initiated to identify the hazards and evaluate the risks. A Risk Facilitator was engaged to assist Mill Operations Management in conducting a risk assessment on the NaCN system. The goal was to determine high risk areas and generate appropriate solutions that reduced the potential risk of injury for the workers while minimizing impact on the environment, equipment and revenue.

Figure 1 - Sodium cyanide briquettes [2]

Figure 2 – Charcoal briquettes [3]

[1] The author may have disguised certain names and other identifying information to protect confidentiality

Lyndia Stacey of the University of Waterloo prepared this design case study for classroom use. The authors do not intend to illustrate either effective or ineffective handling of an engineering situation. The author may have disguised certain names and other identifying information to protect confidentiality.

This case study was used for the 2016 Minerva-CIAC Responsible Care case study Competition.

Risk Management

The engineering project was initiated by Mill Operations to assess current NaCN process issues. At the Mining Company, risk management processes are employed to properly define threats to the operation. It is also employed throughout the life cycle of a project to assure risks are not introduced to the operation as a result of the change. This management methodology and philosophy enables quality decision making.

The Mining Company

The Mining Company prioritizes health and safety, environmental management and the well-being of all workers as a means to achieve long-term success. They undergo regular internal and external audits to assure compliance with policies and standards and they acknowledge the importance of continuous risk monitoring.

Metal Extraction

Figure 3 provides an overview of the entire process. Note that use of NaCN is only a very small part of the ore milling step; it is not a standalone procedure for separation.

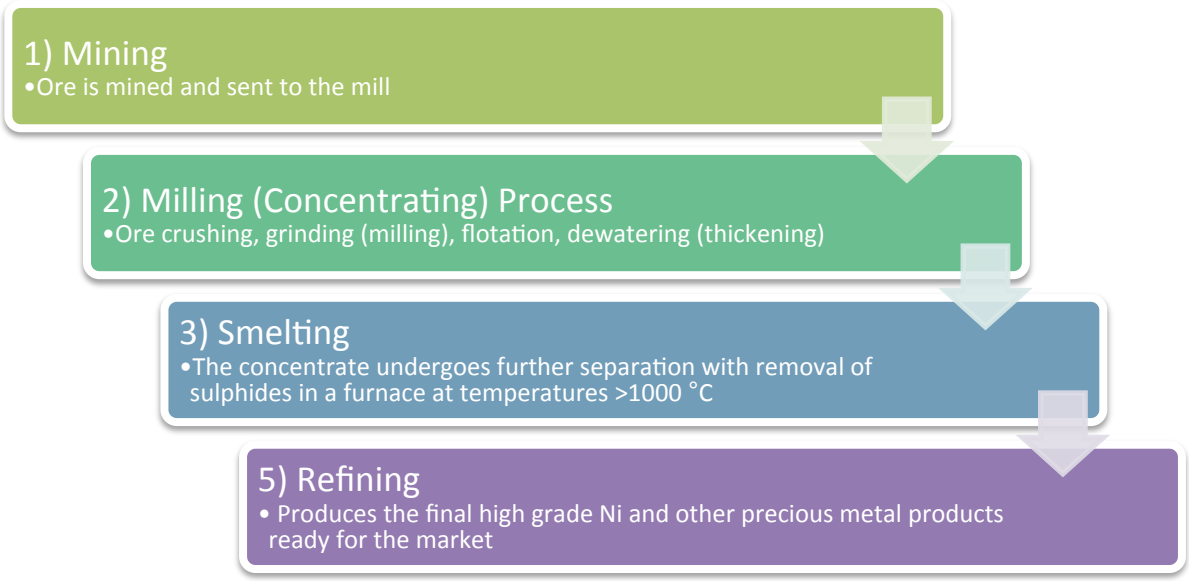

Figure 3 - Broad level overview of metal extraction process from ore [2][4]

Sodium Cyanide

NaCN is a white crystalline solid or powder and is considered to be a dangerous substance. It can decompose and release hydrogen cyanide gas ($HCN_{(g)}$) by contact with water, moisture, carbon dioxide or acids. $HCN_{(g)}$ is a highly toxic chemical asphyxiant that prevents the body's organs from using oxygen [4]. NaCN is also a deadly human poison and is toxic by skin absorption, by ingestion, and by dust inhalation. Exposure to NaCN or $HCN_{(g)}$ can be rapidly fatal [5].

