Training measures and technologies for air contaminant risks

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Appended papers

Paper I

Short-term Variation in Occupational Exposure to Air Contaminants
Karl Gummesson, Ing-Marie Andersson, Gunnar Rosén
Journal: American Industrial Hygiene Association Journal
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Paper II

Safety Motivation at Work: Evaluation of Changes from Six Interventions
Ann Hedlund, Karl Gummesson, Alexis Rydell, Ing-Marie Andersson
Journal: Safety Science
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Paper III

Effective Measures to Decrease Air Contaminants through Risk and Control Visualization – A Study of the Effective Use of QR codes to Facilitate Safety Training
Karl Gummesson
Journal: Safety Science
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Paper IV

Safety and Health Training in Managing Wood Dust – On safety representatives’ experiences
Karl Gummesson, Alexis Rydell, Annika Vänje
Journal: not decided
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Prologue

“It is so sick that in summer when the sun shines into the wood industry, the workers go around the sunbeam because in the shadow the dust is not visualized.”

This quotation from an interview with a safety representative inspired me in my thesis work and made me understand not only the importance of using visualization to create awareness of the risks, but also the benefits of knowledge in the workplace.

Having worked in various companies and industries, and having friends and family share their experiences of their work lives, it is clear to me that the workplace plays a large part in people’s lives. That fact largely inspired me to focus on the theme of this thesis and thus help contribute to improving the working situation and safety for the individual in such workplaces. My understanding is that many individuals who are new to a company are inexperienced, and/or perhaps lack knowledge about how to behave safely in the working environment.

My intentions therefore stem from a keen curiosity in health and safety and from a personal interest in making a positive difference in the work life of the human individual. This thesis was generated by the inspiration, comments and guidance of my supervisors Marianne Ekman Rising, Ingrid-Marie Andersson, Annika Vänje and Gunnar Rosén. Thank you for all the time, help, discussions and support.

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Abstract

As air contaminants continue to pose a problem in organizations, more studies are needed to identify and reduce employees’ exposure to air contaminants, not only for public health reasons, but also to reduce costs incurred by organizations and societies. Limited research proposes methods for managing and controlling air contaminants, especially with focus on reducing exposure by improving safety behavior, safety knowledge, safety attitudes and safety motivation among employees in the workplace, by, for instance, using safety training.

The aim of this thesis is to develop existing safety measures and analyze new measures for reducing air contaminants in typical industrial work situations by focusing on human aspects, such as safety attitudes and safety motivation. This is carried out by studying safety attitudes, safety motivation, and safety training in relation to air contaminant safety in current Swedish organizations by means of questionnaires, interviews, reviews of research, as well as the exposure monitoring method, Picture Mix EXposure (PIMEX) (see Central and related concepts of the thesis, and Methodology).

This thesis focuses on the study of air contaminant exposure peaks, which has received limited attention in the literature. Exposure peaks are identified in typical work situations in Swedish industrial organizations. Using the video-based exposure monitoring method PIMEX, observations and control measures of exposure to increase safety have been performed in work situations. Peak exposure indicates risks in work situations and is identified among workers in Papers I, II and III. Video sequences can be produced based on PIMEX measurements and videos. Control measures to handle air contaminant risks to control air contaminant exposure are shown in safety training interventions in Papers II and III.

This thesis comprises four papers. In the first paper, ten industrial work situations were examined in the engineering, pharmaceutical, print shop, stone and wood industries, using the PIMEX method. Measures of exposure variation were calculated, such as geometric standard deviation (GSD), geometric mean value (GM), and maximum exposure, divided by arithmetic mean (Maximum/AM). The results showed that the characteristics of exposure variation vary between industrial work situations among workers, with samples of work situations from the stone, wood, and pharmaceutical industries that generated highest peak exposure. Combining PIMEX with the calculation of exposure variation measured as GSD can help to identify and reduce exposure to air contaminants in industrial situations by introducing more targeted control measures, such as improving work practice.

Paper I showed that the identification and reduction of peak exposure can reduce overall exposure by more than 50%. Papers II and III were created to apply this knowledge to safety training. In Paper II, six safety training interventions included: 1) PIMEX (see PIMEX) visualization of risks and control measures in presentations by a safety representative, 2) Practice of PIMEX and related discussions in a work situation, 3) Swedish regulation and work with systematic work environment management. Safety training intervention, 4) risk and
control at computer screens, 5) individual health assessment with feedback from occupational health services was also implemented. In addition, the six safety training interventions included also: 6) effective workplaces that embraced improvement work, such as "lean production" and systematic work environment management, by means of lectures and reading, as well as practical safety activities.

