## 7. Risk analysis and prevention.

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A heavy responsibility for safe mines lays on the mine planners’ shoulders. They must find solutions that promote high productivity and good economy as well as safety and a healthy work environment. The mine planners will initially shape the general and specific work environment for miners for many years to come. If the planners design a poor solution and it is necessary to redesign it, it will also probably be very expensive to correct after it has been implemented.

Work environment and safety issues are unfortunately often left quite unattended in the early stages of mine planning and design when they instead should be systematically highlighted and developed from the very first planning steps. The best and most efficient way to gain safety is through proactive planning instead of reactive corrective actions. It is also the best way to reduce the associated costs for risk elimination and reduction.

The mine planner is however not alone, he or she works in a company context where safety climate and culture, safety policy and safety management have a strong influence on how well the planner can succeed in his or her work.

The slogan “Safety first” has been heard in the mining business for many decades but is still in many cases no more than a slogan since safety first is not fully practiced, especially if the business has financial problems. It seems however that the times are changing and many mining companies are now making great efforts to improve their safety climate and safety culture. Research on safety has shown that at positive safety climate and well developed safety culture is an important requisite for a healthy and safe work environment, especially in heavy industries.

In order to manage the risks in the business every mining company is also in need of a strategic long-term policy regarding how to deal with safety issues and strive for better work conditions. The safety policy shall direct and establish systematic ways to manage (plan, steer and control) the safety work, also including early planning and design activities.

Because mining is a very risky business it has to follow and obey a lot of directives, laws and provisions. Most of these rules only stipulate minimum demands and the companies are free to exceed them. This is also what mine planners should aim at, exceeding minimum demands. A first step for a mine planner is therefore to get acquainted with the national and international (ie EU regulations) system of rules and basic demands. Many of these demands are provided by the national or EU authorities. This has to be done in a thorough way in each country there are quite a large number of directives, laws and provisions that regulate and give guidelines for health and safety issues in underground mining.

The basis for all activities in systematic health and safety work shall always be an initial thorough risk assessment both of the present state and a future planned state. It is of course easier to assess present or historical risks than future risks, especially if the future holds large changes in technology and or work organization. Still a mine planner needs to assess the risks with different mining concepts that are developed and planned.

Mining might develop in a revolutionary way, but will most probably develop in another way, in an evolutionary way. This means that much can be learned from history and from the present state. Thorough evaluations of present and historic designs have for example systematically been used by the Swedish mining company LKAB in the design of their newest main level at 1365 m below surface. This evaluation has been very important since the time span from the first conceptual designs to the final solutions has stretched over 12 years and a large number of planners.

Risk assessments can be performed in number of ways depending on the situation and circumstances. All risk assessment shall however be based on probability and consequence for unwanted events. A practical tool for this purpose is a risk matrix that eases a systematic and consequent risk assessment, se below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Very common  - 1/week | **R3** | **R4** | **R5** | **R5** | **R5** |
| Common  - 1/month | **R2** | **R3** | **R4** | **R5** | **R5** |
| Relatively common  - 1/år | **R2** | **R3** | **R3** | **R4** | **R5** |
| Quite unusual  - 1/10 år | **R1** | **R2** | **R3** | **R3** | **R4** |
| Not probable  - 1/100 år | **R1** | **R1** | **R2** | **R2** | **R3** |
| **Probability**  **Consequence** | Some discomfort  but harmless | Injury but no  sick leave | Short sick leave | Long sick leave | Permanent serious injury or death |

Figure 7.1. Risk matrix based on probability and consequence.