Cyanide Mix Tank

A 10% aqueous solution of NaCN is created by combining NaCN briquettes with high pH water in a mixing tank located in the Reagent Room at the mill. The current system consists of an agitated cyanide mix tank that has a 9 foot diameter. Figure 4 highlights the operating levels and dimensions of the cyanide mix tank.

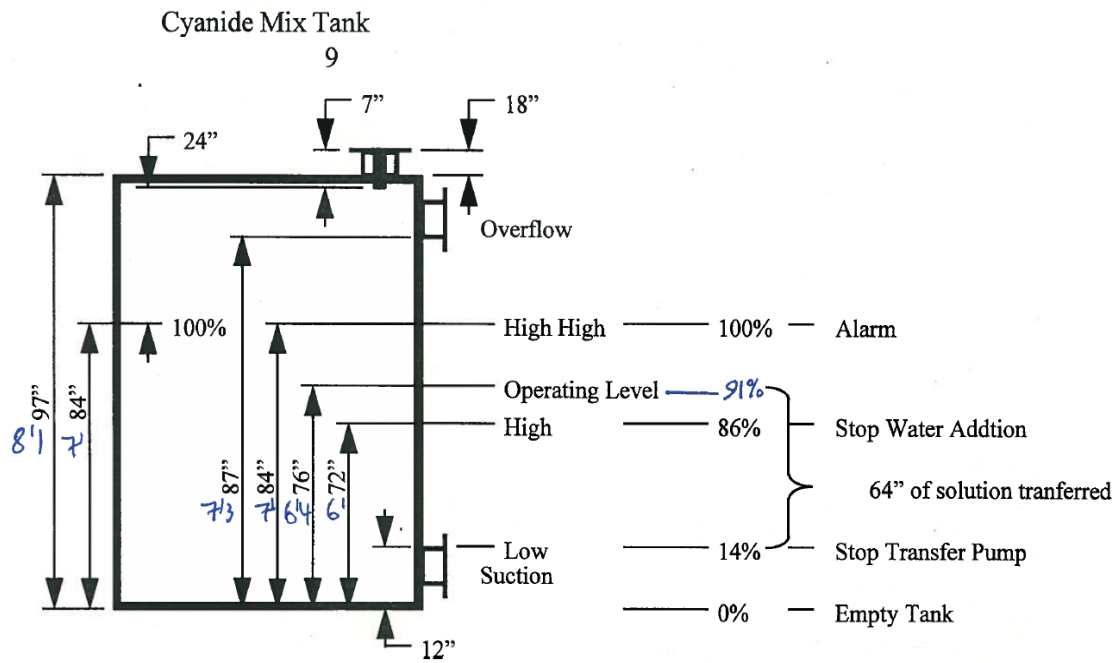

Figure 4 – Cyanide mix tank [2]

On top of the mix tank is a feed hopper and bag breaker, Figure 5. The briquette bags are double-sealed and washed so they are safe for handling. The feed hopper is where the forklift drops the bags of NaCN briquettes. The bag breaker has fixed knives that open these bags under the weight of the bags when they are lowered into place, Figure 6. The feed hopper has vibration isolators, bag positioners, clamp bars, rubber seals and cutting blades.

Mixing Procedure

A 1000 kg box of cyanide briquettes is mixed to 10 w/w% solution (making about 9625 L) in the mix tank. This is done by unloading the briquette bag within a box (1 double-sealed bag per box) into the feed hopper via forklift. A 1000 kg batch of cyanide briquettes lasts approximately 4 weeks. Their current maximum consumption rate is around 450 cm^3 per minute for a 10% solution, which is pumped to a distribution tank.