In Paper II, a validated safety motivation questionnaire (see Appendix A) was used in two metal companies, one paper mill company, two municipal agencies, and one plastic company. The paper contributes to the practical use of a safety motivation questionnaire and a theoretical path diagram about safety motivation. Paper II also showed that in the PIMEX training, where visualization of risks and control measures were presented for the workers, that safety motivation increased. The workers said that they followed existing procedures concerning the work environment to a higher degree and that work environment improvements felt more important after the safety training than before the training. Paper II showed that factors for occupational training are influenced by decision makers of the target groups in training. In addition, an increased number of training times and a high degree of participation in relation to the occupational training in question were shown to be essential for an effective training intervention.

In Paper III, QR codes linked to PIMEX videos were attached to wood machines in vocational programs at senior high schools. A QR code is a two-dimensional barcode that can be read with a smart phone or IPhone. The purpose of implementing these systems in schools was to train students about air contaminant exposure risks and control measures. The students were interviewed and the interviews transcribed and analyzed. The results of the study showed that linking QR codes to PIMEX videos effectively increases safety awareness, knowledge, and attitudes, which supported control of air contaminant risks among future workers/students.

Based on the empirical experiences in Papers II and III, Paper IV was created to gain further clarity of safety training measures, in order to reduce air contaminants exposure among workers. Consequently, in-depth interviews were performed. The interviews were transcribed and analyzed using value coding. Safety representatives were interviewed as they have safety experiences and knowledge about the workplace where air contaminants are common. The results highlighted: 1) safety routines, 2) a strategic plan of safety training, 3) safety training focus, 4) safety training tools, and 5) safety training subjects that can facilitate safety training to reduce air contaminants. For instance, essential factors for making safety training effective towards decreasing air contaminant exposure were small group sessions and group tasks in training.

This thesis includes studies about implementation of health and safety training in Sweden to reduce exposure to air contaminants among workers, primarily, in industries, such as the wood and printing industries. New safety training methods to reduce exposure to air contaminants were developed and tested, and safety training research was analyzed. Consequently, improvement of control measures to decrease air contaminant risks with the help of safety training were performed in this thesis. Safety training has been shown to increase safety
motivation and safety attitudes in relation to the control and reduction of air contaminants in typical work situations.

**Sammanfattning**

Syftet med denna avhandling är att utveckla befintliga arbetsmiljöåtgärder och analysera nya metoder för att hantera exponering i arbetssituationer där luftföroreningar finns. Detta görs genom att studera arbetsmiljöattityder, arbetsmiljömotivation och arbetsmiljöutbildningar som är relaterade till luftföroreningar i svenska organisationer. Arbetsmiljöattityder, arbetsmiljömotivation, arbetsmiljöutbildning och kontrollmetoder för att minska risken i form av luftföroreningar studeras med hjälp av enkäter, intervjuer, tidigare forskning och Picture Mix EXposure (PIMEX) (se Central and related concepts of the thesis, och Methodology).


Denna avhandling består av fyra delstudier. I Paper I (delstudie 1) studerades tio olika arbetssituationer inom svenska organisationer med hjälp av PIMEX-metoden. Variation har beräknats, genom värdenivår såsom geometriska standardavvikelsen (GSD), geometriskt medelvärde (GM), och maximala exponeringen dividerad med det aritmetiska medelvärdet (Maximum/AM). Resultaten visade att exponeringen av luftföroreningar hos arbetstagaren varierade mellan industriella arbetssituationer. Arbetssituationer inom sten, trä och läkemedelsindustrin genererade högsta kortvariga exponeringen. En slutsats från Paper I är att kombinationen av PIMEX med beräkningen av exponeringsvariation mått som GSD kan bidra till att identifiera och minska exponeringen för luftföroreningar i industriella situationer genom att utveckla riktade kontrollåtgärder, såsom förbättring av arbetsutförande.
Paper I bidrog med kunskap om att minskning av hög kortvarig exponering kan reducera den totala exponeringen med mer än 50 %. Paper II och III utvecklades för att använda kunskap om hög kortvarig exponering i arbetsmiljöutbildningar. I paper II har sex utbildningar inom arbetsmiljö utförts och utvärderats genom mätningar före och efter utbildningen med en enkät om motivation till arbetsmiljö, såsom användning av skyddsutrustning. De sex utbildningarna inkluderade 1) Picture Mix EXposure (se PIMEX) – videos där risker och kontrollåtgärder var visualiserade i en presentation av ett skyddsombud och, 2) utövande av PIMEX samt tillhörande diskussioner i en arbetssituation. Arbetsmiljöutbildningarna 3) svensk lagstiftning och systematiskt arbetsmiljöarbete, samt 4) risker och åtgärder inom arbete med datorer på arbetsplatsen och 5) individens hälsa samt funktionell bedömning med feedback från företagshälsovården innefattades också i de sex interventionerna. Paper II omfattade även arbetsmiljöutbildningen 6) effektiva arbetsplatser, om förbättringsarbete i organisationer såsom ”lean production” och systematiskt arbetsmiljöarbete, genom utbildning såsom praktiska arbetsmiljöaktiviteter, läsning samt undervisning.

