ГОДИШНИК НА МИННО-ГЕОЛОЖКИЯ УНИВЕРСИТЕТ "СВ. ИВАН РИЛСКИ", Том 53, Св. IV, Хуманитарни и стопански науки, 2010
ANNUAL OF THE UNIVERSITY OF MINING AND GEOLOGY "ST. IVAN RILSKI", Vol. 53, Part IV, Humanitarian sciences and Economics, 2010

THE MINE EMERGENCY PREPAREDNESS MANAGEMENT SYSTEM: FOCUS ON CYANIDES IN MINING OPERATIONS

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ABSTRACT. Emergencies often occur as the result of lack of systems, or failure of existing systems, to limit, control or prevent circumstances that trigger incidents which can lead to disasters. A mine emergency can be defined as an unplanned event that impacts upon the safety or health of mine workforce, the affected public or the environment, which requires an effective and timely response in order to control or mitigate the situation. Emergency preparedness and response arrangements should be commensurate to the potential for emergency situations, reflecting the adequate measures for impact mitigation. The use of cyanide in mining operations, because of its acute toxicity, presents particular hazards and risks that may accentuate emergency situations. The paper presents an approach to an emergency preparedness management system applicable to mine operations. The emergency control levels and key elements required for an adequate emergency preparedness plan are synthesized, with special focus on the case of cyanide use in gold mining operations.

СИСТЕМА ЗА УПРАВЛЕНИЕ НА НЕПРЕДВИДЕНИ ИНЦИДЕНТИ: ОСНОВНО ПРИ ИЗПОЛЗВАНЕ НА ЦИАНИД В МИННИТЕ РАБОТИ

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РЕЗЮМЕ:Често в производствени условия се проявяват непредвидени обстоятелства, които водят до бедствия включително и до човешки жертви. Това се дължи на липса на системи за сигурност, повреди в подобни системи или недостатъчен контрол при предотвратяване на подобни инциденти. В условията на минното дело подобни инциденти водят до нарушаване безопастността на работниците и увреждане на тяхното здраве. Това изисква адекватни мерки за контрол на работните условия и избягване на подобни ситуации. Готовността за решаване на непредвидени инциденти трябва да бъде съобразена с техния произход и същност, което определя и вземане на ефективни мерки. Използването на цианид при минните работи носи големи рискове поради неговата токсичност. Статията разглежда някои контролни нива и ключови елементи за изграждане на адекватни планови действия при евентуални инциденти, фокусирайки се върху безопасното използване на цианид при производство на злато.

Introduction

Regardless of the level of preparation and training, accidents do occur due to human error, mechanical failure, and nature. The goal of emergency response is to protect human health and the environment to the extent possible through minimization of impacts (Babut and Moraru, 2002). It is critically important that emergency response be carried immediately in accordance with a well thought out and administered plan.

Emergencies often occur as the result of lack of systems, or failures in existing systems, to limit, control, or prevent circumstances that trigger incidents which, when ineffectively managed, can lead to disasters (Moraru and Babut, 2000). A mine emergency may be therefore defined as an unplanned event that impacts upon the safety or welfare of the mine workforce, the affected public, or the environment, which requires n effective and timely response in order to contain, control, or mitigate the situation.

Emergency preparedness and response arrangements should be commensurate to the potential for emergency situations, reflecting the adequate measures for impact mitigation. An Emergency Response Plan should be prepared in accordance with the guidance of the UNEP APELL for Mining: Awareness and Preparedness for Emergencies at the Local Level process (UNEP, 2003).

The nature of mining projects (e.g. location in remote areas with long material/product supply chains) requires proactive and sustained interventions to minimize the incidence and transmission of communicable diseases caused by the influx of migrant workers, associated extended family members and other service workers at the site. Long haul transport activities may serve as disease conduits particularly for sexually transmitted infections. At the mine site, good international industry practice for solid waste management, surface water drainage, and sanitary wastewater management are usually effective in reducing vector borne and water related communicable diseases. Closure and post closure plans should include appropriate aftercare and continued monitoring of the site, pollutant emissions, and related potential impacts. The duration of post-closure monitoring should be defined on a risk basis; however, site conditions typically require a minimum period of five years after closure or longer (UNEP, 2001).