As can be seen in figure 7.1 probability is expressed as a frequency for a specific event or deviation. The assessed risk level during planning can also be coupled to a specified need for action, se below.

|  |  |
| --- | --- |
| **Risk level** | **Need for action during planning** |
| **R1**  Low risk – negligible risk | No need for any redesign of the basic concept |
| **R2**  Small risk | A limited redesign of the basic concept might not be needed |
| **R3**  Average risk – certain risk | A thorough redesign of the basic concept is recommended for parts related to identified risks |
| **R4**  Severe risk | A redesign of major parts of the basic concept is necessary to reach a less than average risk |
| **R5**  Very severe risk | Any further development of the design concept is not permitted until the identified risk is reduced to a less than average risk |

Figure 7.2. Risk level and need for action during planning

The risk matrix for risk assessments during planning can also with some modification be used for risk assessments in the operative production stages. The risk matrix has therefore become a quite well known and used tool in the mining companies.

|  |  |
| --- | --- |
| **Risk level** | **Need for action during production** |
| **R1**  Low risk – negligible risk | No need for action |
| **R2**  Small risk | Action might not be needed within months |
| **R3**  Average risk – certain risk | Reasonable risk reduction needed within a week |
| **R4**  Severe risk | Promt action is necessary within hours |
| **R5**  Very severe risk | Work is not permitted until risk is reduced to an acceptable level |

Figure 7.3. Risk level and need for action during production

The classical tools for the identification of occupational risks in the existing production environments are Safety rounds, Incident and Accident reporting. These tools are however less suitable to identify and assess risks in future work environments. There you need other types of more proactive methods such as:

* Preventive deviation analysis
* Preventive energy analysis

A deviation is according to Harms-Ringdahl (2013) defined as an event or condition that deviates from the intended or normal. The purpose of a deviation analysis is to prevent, to predict abnormalities that can cause damage and to develop proposals to improve safety measures. Deviation Analysis is a very useful method since it takes into account the entire system, Human-Technology-Organization. Energy analysis focuses more on technology and might be useful when developing new productions systems. Three main components considered in an energy analysis are:

* Energy that can damage
* Targets that may be harmed
* Barriers to Energy

The energies usually considered are: Gravity, height (including static load); Linear motion; Rotary motion; Stored pressure; Electrical energy; Heating and cooling; Fire and explosion; Chemical effects; Radiation; Miscellaneous (human movement, sharp edges, and points).

There are also many other different risk analysis methods that can be used during the development of new production systems. Besides the methods mentioned above methods like Preventive Work Safety Analysis (PWSA), Failure Mode Effect Analysis (FMEA), Fault Tree Analysis (FTA), Event Tree Analysis (ETA), Work Environment Screening Tool (WEST) etc. are possible to use. The most appropriate tools have to be chosen for every specific analysis task and the users of the tools must also have the necessary competence in order to attain reliable and relevant results. Here the mining business probably can learn much from other industries that have strong safety cultures and long experience of systematic risk management. Especially important will be to learn how to proactively manage risks for fatalities and other severe risks. Here so called leading indicators are preferred instead of lagging indicators.

Even if there are many risk evaluation tools available the mining industry seems to need new and efficient tools for description, evaluation and design of work environment during early phases of strategic decision making and production system design. The most important decisions regarding work environment and safety are made by top management when mining methods, technology, work organization etc. are decided. Therefore risk analyses regarding these matters should be made as early as possible in the mine design process.

Once a risk analysis is completed it often requires measures which in most situations should be implemented in the following well known order:

1. Prevent already in the planning stage, replace the hazards entirely. For example, through automation to eliminate manual or mechanized underground work.
2. Isolate the individual hazard, risk process. For example, by designing ventilation and layout so that the blasting fumes can’t be spread outside the risk zone.
3. Change process technology and behavior. For example, DTH-drilling with water hydraulics rather than pneumatics to reduce dust emissions.
4. Limit the hazard through enclosures, physical protection. For example, build concrete borders and railings at the shaft openings.
5. Isolate personnel from the hazard risk area. For example, by supplying the mining vehicles with safety cabs with good climate control.
6. Risk is reduced by instructions, procedures, training, etc. For example, procedures for safe handling of explosives.
7. Risk is reduced through personal protective equipment. For example, functional working clothes.

Depending on the complexity and severity of problems one may require different combinations of measures as described above. One recommendation is to always try to attack the root causes of the problem first. It tends to result in the most cost efficient and result efficient solutions. This is an important task for mine planners. They have the best opportunity to eliminate a lot of potential health and safety problems when they develop the first conceptual solutions. Planners that don’t realize this and neglect these matters can cause great harm for many years to the mining personnel and their company.

# References

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