Figure 5 – Cyanide mix tank with feed hopper and bag breaker [2]

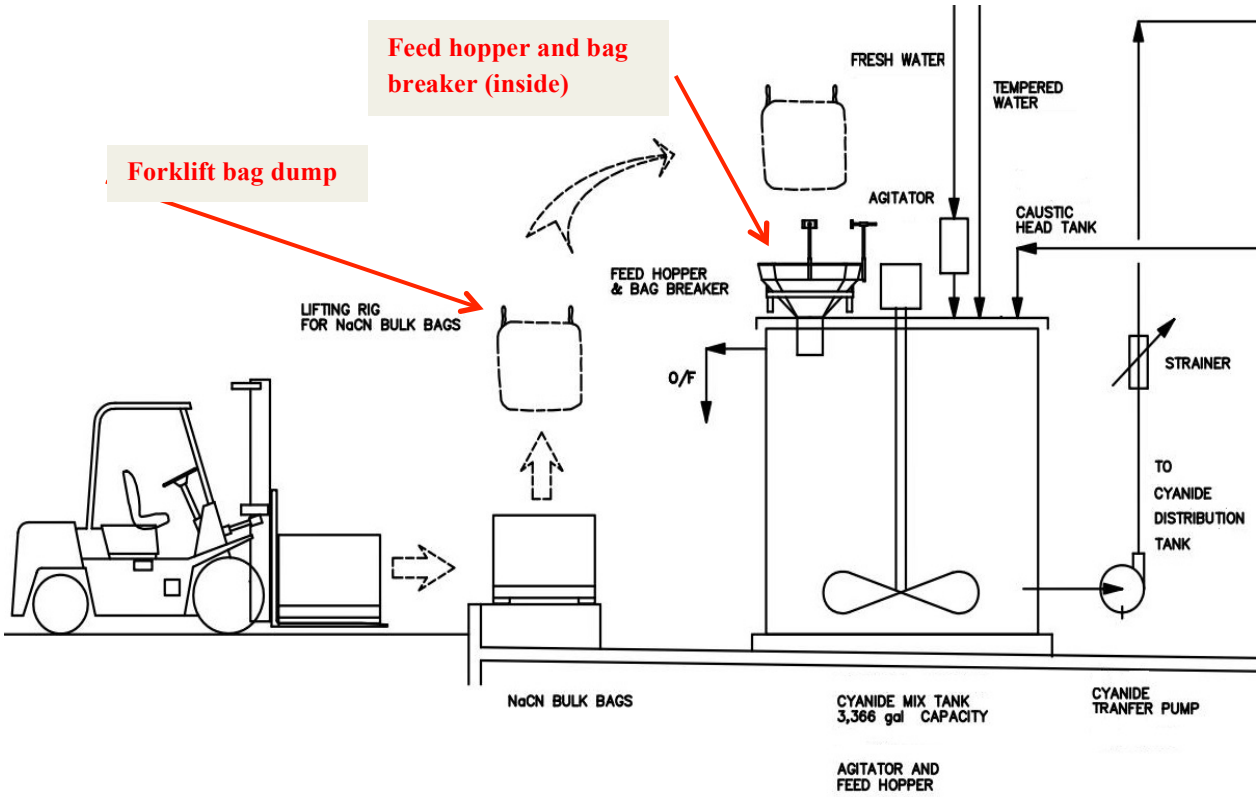

Figure 6 – Cyanide mixing system [2]

The storage facility for the cyanide briquette boxes is caged and locked with access only to qualified personnel. Each technician working on cyanide mixing must wear their own hydrogen cyanide monitor (Draeger-PAC III). Below is a summary of the mixing tank procedure, which requires two mill technicians; refer to Figure 6 as well.

