Accident and disease prevention in working life: Common grounds and areas for mutual learning

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Accident and disease prevention in working life: Common grounds and areas for mutual learning

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ABSTRACT: Globally, there are more than six times more fatalities caused by a poor working environment than due to occupational accidents. In this paper we compare the basic strategies involved in accident and disease prevention. We find that the basic thinking is the same. The preventive strategies involve control of hazards in a hierarchy from elimination to application of personal protective equipment. Also, the Norwegian regulation on internal control of HSE is applicable for both accident and disease prevention, involving the idea of continuous improvement. Still, the nature of the hazards differ, as well as the possible consequences. In the area of occupational safety, the hazards are usually visible and the consequences of accidents are immediate. In the area of occupational health, the hazards are often invisible and the consequences of exposure delayed. There is a potential for better integration of the two areas in practical management, and a potential for mutual learning from concepts and models in the two fields.

1 INTRODUCTION

Protection from harm in relation to work is a responsibility for politicians, authorities and employers. Still, work related diseases, accidents, injuries and fatalities continues to be a significant challenge.

According to ILO, globally 2.3 million deaths take place due to occupational injuries and diseases each year (Takala et al., 2014). Of these, over 2 millions of deaths are due to occupational diseases, among them 23% due to work related cancers.

In Norway, we have from 47 to 25 deaths each year from injuries in the period 2013–2016 (The Norwegian Labour Inspection Authority 2017), and 1% of the working population reported work related lung complaints in 2013 (NOA, 2017). In addition, it has been estimated that approximately 3000 new cases of work related Chronic Obstructive Pulmonary Disease (COPD) each year in Norway, and that 200 persons will die from this disease due to working conditions (Leira, 2011). Although these figures are high, there seems to be a positive trend both in work related accidents and diseases. The number of fatalities was more than 100 annually in the early 1970s, but has steadily declined. In 2016 the number of fatalities was 25 (The Norwegian Labour Inspection Authority 2017). The number of self-reported exposures for chemicals are declining, as well as reports of other work-related diseases (NOA, 2011, 2017)

Accidents in the construction industry still get high attention. However, some highlights the fact that the workers in this sector have increased risk for lung diseases (Bergdahl et al., 2004; Robinson, Petersen, Sieber, Palu, & Halperin, 1996; Vermeulen, Heederik, Kromhout, & Smit, 2002). Also in Norway the statistics from NOA shows that workers in the construction industry have more respiratory complaints, and more declared work related respiratory complaints than the national mean (Aagestad, 2015). Recent studies have also detected an association between exposure and an increased risk of COPD in the construction industry (Fell, Aasen, & Kongerud, 2014). In addition 59% of construction workers state that that they inhale smoke, dust or exhaust in their work situation (NOA, 2017).

The purpose of this paper is to compare the main strategies for the prevention of occupational diseases and occupational accidents.

2 PREVENTION OF OCCUPATIONAL DISEASES

2.1 *Exposure assessment*

The traditional approach for chemical risk assessment is to compare the exposure level of the chemical agent to their Occupational Exposure Limits (OELs). These OELs were established from late 19 century (Jayjock MA, 2000). Still this approach is regarded to be the best practice for risk assessment for chemical agents and noise. These limit values are given for occupational exposures during 8 hours shift, and there is guidelines on how to assess risk of exposure to noxious agents (NS-ISO689) and sound (NS-4815–1).

The sampling and analyses of airborne contaminants and comparing results with the national OELs have been challenging for different reasons. Due to variability in exposure both within workers and between workers, several samples have to be taken for each group of workers regarded as homogenously exposed (Chen, Chuang, Wu, & Chan, 2009; Rappaport, Lyles, & Kupper, 1995). The cost for each analysis and the resources needed to perform the measurements have resulted in a limited number of measurements from the different parts of the Norwegian industry. Reported measurement results from the construction sector are rather sparse, except some from tunnel construction, cement work and Bricklayeres (Bakke, Ulvestad, Thomassen, Woldbæk, & Ellingsen, 2014; Beaudry et al., 2013).

