Underground Mining of Metalliferous Deposits
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Lecture 59
Safety in U/G Metal Mines - I

SAFETY: BASIC TERMS

Safety: It is defined as the state or condition of being safe from being hurt or injury or loss.

Dangerous occurrences: Mishaps which do not result in loss of life or injury.

Accident: It may be defined as an unexpected event causing loss of life or bodily injury.

Reportable injury: Any injury other than a serious bodily injury which involves the enforced absence of the injured person from work for a period of 72 hours or more.

Minor Injury: An injury which results in the enforced absence for a period exceeding 24 hours (but less than 72 hours).

Serious bodily injury: Any injury which involves, or in all probability will involve, the permanent loss of any part or section of a body or the use of any part or section of a body, or the permanent loss of or injury to the sight or hearing or any permanent physical incapacity or the fracture of any bone or one or more joints or bones of any phalanges of hand or foot.

Major accidents: Which results in 4 to 9 deaths.

Disaster: Which results in more than 10 deaths.

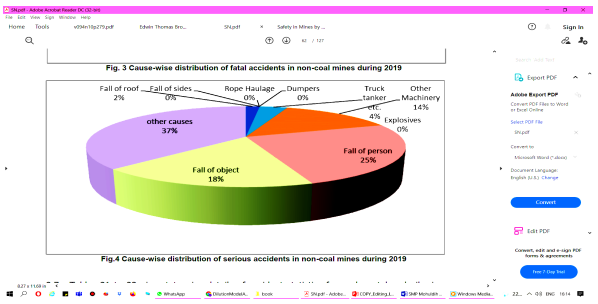

Fig1: Cause-wise distribution of serious accidents in non-coal mines during 2019.

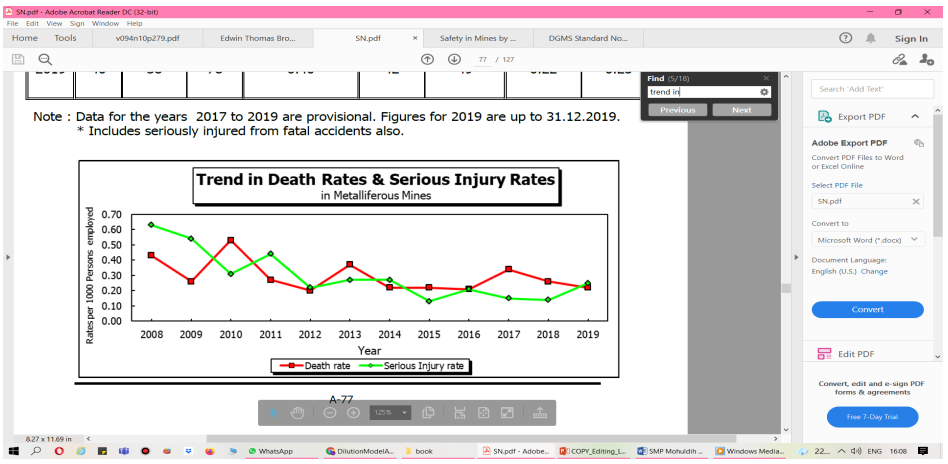

Fig 2: Trend in Death Rates & Serious Injury Rates in metalliferous mines for the years 2008 to 2019.

SAFETY and SUSTAINABLE MINING

Safety is an important dimension of sustainable mining practices, along with the others economy, environment, community, and efficiency.Three of these dimensions—economy, environment, and community—represent the pillars of sustainable development. In mining it is most important to consider safety and efficiency. Safety in the mining industry must encompass the full cycle of exploration, development, construction, operations, rehabilitation, closure, and final walkaway. Of course, associated activities such as mineral processing, smelting, and transport are all part of the industry, and excellence in safety needs to apply there as well.