Organizational priority and commitment

In general, few people are convinced of the need for emergency preparedness unless a potential danger is recognized and seen as directly threatening, highly possible if not probable, and likely to occur in the near future. However, even though cyanide should be an exception to this axiom, the nature of emergencies, even those involving cyanide, is such that this recognition does not usually occur prior to the event actually happening (ICMI, 2009).

As the first step in the development and implementation of an effective emergency preparedness system, both company and site management must recognize the need for such a system and must give priority to providing the leadership, commitment, and support required. Consequently, it is necessary that the management of the company take the steps required to:

- provide and ensure continuing management leadership, commitment, and support.
- establish long-term goals and purpose.
- guarantee financial support.
- guarantee availability of personnel and their access to and involvement in training.
- provide appropriate organizational resources to develop, implement, and maintain the system.

Risk management involves the identification, assessment, and control of hazards and risks (Moraru *et al.*, 2000). The risk management process enables the types of risks to be identified and analyzed to determine the likelihood and the consequence of their occurrence.

This framework then enables the risks to be assessed against established criteria, in order to determine if the risks are acceptable or what actions must be taken for their reduction (e.g. reducing the likelihood of occurrence, reducing the consequence of occurrence, transferring all or part of the risks, or avoiding the risks).

Targeted implementation plans are then developed and executed to control the identified risks.

This framework can be similarly applied to develop emergency plans that enable effective response and control measures to be actuated, should a contingent situation arise. Identification and analysis of risks enables likely emergency scenarios to be predicted with a relatively high degree of accuracy.

Appropriate control measures can then be identified to address each of the recognized potential emergencies. These then form the basis for structuring emergency preparedness strategies.

Emergency control levels and key elements

Three levels of response should be identified, evaluated, and developed within the emergency preparedness system. All are key to effective response.

Primary response comprises he actions of individuals who are present upon the discovery of a hazardous situation or an incident, and includes, most importantly:

- notification of appropriate supervisory or management personnel.
- arresting and containing the hazard.
- evacuation, escape, or refuge.

Secondary response comprises the actions of trained responders upon notification of the incident, who possess the advanced skills, competencies, and equipment to deal with most emergency situations.

Tertiary response comprises the deployment of specialized experts, systems, equipment, and technologies in situations where primary and secondary response cannot be safely or effectively utilized. Commonly, these resources are external to the resources of the immediate area.

Emergencies grow more serious the longer the situation is allowed to proceed. Onsite personnel must be prepared to respond appropriately to emergencies. A multitude of activities must be coordinated and managed to ensure that the situation is rapidly and effectively controlled.

Emergency organization provides a structured framework that defines and integrates:

- emergency strategies;
- management structure (or chain of command);
- personnel resources, roles and responsibilities;
- equipment and facilities; and systems and procedures.

It encompasses all phases of an emergency, from the initial identification and containment activities, to notification, mobilization, deployment, and recovery.

The emergency organization should address a number of key elements, including:

- capability for primary and secondary response to an emergency.
- capability to manage and control an emergency.
- coordination and communications, including gathering, assessing, and evaluating data, decision-making, and implementation.
- the breadth of procedures necessary for effective control, including identification and containment, notification and early reporting, declaration of an emergency, specific operational procedures, evacuation, extrication, and life support, monitoring and review.
- control, advisory, technical, administration, and support services.
- transitional arrangements from normal to emergency operations in terms of lines of communication, authority levels, accountability, compliance, liaison, and policy.
- capability and capacity to sustain emergency operations for extended periods.
- impact of organizational changes in an emergency situation, including supervision and control of personnel;
- motivation, commitment, and discipline; roles of experts and specialists, external agencies, and order stakeholders.

- contingency provisions to address situations such as those arising after hours or where key organizational members are unavailable or incapacitated by the emergency.
- integration and deployment of tertiary response personnel, systems, equipment, and technologies.