A new approach to risk analyses on health effects have been widely used since the introduction of REACH (Money, 2003; Office, 2017; UK, 2017). This new approach take into consideration the health classification of chemicals or particles are use this together with an exposure assessment (Money, 2003). The classification of health effects are performed on the basis of the agent's inherent toxic property, often by use of the CLP classification (CLP-ref) but the risk assessment are also dependent on the exposure. This exposure assessment may be founded on subjective assessment and exposure toolkits (Office, 2017; UK, 2017). The subjective assessment method uses a structured approach, based on descriptive information about work activities and the work environment, and have been validated against exposure measurements (Cherrie & Schneider, 1999). This new approach makes it possible to do risk assessment of chemicals and particles which do not have an OEL and without measurements. However, when the risk analyses shows that there may be an unwanted risk; measures have to be taken to comply to the model, or measurements have to be performed in the old fashion way to document that there is an acceptable risk.

2.2 *Hierarchy of exposure controls*

Within occupational hygiene, control of exposure is a fundamental method for protection of workers. Traditionally ahierarchy of controls has been used as a mean of determining how to implement feasible and effective control solutions. The hierarchy is often illustrated as in Figure 1, where elimination is the most effective measure, and include physically removal of the hazard. Substitution is replacement of the hazard, engineering controls isolate people from the hazard, administrative controls change the way people work and Personal Protective Equipment (PPE) is the weakest measure protecting the worker against the hazard.

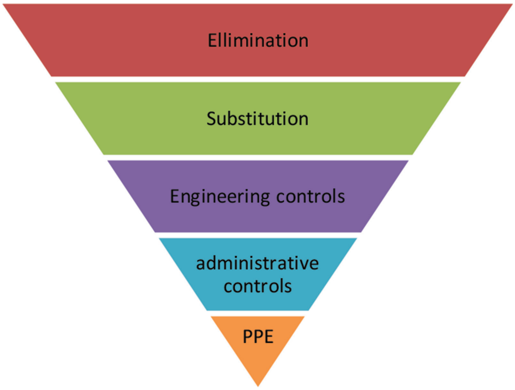


Figure 1. Control of exposure.

The principle behind this hierarchy is that the control methods at the top of graphic are potentially more effective and protective than those at the bottom.

In practical use, however, it is often more difficult. Using a smelting plant as example, the production of metal or metal alloy like aluminium, silicon, silicon carbide or ferromanganese is the basic idea behind a production plant. The top two measures, elimination and substitution of the raw material is impossible; and the occupational hygienist only have the three lowest ranked measures available. The smelting industry is very energy-intensive and access to cheap energy often determines where the factories are located. The processes are often old and physically relatively simple, but produce large amounts of pollutants. In the silicon carbide industry the cancer risk have been documented since 2000 (Romundstad, Andersen, & Haldorsen, 2001), and the dust exposure is documented to contain both fibers (Bye, Eduard, Gjonnes, & Sorbroden, 1985) crystalline silica, silicon carbide (SiC) and sulphur dioxide (S. Føreland, Bye, Bakke, & Eduard, 2008). The workers in this industry is heavily loaded by personal protective equipment using dust mask, CO alarm, eye protection, hearing protection, safety helmet, gloves and safety clothes. The Silicon carbide industry is not the only industry using this as main principle, even that isolation of the process; local exhaust ventilation or general ventilation would have been more effective types of measures.

This was pointed out by Føreland (Solveig Føreland, Bakke, Vermeulen, Bye, & Eduard, 2013) as late as 2012stating that "recommendations for exposure reduction based on this study are (i) to separate the sorting area from the furnace hall,

(ii) minimize manual work on furnaces and in the sorting process, (iii) use remote controlled sanders/grinders with ventilated cabins, (iv) use closed systems for filling pallet boxes, and (v) improve cleaning procedures by using methods that minimize dust generation".

Following the hierarchy normally leads to the implementation of inherently safer systems, where the risk of illness or injury has been substantially reduced, but as the example shows, it is not always possible to use the most favorable measure.

The same kind of example could be used for the construction sector, as the work itself produces pollutants that is impossible to avoid as concrete, wood dust, stone dust and exhaust from vehicles. The only one that may be substituted is the exhaust when new vehicle technology is developed. This makes it necessary to use the last favorable protective measure; the personal protection devices.