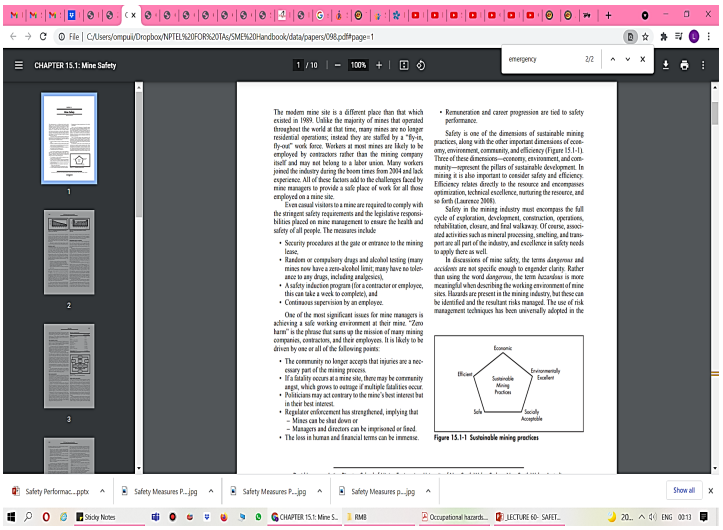

Fig 3: Sustainable mining practices.

HUMAN FACTORS

Human factors is the systematic application of relevant information about human characteristics, abilities, expectations, and behaviours to the design of machines, tools, facilities, procedures, and environments that people use. The simplest definition of human factors is designing things for human use The goal of human factors is to enhance the operational efficiency, and the health and safety of the people using the system. Despite the best systems and procedures, accidents and incidents do occur and many of these are caused by risk taking or human error. Too often, the serious accidents are a result of *conscious risk-taking, such as taking the easy way out, taking a short cut or not thinking about the risks in your workplace before starting work.* It is not uncommon to find that the victims knew the potential risk of accidents before the incident occurred".

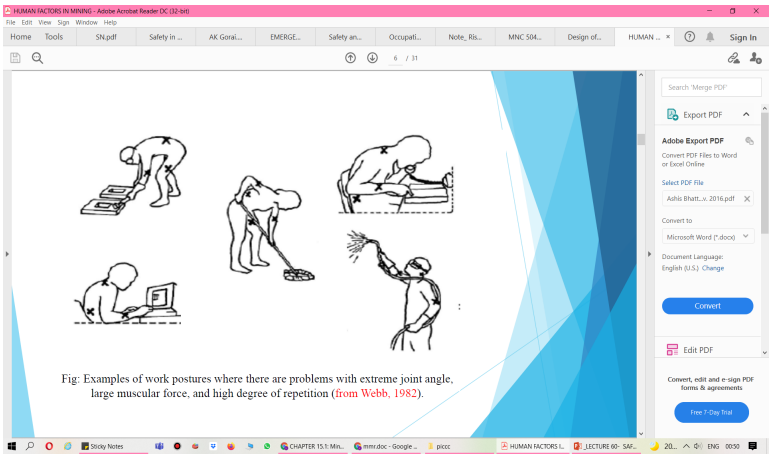

Fig 4: *Examples of work postures* where there are problems with extreme joint angle, large muscular force , and high degree of repetition (Webb, 1982)

HUMAN ERROR

Several researchers suggested that while mechanical and environmental failures are major contributors to many accidents, human behaviour plays a significant causative role. For example human error has been identified as the major causative factor in mine accidents in a study conducted by the former United States Bureau of Mines. USBM concluded that while a few accidents are caused by a single factor, human error was the most significant contributing factor and accounted for 93% of the total accidents.