1. Put on Personal Protection Equipment (PPE), listed in Exhibit B, and visually inspect area for hazards.
2. Remove plywood cover on mix tank and dispense two 10-litre pails of sodium hydroxide (NaOH) powder which buffers the cyanide solution to a pH of 12. Mix tank level must be below 14%. Add water to the mix tank's 86% level (Figure 4).
3. While the tank is filling with water, both workers prepare the bulk NaCN briquette bag within a single wooden box for hoisting with the forklift.
4. Lift the bag with the forklift and position over the mix tank spike. Lower bag and allow bag to empty into mix tank hopper.
5. Thoroughly rinse the empty bag and hopper with water, and then place the empty bag back inside the wooden box. Lock the storage gate and replace the plywood cover on the bag breaker.
6. Start mix tank agitator and open the drain on the fresh water line.

Supply and Storage

The Mining Company is only able to purchase a 6 month NaCN supply at a time due to storage capabilities. The briquette boxes are in a secured area inside their warehouse that is equipped with an alarm system. Safety placards are posted indicating NaCN storage areas. Each box is 1 cubic meter and only 6 boxes can be stored safely at a time. Figure 7 shows the storage of NaCN boxes.

Due to high NaCN demand in the gold industry, the Mining Company lost their supplier in 2013. A new supplier up for consideration was found in Houston, Texas. Cost comparisons are summarized in Table 1. To resolve supply issues, ideally 12 boxes could be delivered by the new supplier but it was determined that the Mining Company did not have safe storage for this. The Mining Company also deliberated having a local third party store the briquettes; however, this could cause issues under the International Cyanide Management Code [6]. They could change their procedure so that the solution with briquettes increased from 10 w/w% to 30 w/w%. At this concentration, the mix tank could be significantly reduced in volume to make room for a change to the system. The new supplier could also deliver an alternative form of NaCN that is a 30 w/w% solution (already a liquid); however, these would require changes to the mix system.

Table 1 – Summary of costs for NaCN options

NaCN Option	*Yearly Operating Cost*	*Amount of NaCN*
Current system	$82, 000	12 briquette boxes/ year (1000 kg each)
New supplier	$82, 000	12 briquette boxes/ year (1000 kg each)
Liquid NaCN (30 w/w% solution)	$106, 000	4 shipments of 10,000 L each year

Figure 7 – Storage of NaCN briquettes in boxes [2]

Safety Practices

Exposure to cyanide gas must be immediately treated with an appropriate antidote. Cyanokits® are the only available cyanide antidote kit on the Canadian market [7]. A NaCN antidote kit is maintained in a conspicuous location in the warehouse. The local medical facilities know of the warehouse's storage of NaCN and are trained to respond. The local hospital has a limited amount of Cyanokits® on hand. There is a safety shower and eyewash station located nearby. The SOPs are on location and an up-to-date MSDS for NaCN is available.

Disposal

NaCN boxes containing empty bags are disposed right away in accordance with the Environmental Management System and regulatory requirements. The technicians ensure the boxes contain only empty bags and a forklift is used to load them onto a truck for safe transport to a suitable burial site.

Potential Spills

The required PPE for cleanup are a rubber suit, rubber gloves, rubber boots, full-face respirator with organic vapour cartridges and HEPA filter, and a personal monitor for HCN gas. All PPE is resistant to NaCN. The company has spill response procedures for Levels 1, 2 and 3 spills. A spill kit is also available in the Reagent Room.

Incident Reports

The incident reports associated with NaCN are provided in Appendix A. The first incident report was due to an equipment failure. The cyanide mix tank did not indicate its level correctly after the NaCN had been added and it overflowed. Procedures for a Level 2 spill had to be followed. The second incident report highlights a communication error that lead to the shipment of 18 containers, which would exceed storage capacity. The confusion came from discussions on increasing the number of boxes that the Mining Company could store. The third incident involved a probable false alarm for HCN gas from a personal monitor in the Reagent Room. The last incident report describes a forklift operator hitting an HVAC unit due to maneuvering in a tight space.