3 PREVENTION OF OCCUPATIONAL ACCIDENTS

The barrier concept is a basic foundation in strategies for occupational accident prevention. An accident can be understood as caused by energy out of control (Gibson, 1961), where a hazard (source of energy) releases energy. This energy is then absorbed by a victim which leads to loss (health, life). Following this energy model, accidents can be prevented by barriers that stops or prevents a sequence of events that lead to loss of control of hazards (Kjellén and Albrechtsen, 2017). As shown in Figure 2. the barrier philosophy follows the same logic as control of exposure (Figure 1)

Seen in a functional perspective, safety barriers perform tasks, such as preventing falling objects from hitting people working below. Such functions or tasks are performed by different barrier elements that constitute a barrier system (Rosness et al. 2010). Physical devices, human actions and administrative procedures serve as barrier elements meant to protect vulnerable targets from harm (Sklet, 2006).

A 'defence in depth' strategy is commonly applied in the prevention of accidents. According to Reason (1997:12), major accidents occur as a result of failures in multiple layers of the defences separating potential hazards from people and assets. Accident trajectories pass through 'holes' in these defences, created by active failures—errors and violations—and/or latent conditions, such as lack of competence, design flaws and unrealistic procedures.

For example for a lifting operation, two barrier functions must be in place: 1) prevent sudden release of the gravity energy that the lift represent and 2) separate the gravity energy that the lift represent and workers (establish a safety zone). The first barrier function (prevent sudden release of energy) is realized by a set of barrier elements: sling mechanism, crane driver competence, slinger competence, signal man, control rope etc.

Haddon's (1980) defined ten generic principles for the prevention of harm (injury) from transfer of energy. These ten strategies are generic barrier functions to either control the hazard; separate the hazard and a victim; or make the offer more robust to harm. See Figure 3.

Haddon's (1980) strategies and the energy accident model (Gibson, 1961) have had significant influence on European legislation and standardisation work such as that related to hazardous chemicals (European Council 1998) and machinery safety (European Council 2006). The strategies are central components in accident investigation methods such as in the OARU, Management Oversight and Risk Tree MORT, Safety Management and Organisation Review Technique (SMORT) (Kjellén and Albrechtsen, 2017).

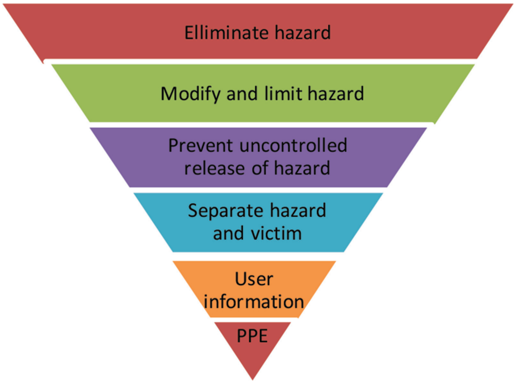
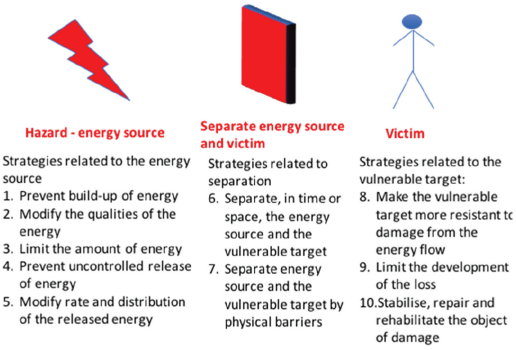


Figure 2. Control of hazards.



Strategies related to the energy source
1. Prevent build-up of energy
2. Modify the qualities of the energy
3. Limit the amount of energy
4. Prevent uncontrolled release of energy
5. Modify rate and distribution of the released energy

Strategies related to separation
6. Separate, in time or space, the energy source and the vulnerable target
7. Separate energy source and the vulnerable target by physical barriers

Strategies related to the vulnerable target:
8. Make the vulnerable target more resistant t damage from the energy flow
9. Limit the development of the loss
10. Stabilise, repair and rehabilitate the object of damage

Figure 3. Haddon's principles for accident prevention.