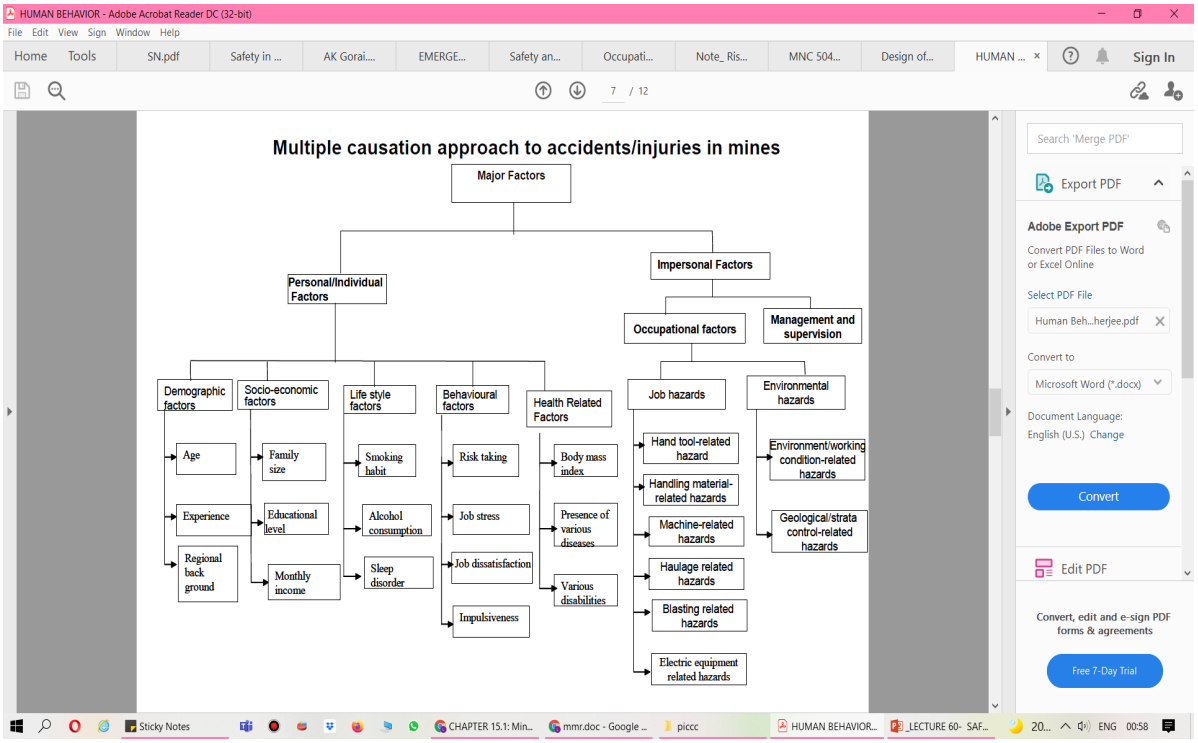

Fig 5: Multiple causation approach to accidents/ injuries in mines

WHEEL OF SAFE WORK

Work process model or Nertney wheel of safe work:

Nertney wheel of safe work shows important work process to achieve safe production:

Competent people:

Competency, Training, Fitness for work.

Fit for purpose Equipment:

Safe design/Manufacture, Safety Provisions.

Controlled work environment:

Dust, Noise, light hazard must be controlled. Proper Housekeeping, ensure safety while working at heights, near water-bodies, Gas, etc.

Safe work practices:

Practicing Risk Assessment, following Hierarchy of control, implementing SOP, ensure effective emergency management , etc.