Deficiencies with System

After discussions between supervisors, mill technicians and risk facilitators, a list of issues with the current cyanide system was generated:

- Lifting of sodium cyanide bags –the forklift is awkward to maneuver and bags may slide off
- Risk of worker exposure to HCN gas and NaCN powder during mixing
- Need to dispose of boxes and bags in the landfill
- Environmental and safety risk of NaCN dust becoming airborne during transportation to landfill
- Supply can be problematic given their low demand compared to other industries (i.e. gold mines)
- Limited storage capability (therefore needing more deliveries per year)
- Limited availability of capital

Problem Statement

The Mining Company identified the need to resolve issues with the cyanide mix tank system as well as the procedures in the mill's Reagent Room. An engineering project was initiated to analyze these issues, identify options and recommend the best solution to Mill Operations Management.

References

[1] International Council of Metals and the Environment (ICME), "The Management of Cyanide in Gold Extraction". Internet. http://static1.squarespace.com/static/516c6bb1e4b0e4e26c1d8e53/t/51b9546ae4b003975d41bbca/1371100266892/ICMMCY~1.PDF [Accessed August 13, 2015].

[2] Personal Communication with the Risk Management Champion, The Mining Company. July 31, 2015.

[3] Wikimedia Commons, "File:Charcoal Briquette.JPG". Internet. https://commons.wikimedia.org/wiki/File:Charcoal_Briquette.JPG [Accessed September 18, 2015].

[4] The National Institute for Occupational Safety and Health (NIOSH) and Centers for Disease Control and Prevention (CDCP), "Sodium Cyanide". Internet. http://www.cdc.gov/niosh/ershdb/emergencyresponsecard_29750036.html [Accessed September 16, 2015].

[5] National Centre for Biotechnology Information, "Sodium Cyanide". Internet. http://pubchem.ncbi.nlm.nih.gov/compound/sodium_cyanide#section=Top [Accessed September 16, 2015].

[6] International Cyanide Management Code, "The Cyanide Code – Principles & Standards of Practice". Internet. http://www.cyanidecode.org/about-cyanide-code/cyanide-code [Accessed September 17, 2015].

[7] Cyanokit, "Home". Internet. http://www.cyanokit.com/ [Accessed September 17, 2015].

[8] Minerva Canada Teaching Modules , Hazard and Risk Identification http://www.safetymanagementeducation.com

WCDE 00386–01

Appendix A - Excerpts from the Four Incident Reports

#1

DESCRIPTION (Describe briefly how the event occurred)

Unspecified, Insufficient Data (No accident)

Activity **Mixing** Task **Operating Mill Equipment**

Incident occured while employees were mixing cyanide. As part of the process, water addition was initiated and cyanide briquettes added at approx 11:20. The water turns off automatically on receiving a signal that the water level is ~95%. Level indication outside the cyanide cage showed 48% full at the time. Employees noticed that tank was taking longer than normal to fill, and ch[redacted] see if the valve had been throttled back. At approx 11:30, the sump alarm went off with the source being solution from the mix tank overflow. The water was isolated and area barricaded. The procedure for a Level 2 cyanide spill (greater than 30 gal contained within 126 sump and less than 2.5ppm HCN) was followed and measures were taken to avoid evolution of HCN gas. Solution was disposed [redacted] environmental [redacted] Further investigation revealed that a parameter on the level transmitter was changed [redacted] 1 at ~ 4:23pm [redacted] level output to half.

INCIDENT (POTENTIAL LOSS)

Witness Emp #	Witness Name	Witness Emp #	Witness Name
[redacted]	**Patrick**		
Person Reporting Incident	**Rob**	Directly Involved	
Type of Potential Loss	**Injury**	Environmental Incident	**No**

Identify Equipment / Material Involved

Chemicals, Chemical Compounds (solids, liquids, gases)

Machines - incl. agitators, flotation cells, screen, mill equipment

Cyanide Mix Tank

#2

DESCRIPTION (Describe briefly how the event occurred)

Unspecified, Insufficient Data (No accident)