Risk mitigation in the European Council (2006) Directives on Machinery is based on Haddon's strategies. ISO 12100:2010shows a strategy for selection of safety measures of machinery, see Figure 4. The strategy reflects that hazards should be prevented or limited at the design stage, i.e. designed out. If this is not possible, protective measures and safety controls should be established to separate victims and the hazards of the machinery. Residual risk after these measures can be accepted, but requires that the producer inform the user about these. The user of the machinery is responsible for training, and safe operation at work, including providing necessary personal protective equipment.

To implement the correct barrier system (functions and elements) risk assessments are essential. The results of risk assessment serve as decision-making support to implement adequate safety measures. ISO31000 Risk Management gives descriptions of the principles and steps in risk assessment and risk handling. Briefly, the steps are: identify hazards and incident scenarios; analyze causes; analyze frequency and consequences; analyze risk; evaluate risk according to risk acceptance criteria; and mitigate risk. The analysis of risk is made by systematically collect available knowledge about the analysis object and use this knowledge to express what can go wrong in the future; what the likelihood of it happening; and the consequences if it happens (Rausand, 2011). This risk picture is then evaluated to risk acceptance criteria to detriment whether the risk is acceptable or not.

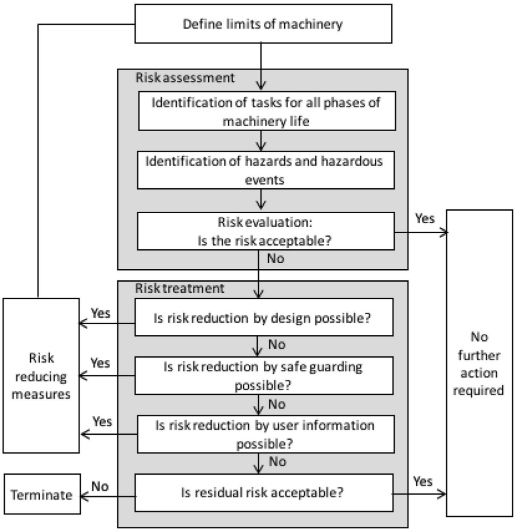


Figure 4. Risk treatment and risk assessment of machinery (based on ISO12100).

The Directives of Machinery shows how risk assessment is the input to risk mitigation, see Figure 3. ISO 12100:2010show the steps for risk assessment of machinery. It follow the same steps for risk assessment as described in ISO31000, but starts with an identification of the machinery and intended/unintended use of the machinery for all life phases of the machinery.

3.1 *Tunnel construction as example*

An analysis of fatal accident from hydropower instruction projects in Kjellén and Albrechtsen (2017) show that there are two types of fatal accidents in tunnel excavation: falling rock/rock burst and workers squeezed or driven over by vehicle. Barriers to prevent such fatal accidents would mainly be to separate in time/space the hazard and the victim. For blasting work workers are moved away from the blasting area.

During construction work other than blowing work, accident risks are in particular conflicts between workers and heavy machinery, falling objects (rock fall/rock burst) and getting squeezed during rigging.

One of the work activities in tunnel excavation are assembly of different materials and infrastructures in the roof. The accident risk for such operations are falling objects and squeezing. In Norway, there has been fatal accidents at scissor lifts, where the victim has been squeezed between the lift and the roof. Risk mitigation for this scenario is to design in pressure-released stop of the lifting mechanisms.

Work at height will also involve significant occupational hygiene risk. From an occupational hygiene perspective it is well known that tunnel workers are exposure to both particulate and gaseous air pollution and that tunnel workers are known to be at increased risk of long-term and short–term lung function decline and CORP (Ulvestad et al.). Different activities causes different exposures to these workers. Exposure to gases and particles from diesel emissions has been considered to be among the dominating burdens during tunnel construction due to weel-going diesel machines; also during drilling and blasting operations, workers are exposed to dust, with α-quartz as the most important agent. α-quartz in the dust from tunnels varies between <1% and more than 50% (Norwegian Tunnelling Society,Publication No.13) and α-quartz exposure may lead to COPD. Exposure to oil mist and oil vapour is another type of exposure that may also occur during drilling. Exposure to oil mist may cause occupational asthma and also pulmonary fibrosis (Robertson et al., 1988) Risk assessment hence have to be performed with focus on all these possible exposures.