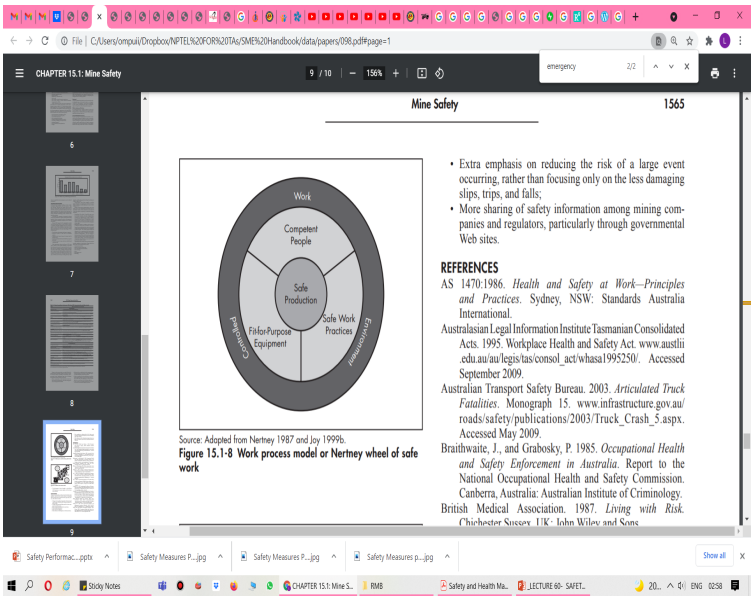

Fig 6: Work process model or Nertney wheel of safe work

SAFETY: SOME BASIC DEFINITIONS

- **HAZARD** is a source of potential harm, injury or loss.
- **RISK** is combination of the likelihood of a specific unwanted event and the potential consequences should it occur.
- **RISK MANAGEMENT** is an overall description of the steps taken to manage risk, by identifying hazards and implementing control in the workplace.
- **RISK ASSESSMENT** is a process that involves measurement of risk to determine priorities and to enable identification of appropriate level of risk.
- **RISK ASSESSMENT PROCESS** is a methodical examination of each and every aspect of work undertaken on a regular basis of identity hazards, determine risk rating and controls and to review the implementations of risk controls from previous risk assessment process.
- **CONSEQUENCE** is the outcome of an event or situation expressed qualitatively or quantitatively, being a loss, injury, disadvantage or gain.
- **LIKELIHOOD** is used as a qualitative description of probability and frequency.
- **PROBABILITY** The term probability can be defined as the likelihood of a specific outcome happening is the likelihood of a specific outcome, measured by the ratio of specific outcomes to the total number of possible outcomes.

- **RISK RATING** is a category or level of risk assigned following risk assessment.
- **RISK CONTROL** is an implementation of strategies to prevent or control hazards.

RISK ASSESSMENT PROCESS

Risk Identification: The risk identification involves finding the probability (the chance of getting harmed), the exposure (the percentage of the time a person is being exposed to risky situation or place) and identifying the possible consequences (minor injury, serious injury, fatality, etc.)

Risk Analysis: Risk analysis determine the risk score using the above identified risks such as probability, consequences of risks and the exposure. There are three types of risk analysis- Qualitative, Semi-quantitative and Quantitative risk analysis.

Risk Evaluation: The Risk Evaluation is the process used to compare the calculated risk score against the given risk criteria set by the organization so as to determine the acceptable risk, tolerable risk and intolerable(unacceptable) risks. There are two types of risk evaluation:

Risk acceptance(As Low As Reasonably Practicable - **ALARP**): Based on the risk criteria set by the organization. The risk can be of either acceptable (negligible) risk, tolerable risk and intolerable(unacceptable) risks.

Risk aversion: Risk aversion focus on the decision required to control the risk. It decides the actions to be taken to reduced or mitigate the risk.

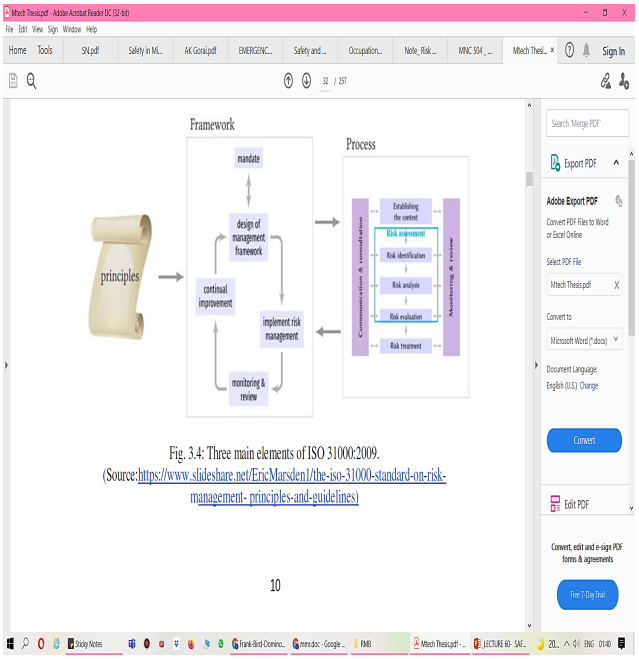

Fig. 3.4: Three main elements of ISO 31000:2009.
(Source:https://www.slideshare.net/EricMarsden1/the-iso-31000-standard-on-risk-management- principles-and-guidelines)

Fig 7: Risk management

SAFETY MANAGEMENT PLAN (SMP)

Safety Management Plan(SMP) is a working document, which outlines all of the actions to be carried out to ensure safety and health at the workplace.