Activity **Activity, not specified** Task **Task Unspecified**

Supplier was sent a PO for bulk order (the PO was to cover 1 years supply of product to be delivered in lots as set out by [redacted] representative throughout the year via email). Communication between the buyer and the vendor was clear and consise on this matter and both parties agreed to the terms. An initial shipment of 2 totes was requested after sending the PO. Shortly after the PO was sent, the supplier shipped the full amount of 18 totes. The product shipped was sodium cyanide which is a dangerous goods and which has very specific storage requirments. The Mill is reviewing their capability but at this point only two totes can be stored safely at one time. Product was offloaded in the warehouse and the supervisor was called by the warehouseman to determine what to do with the product immediatly. Warehouse was asked to remove the excess product but first contacted the supplier for instructions on how to do so safetly. Product was later shipped back at their cost.

INCIDENT (POTENTIAL LOSS)

Witness Emp #	Witness Name	Witness Emp #	Witness Name
[redacted]	**Neil**		
Person Reporting Incident	**Chris**	Directly Involved	
Type of Potential Loss	**Production Loss**	Environmental Incident	**No**

Identify Equipment / Material Involved

Chemicals, Chemical Compounds (solids, liquids, gases)

WCDE 00386–01

WATERLOO | ENGINEERING

#3

DESCRIPTION (Describe briefly how the event occurred)

Unspecified, Insufficient Data (No accident)

Activity **Loading/Unloading** Task **Handling Materials Mechanically**

While disposing an empty sodium cyanide box at the Cu bunker area, loading it on the [redacted] nim bin using the reagent room forklift; as the box dropped into the nim bin, hydrogen cyanide gas personal monitor of the forklift operator alarmed and peaked at 10.1ppm. Alarm lasted approximately 20 sec, alarm trigger point is set at 2.5ppm. Once alarm cleared, employees checked area around the [redacted] truck, forklift and reagent room, and did not observe anything unusual or detected any readings [redacted] truck driver personal monitor did not alarm [redacted] truck was running at the time of the incident, potentially producing exhaust gas interference with personal monitor [redacted] truck nim bin was checked after disposal of sodium cyanide box, no readings detected. Both monitor had been calibrated the day before and bump tested before incident. Assessment of the conditions in the area leads to conclude that it is unlikely that hydrogen cyanide gas was generated. Monitor false alarm is suspected.

INCIDENT (POTENTIAL LOSS)

Witness Emp #	Witness Name	Witness Emp #	Witness Name
[redacted]	**Patrick**		
Person Reporting Incident	**Bernie**	Directly Involved	
Type of Potential Loss	**Injury**	Environmental Incident	**No**

Identify Equipment / Material Involved

Chemicals, Chemical Compounds (solids, liquids, gases)

Miscellaneous Equipment - incl. fill fence, vent tubing, chute, etc.

HCN Gas BadgePro from Industrial Scientific

#4

DESCRIPTION (Describe briefly how the event occurred)

Vehicle collision w standing obj

Activity **Operating** Task **Inspect/Check**

While doing forklift pre-op before mixing cyanide in the reagent room, worker had check battery fluid level, brakes and steering. He proceeded to do boom extension check, however he could not do it in place so he drove the forklift 10 feet and proceeded with boom extension check (in front of reagent room entrance). When extending boom, he did not notice H-vac unit in area and hit it with the forks back support. Top windows were dirty and prevented clear view. Co-worker alerted forklift operator of incident and work was stopped. H-vac unit sits approx. 20 feet above ground. Area under the H-vac has been barricaded pending structural review. Forklift has been tagged out.

PROPERTY DAMAGE / PRODUCTION LOSS

Witness Emp #	Witness Name	Witness Emp #	Witness Name
[redacted]	[redacted]		
Property Damaged	**Structural steel frame for H-vac system and forkli**	Equipment Number	
Production Loss		Equipment Damage Report ID	**0** **View This EDR**
		Do this involve Tire failure or damage?	**No**

Identify Equipment / Material Involved

Machines - Earth Moving - Surface - incl. power shovel, front end loader, backhoe, dump truck, grader, etc.

Heating Equipment - incl. industrial furnace, convertor, lance, smelter and refinery process equipment

Toyota forklift