If we look into Figure 1 in order to identify preventive measures it seems logic that elimination and substitution is difficult. None of these activities could be eliminated if the tunnel should be constructed. Substitution might be possible if we look into the type of explosive used for blasting. Ammonium nitrate fuel oil is used as explosive, and if this agent is substituted with size-sensitised emulsion, the worker exposure lower (Ulvestad). Apart from this example engineering controls often is the first possible preventive measure, where ventilation of the tunnel, pollution-abatement equipment for diesel vehicles is some of the measures often used. High frequency maintenance routines are an example of administrative controls, while personal protection equipment only should be the last solution, but in real life often is used on a daily basis.

4 DISCUSSION

4.1 *Common grounds*

The law/regulation on internal control makes it clear that all enterprises in Norway should have a system for safeguarding health, safety and environment. This system includes information on health and safety regarding issues in the working environment, requirements for establishing goals for the HSE-work, performing risk analyses for any hazard and establish routines for unveiling, correcting and preventing violations of the law and regulations.

The internal control regulation that is the source for management systems for HSE control is the same for both safety and workers health, and builds on quality principles. Theories on quality gained much attention in industry from the 1980s, and was first related to improvements in the production processes. Total quality management became an influential movement, spurred by the works of Deming (1986) and Juran. Later, the principles were used as a foundation for internal control for HSE in Norway (Saksvik & Nytrø, 1996).

The idea of continuous improvement is evident in both the prevention of occupational diseases and in the prevention of occupational accidents, illustrated in Deming's circle (Figure 5):

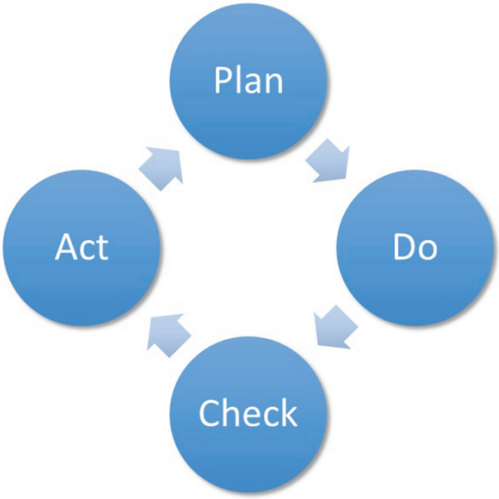


Figure 5. Deming's circle.

In the prevention of occupational diseases related to the exposure to chemical, quality principles are at work when exposure levels are compared to OELs, and when measures are taken to mitigate or eliminate the exposure, illustrated in the hierarchy of controls (Figure 1).

In the prevention of occupational accidents, the idea of continuous improvement is the foundation for safety information systems, and the experience feedback such systems entail. By means of safety indicators, safety audits, and accident investigations, information is applied to implement measures for accident prevention.

The barrier philosophy of both areas is the same. Both aim at first prioritizing efforts directed at the source of danger by elimination, modification and limitation. Second, both areas emphasize to avoid interface between risks and victims by substition and separation. Third, both areas emphasize engineering control by built-in solutions in design. Finally, the last measure in both areas is to approach the victim by information, training, procedures and lastly personal protective equipment.

Many of the occupational hygiene risk factors can contribute to higher accident risk by influencing human performance. The human operator is an essential barrier element to realize barrier functions. Stress (fatigue, time load and task load); situation/environment (physical and chemical work environment); and human-machine interactions are among performance shaping factors (Groth and Mosleh, 2012) that affect the quality of the human barrier element in accident prevention.

4.2 *Differences in the nature of hazards and consequences*

One obvious difference between the health and safety field, is the nature of the hazards that should be handled. Hazards in the field of safety are a form of energy that is not properly controlled. Further, hazards may cause immediate harm if safety barriers are not in place, or if they are not functioning as intended.

In the area of occupational health, hazards are not limited to energy sources, although vibration, radiation and noise is clearly within the energy perspective. But also toxic fumes, cancer inducing and poisonous agents represent hazards, not directly related to energy and more or less invisible in nature.

Further, hazards within the occupational health domain do in many instances not cause immediate harm, but the harm may be delayed. In some instances it may take several decades from exposure to the loss is evident. Although there are nuances in this, this can be summed up in a general manner as in Table 1:

Table 1. Differences in the nature of hazards and consequence in occupational safety and occupational health.