Emergency facilities, equipment, supplies, and materials

The nature, extent, and scope of facilities, equipment, supplies, and materials required to control and mitigate emergencies are identified through application and extension of the risk management process and determination of the emergency control strategies. These will be provided and deployed according to the risk profiles that are established.

These commonly include provisions for incident command, safety support, medical support, site security, field communications, transportation, personnel support, and equipment support, and emergency shelters.

Emergency preparedness skills, competencies, and training

The skills and competencies required to cope effectively with an emergency are established by the core risks and emergency control measures, the emergency organization, and the emergency facilities, equipment, supplies, and materials to be employed.

The training of all involved parties in basic hazard awareness, the early recognition and notification of incipient incidents and trigger events, and primary response and escape skills is essential to a successful program.

Emergency preparedness skills and competencies include not only a diverse range of basic skills associated with the primary and secondary response initiatives, but also those required to plan and manage an emergency (Smith, 1995).

The elements of the emergency preparedness system serve as the framework for the development of an effective training program by identifying the extent of specific outcomes in an emergency situation and the underpinning competencies. This includes:

- A primary statement of intent that details why the necessary expertise, skills and competencies are to be developed.
- Risk management and measures to manage emergencies that identify key control elements.
- A definition of the emergency organization that includes strategies, structure, staffing, skills, system, and procedures; and that identifies who is to be trained, their role in an emergency, and the skills and competencies required.
- Identification of training resources that designates what aids, equipment, facilities, and instructors are needed.
- Training of personnel in identification and containment, notification, mobilization, deployment, and post-incident activities.

Routine testing, evaluation, and enhancement of the overall system, coupled with periodic risk and capability reassessment.

Audit, review and organizational outline

Few risks remain static. Consequently, risks and the capability of control and emergency preparedness measures needs to be monitored and evaluated to ensure that changing circumstances do not alter risk priorities or lessen system capabilities.

Audit and review processes need to be conducted to assess and evaluate the effectiveness of the overall emergency systems, procedures, facilities, maintenance programs, equipment, training, and individual competencies. This provides opportunities for improvement, constructive criticism, and verification of performance.

Two basic forms of auditing are commonly used. Horizontal auditing involves the testing small, specific elements of the overall emergency preparedness management system. Vertical auditing tests multiple elements of a plan simultaneously through simulation of an emergency event. Simulation may involve personnel from more than one organization or locale, mutual-aid organizations, tertiary responders, and other groups.

The organizational framework regarding the mine emergency preparedness management system should be developed by systematic approaching the following issues:

- Preparedness
  - general;
  - command (communication, safety, liaison);
  - operations (response objectives, discharge or release control, assessment/monitoring, containment, recovery, decontamination, medical needs, rescue plans);
  - planning (hazard assessment, protection, training and skills, coordination with external parties, waste management);
  - logistics (safety support, medical support, site security, field communications, transportation, personnel support, equipment support, finance/procurement/ administration).
- Discovery
- Initial Response
- Notification
  - internal;
  - community;
  - regulatory authorities.
- Investigation
- Corrective Action
- Mitigation/Prevention
- Communication
- Record Keeping
- Incident Closure
  - accident investigation;
  - critical response;
  - plan review and modification;
  - follow-up reports.

Emergency preparedness and response: the case of cyanide mining

The use of cyanide in mining operations, because of its acute toxicity, presents particular hazards and risks that may accentuate emergency situations. Emergencies involving cyanide can occur on or off the mine site, and can take place at any time from the commencement of production to well beyond the closure of the operation. It is therefore imperative that every mining operation that uses cyanide be properly prepared to respond to such emergencies. Timely and effective response can make the difference between an incident being a "non-event" or a disaster (European Commission, 2006).