Safety Management Plan based on Risk Assessment needs to be developed and implemented (vide DGMS Cir. 05 of 2016, DGMS(Tech) (S&T) Cir No 2 of 2011& 13 of 2002). A safety management system should set the culture, framework and action necessary to ensure that mining operations are carried out safely.

Steps for preparation of Safety management plan(SMP):

1. Formation of Hazard identification & Risk management team
2. Study of Tools of Risk management
3. Identification of the hazards & categorization
4. Specifying the mechanism contributing the hazard
5. Measuring the risk involved by taking into account ‘Consequences, ‘Probability’ & ‘Exposure’
6. Calculating the Risk Rating (Risk Score) of each identified hazard
7. Summarized hazard identification.
8. Development of worksheet for Risk assessment, control & audit.
9. Indicating the person(s) responsible for implementing the controls, and
10. Suggesting time frame/schedule for completion of task.

OCCUPATIONAL HAZARDS

Table 1: Occupational hazards

Physical hazards	Chemical hazards	Mechanical hazards	Biological hazards	Ergonomic hazards	Psychosocial hazards
➢ PHYSICAL INJURY •Fatal •Serious •Minor •Reportable ➢ NOISE INDUSED HEARING LOSS ➢ HEAT STRESS / HEAT STROKE ➢ WHOLE BODY VIBRATION •spinal disorders ➢ Hand–arm vibration syndrome ➢ Radon daughter exposure •Risk of lung cancer ➢ Solar ultraviolet exposures	➢ Toxic or Noxious gases •CO poisoning due to mine fire •Exposure to SOx/Nox ➢ Crystalline silica •Silico-tuberculosis •lung cancer ➢ Diesel particulate exposures ➢ Exposure to Coal dust •Pneumoconiosis ➢ Exposure to Asbestos •Asbestosis ➢ Manganese Poisoning (Nervous type)	➢ Injury due to mechanical energy • Hit by machines • Collision, Run-over forward movement or reversal •Trapped in machines –moving parts •Bursting of high pressure fluids / compressed air •Extremity caught in between •Material handling •Fall of objects •Fall from height	➢ Malaria and Dengue fever at some remote mining locations ➢ Leptospirosis and Ankylostomiasis ➢ Legionella	➢ Cumulative trauma disorders ➢ Overhead work is common underground, during ground support and during the suspension of pipes and electrical cables. This can cause or exacerbate shoulder disorders. ➢ Broken ground is often encountered and can cause ankle and knee injuries ➢ Fatigue in relation to shift work –Sleep deficits	➢ Fatal and severe traumatic injuries continue to occur in mining and often have a profound impact on morale. ➢ Work related stress •Frustration •Depression •Anxiety •Memory loss •Dissatisfaction ➢ Bullying ➢ Violence ➢ Sexual Harassment

SAFETY

OPERATIONAL HAZARDS IN UNDERGROUND METALLIFEROUS MINES:

- Improper strata control (roof fall/side fall)
- Drilling (Misfired explosives being initiated during drilling operations)
- Blasting (handling of explosives by unauthorized persons/charging & shot firing by unauthorized persons/Exposure to fumes)
- Loading of material (overloading)
- Haulage & transport failure(Over speeding of vehicle/collision)
- Slippery road way/improper travelling roadways.
- In adequate ventilation (mine gases/ respirable dust)

- Fire(fuel leakage/ short circuit/ welding & cutting)
- Noise
- Lack of illumination
- Inrushes (water/ slurry) including Tailing leakage
- Rockburst
- Airburst
- Electrical maintenance(fall from height, fall of object, shock)
- Fall of person (Slippery floor/ Stepping down from vehicle/Working at height/ Scattered material, tools etc.).