	Hazards	Consequences
Occupational safety	Visible	Immediate
Occupational health	Invisible	Delayed

Even if more than six times more occupational deaths are caused by diseases than accidents, there is a tendency that accidents get more attention. Accidents are concrete, often dramatic events, and with immediate consequences. This will naturally generate attention from employers, authorities and the general public, often followed by demands for measures that ensures that similar events will not take place in the future.

Occupational diseases are less dramatic, and as the consequences are often delayed, there will also be an issue of employer responsibility for the harm. The employee might have changed employer several times before the disease is evident. Diffused responsibility, coupled with the more invisible nature of the hazards, and the latency period from exposure to disease, might result in less attention from outside actors.

In the end it might also lead to less resources to the prevention of occupational diseases, relative to the needs. The regulatory authorities should be aware of such mechanisms, and implement requirements to ensure that the prevention of occupational diseases get proper attention and the resources.

4.3 *Cross-disciplinary learning?*

Although some of the preventative strategies related to accidents and diseases seems to be the same, the professional concepts that are applied differ. For example, control of exposure vs. control of hazards refers to the same line of thinking. The professional concepts in the two fields have developed over a long period, and are institutionalized and applied in research and theory building. The distinct repertoires of concepts ensures precision and are a foundation for theory development within the two fields. Thus, the development of a common professional language seems unrealistic and also undesirable.

Still, mutual awareness of the concepts, models and theories that have been developed in the respective fields can represent a fruitful cross-pollination, and instigate new ideas for prevention. For example, within the safety field, there exists many accidents models; domino models (Heinrich, 1931), information models (Turner & Pidgeon, 1997), and the swiss cheese model (Reason, 1997) to name a few. There are also perspectives related to what kind of organizational characteristics that may prevent accidents, including the theory of high-reliability organizations (Weick, Sutcliffe, & Obstfeld, 1999) and Resilience Engineering (Hollnagel, 2014). Researchers with occupational health might find such models to be inspiring and of relevance.

A basic concept related to the prevention of occupational diseases is OELs. Actual exposure levels of chemical agents are compared to OELs to determine whether the exposure might induce harm. Much research lies behind the definitions of OELs. This might be an interesting area for occupational safety. Although the hazards are of a different nature, setting clear thresholds for exposure might be an issue for further exploration, even if there exist similar lines of thinking (e.g. the notion of acceptance criteria, and the ALARP principle, As Low as Reasonably Practicable).

In many instances, HSE practitioners working within companies (e.g. HSE engineers, managers etc.) will have responsibilities related to both health and safety. From their professional background, they will have insight into the different research fields, and be in a position to integrate them, and treat HSE as a holistic concept. Academics tend to be more specialized within one of the fields of research. Thus, for researchers interested in cross-disciplinary learning, HSE practitioners might be a resource for practical knowledge integration. It is also a responsibility for academics and educators to prepare prospective HSE workers for the cross-diciplinary challenges they will meet in working life. Real working life problems do not necessarily follow professional boundaries, but require a cross-disciplinary approach. Thus, cross-disciplinary learning in the areas of occupational health and safety should be an important issue in university education.

5 CONCLUSIONS

The paper demonstrates that there are similarities between management of occupational health and safety, but also that there are potential improvements for better integration of the two areas in practical management.

As indicated in the introduction of the paper there are far more death and personnel harm due to poor working environment than there are deaths and injuries due to occupational accident. However, accidents and accident prevention seems to get more attention by HSE practitioners and mass media. Possible explanation for this picture could be the different nature of the hazards and the lagging consequences of occupational exposure compared to the sudden consequences of an accident.

Common for both prevention of both occupational disease and occupational injury is that adequate planning would prevent many events by establishing adequate barriers

Topics for further research of the interaction between occupational health and safety can include:

How is HSE implemented in practice in the building and construction industry? Is safety more focused than work environment? And if any difference could be identified, what is the explanation behind this. Some hypotheses could be investigated: A) Simple measurable parameters within security, such as accidents per 1000 hours of work or absence per 1000 hours make safety easier to control. B) Control of exposure is not defined as a project-specific activity and hence an activity belonging to the internal control system of the sub contractors, which in practice means greater variation in how much focus it gets in practical work. C) Differences between safety culture and work environment culture exist.

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