Even though the probability of a major cyanide incident occurring could be considered by some to be unlikely, it is incumbent upon all mining operations using cyanide to ensure that adequate HSE cyanide management systems and procedures are in place and that they are adequate to protect employees, the public and the environment from the adverse consequences of an accident. To do this, all mining companies using cyanide should conduct strategic risk reviews of site specific cyanide management practices using HSE auditing procedures adequate to evaluate if existing training, transportation and handling procedures, operating practices and engineering designs exist, and are adequately maintained and regularly reviewed to minimize the likelihood of an accident (ICOLD, 2005). Every emergency response plan should be regularly updated and tested for improvement. Because of the public's perception of the hazards and risks associated with using cyanide, trained experts should be readily available to communicate to media and interested parties, regardless of the facility's location or the magnitude of the accident (Fox, 2001).

There are five basic elements to consider in developing and implementing an emergency response plan or procedure, in this case:

- notification;
- containment;
- treatment;
- monitoring;
- training.

Notification of the appropriate site personnel, as well as local, governmental agencies must be an immediate priority in the event a cyanide spill occurs at a mining operation, regardless of the time of day. Of critical importance in the event of a cyanide spill reaching surface water, is the notification of all down stream individuals, municipalities, or other industrial users that rely upon it as a primary source of potable water. Other notifications include those required under law or those noted in the operating permit for the mine. The notification process should involve a single call from a worker to an individual of authority, who is on call and on behalf of the company makes the appropriate notifications. A designated chain of command must be established to ensure the notification process proceeds without interruption.

Containment of the cyanide spill on site should be the first physical priority in conjunction with proper notification. If there is any indication that the pH of the solution has been lowered and hydrogen cyanide gas has been released, all personnel accessing the spill area should be equipped with a self-contained breathing apparatus. A decision must be made immediately regarding the evacuation of the other on site and off site personnel to some predetermined distance. Containment could involve diverting the spill to a holding pond, building a temporary dam or collection system, and/or pumping of solution. If the spill is from a tailings impoundment in which the cyanide levels have been lowered for protection of wildlife, then further treatment may not be necessary. However, if the cyanide levels are at full strength and/or the spill could enter surface water, then further treatment could be mandatory.

Treatment of the spill to lower the cyanide concentration may become necessary if it is or could eventually enter surface water and effect the environment or human health down stream of the mine site. Treatment is only effective if it can be accomplished in conjunction with the occurrence of the spill. If the spill has already occurred, then addition of treatment chemicals to surface water, like a stream, is not advised, since the addition of these chemicals could result in additional environmental impacts and are generally not effective in downstream cyanide levels. Specifically, chlorine or hypochlorite reagents are not recommended for direct treatment of cyanide spills in flowing surface water, since these compounds are quite toxic and form additional toxic intermediates that can cause further undesirable environmental impacts. Furthermore, ferrous iron reagents should not be added directly to surface water to precipitate cyanide as this too will result in secondary adverse environmental impacts if done improperly.

If treatment is deemed necessary and appropriate and a permanent treatment facility is not already available, then selection of either hydrogen peroxide for treatment of solution spills or the sulfur dioxide/air process for treatment of slurry spills is preferred. These chemicals should only be used as a last resort if containment is not achievable and the spill can be treated directly at the point of release.

Although additional chemicals are being added in conjunction with these treatment processes, their impacts are limited in comparison to those arising from the use of chlorine or hypochlorite. Removal of cyanide with ferrous sulfate is not recommended either as this process involves merely precipitation of the cyanide as an insoluble iron salt, which can again dissolve under elevated pH conditions releasing free cyanide. A permanent treatment facility of some type should be mandatory at a mining operation that utilizes cyanide in elevated concentrations.

Monitoring of on site and off site downstream water quality must be incorporated into an emergency response plan. If the cyanide spill reaches an off site surface water source, then extensive monitoring of water quality downstream must be initiated to determine the extent of the spill and potential

environmental impacts. As soon as possible, additional monitoring of sensitive ecosystems, such as aquatic life, should be implemented. The more intensive water quality monitoring program should continue until there is no further threat to human health or the environment.

Training of on-site personnel and members of the public should be associated with the entire spill prevention and emergency response program. Training should include the various aspects of cyanide chemistry, toxicity, analysis, and treatment. The training should be ongoing with periodic updates and simulated spill events to maintain optimal response performance. With respect to the public there should be ongoing awareness training of the community as a whole but also specific hazardous materials and emergency response training of specific individuals such as firemen, policemen, and other government personnel depending upon local conditions.

Conclusions

Emergency preparedness and response arrangements should be commensurate to the potential for emergency situations, reflecting the adequate measures for impact mitigation. The use of cyanide in mining operations, because of its acute toxicity, presents particular hazards and risks that may accentuate emergency situations. Timely and effective response can make the difference between an incident being a "non-event" or a disaster.

The goal of emergency response is to protect human health and the environment to the extent possible through minimization of impacts. It is critically important that emergency response be carried immediately in accordance with a well thought out and administered plan. In general, few people are convinced of the need for emergency preparedness unless a potential danger is recognized and seen as directly threatening, highly possible if not probable, and likely to occur in the near future. However, even though cyanide should be an exception to this axiom, the nature of emergencies, even those involving cyanide, is such that this recognition does not usually occur prior to the event actually happening.

Quantifying the relative risk of failure is recommended to be accomplished with an event-fault tree approach. In this kind of analysis, the overall risk profile can be determined by subdividing the possible failure mechanisms into discrete events, for which the risk of failure can be estimated.

Individual risk levels for discrete modes can be generally estimated from existing data engineering experience. Modes that are shown to significantly impact the overall risk of a project are subject to additional analysis. The preliminary hazard assessment can be refined to include probabilistic variation of the input data in order to produce a reasonable estimation of the likelihood of failure during the life of the project. All mining companies using cyanide should conduct strategic risk reviews of site specific cyanide management practices using HSE auditing procedures adequate to evaluate if existing training, transportation and handling procedures, operating practices and engineering designs exist, and are adequately maintained and regularly reviewed to minimize the likelihood of an accident. Every emergency response plan should be regularly updated and tested for improvement.

Three levels of response should be identified, evaluated, and developed within the emergency preparedness system. All are key to effective response, as detailed in the paper.

Emergency organization provides a structured framework that defines and integrates the emergency strategies; management structure (or chain of command); personnel resources, roles and responsibilities; equipment and facilities; and systems and procedures. It encompasses all phases of an emergency, from the initial identification and containment activities, to notification, mobilization, deployment, and recovery.

Emergency preparedness skills and competencies include not only a diverse range of basic skills associated with the primary and secondary response initiatives, but also those required to plan and manage an emergency.

References

Babut, G., Babut, S. 2002. *Sanitary risk assessment*. INFOMIN Publishing House, Deva, 204 p. (in romanian)

European Commission 2006. *Best Available Techniques (BAT) - Reference Document for Large Combustion Plants*. European Integrated Pollution Prevention and Control Bureau (EIPPCB). Seville, Spain.

Fox, F.D. 2001. Environmental auditing and emergency response - In: *The Cyanide Guide, Mining Environmental Management Journal*. May, pp. 31-32.

International Cyanide Management Institute (ICMI) 2009. *The International Cyanide Management Code (Cyanide Code)*. Available at: www.cyanidecode.org.

International Commission on Large Dams (ICOLD) 2005. *Risk Assessment in Dam Safety Management. A reconnaissance of Benefits. Methods and Current Applications.* Available at: www.icold-cigb.net.

Moraru, R., Babut, G. 2000. *Risk analysis*. Universitas Publishing House, Petroşani, 114 p. (in romanian)

Moraru, R., Babut, G., Goldan, T., Babut, S. 2000. *Ecological risk assessment*. INFOMIN Publishing House, Deva, 272 p. (in romanian)

Smith, J.M. 1995. *Planning a Workforce Environmental Awareness Training Program* (a booklet in the series on Best Practice Environmental Management in Mining). Environment Australia, Canberra.

United Nations Environmental Program (UNEP) 2001. *Tailings Dams Risk of Dangerous Occurrences*. ICOLD Committee on Tailings Dams and Waste Lagoons.

United Nations Environmental Program (UNEP) 2003. *Explaining APELL for mining.* International Council of Mining & Metals, Division of Technology, Industry and Economics.

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