Ett validerat frågeformulär användes (se Appendix A) där arbetsmiljömotivation utvärderades i två metallföretag, ett pappersbruk, två kommunala organisationer, och ett tryckeriföretag. Paper II bidrar genom att praktiskt använda ett frågeformulär med före och eftermätningar av arbetsmiljömotivation i sex arbetsmiljöutbildningar. Paper II hade även ett teoretiskt bidrag i form av en modell som baserades på tidigare forskning som innefattade faktorer som kunde relateras till arbetsmiljömotivation. I arbetsmiljöutbildningen med fokus på visualisering av risker och åtgärder för att minska luftföroreningar ökade motivation till arbetsmiljö bland medarbetarna. Medarbetarna beskrev att de följde befintliga regler och procedurer när det gäller arbetsmiljö i högre grad, och att arbetsmiljöförbättringar känns viktigare nu än innan arbetsmiljöutbildningen. Paper II påvisade även att påverkande faktorer för att effektivisera en arbetsmiljöutbildning påverkas av beslutsfattare, målgrupper, antal tillfällen och grad av delaktighet i förhållande till arbetsmiljöutbildningen i fråga.


arbetsmiljöutbildning med syfte att minska luftföroreningar såsom 1) rutiner, 2) strategisk plan för arbetsmiljöutbildning, 3) fokus, 4) verktyg och 5) ämnen för arbetsmiljöutbildning. Exempelvis var mindre gruppmöten och grupputgifter uttryckta av skyddsombuden som främjande för en god arbetsmiljöutbildning med syfte att minska exponering av luftföroreningar.

I denna avhandling undersöckes implementering av arbetsmiljöutbildningar i Sverige med ett syfte att minska exponering för luftföroreningar bland medarbetare i organisationer, inom främst industrier såsom träindustri och tryckeriindustri. Arbetsmiljöutbildning och litteratur inom detta område analyserades. Nya utbildningsmetoder inom arbetsmiljö för att minska exponering av luftföroreningar utvecklades och testades. Det påvisades också en förståelse för hur åtgärder av risker i form av luftföroreningar kan förbättras med hjälp av arbetsmiljöutbildning. En förståelse har också skapats i avhandlingen för hur arbetsmiljöutbildningar påverkar motivation och attityder till arbetsmiljö i förhållande till åtgärder och minskning av luftföroreningar i typiska arbetssituationer
Contents
Central and related concepts of the thesis .......................................................... 1
Fundamental Abbreviations .................................................................................. 2
Introduction .......................................................................................................... 3
Aim and research question .................................................................................. 6
Disposition .......................................................................................................... 6
Theoretical framework .......................................................................................... 7
  Societal and organizational progress of work environment safety ...................... 7
  Summary of societal and organizational progress of work environment safety .......... 9
Legal obligations with regard to air contaminants in the workplace ...................... 9
  Summary of legal obligations with regard to air contaminants in the workplace .......... 10
Control of air contaminants to prevent exposure .............................................. 10
  Summary concerning control of air contaminants to prevent exposure ................ 14
Safety motivation in work situations ................................................................. 14
  Safety motivation, safety climate, and safety behavior ........................................ 15
  Safety motivation, management and organization .............................................. 17
  Summary of safety motivation in work situations .............................................. 18
Safety attitudes in work situations .................................................................... 19
  Safety attitudes, behavior, culture, and climate ............................................... 20
  Safety attitudes among leaders and management .............................................. 21
  Summary and understanding of safety attitudes in work situations .................... 21
Safety training in work related situations .......................................................... 22
  Challenges and safety training ................................................................. 23
  Implementation of safety training ................................................................. 23
  Summary of safety training .............................................................................. 24
Safety attitudes, training, and motivation for control of air contaminants ............... 25
Methodology ........................................................................................................ 26
  Qualitative and quantitative research ........................................................... 27
  Interviews ........................................................................................................ 28
  Questionnaire ................................................................................................. 31
  Statistical analysis ......................................................................................... 31
  PIMEX ............................................................................................................ 32
  Literature search ............................................................................................. 34
Central and related concepts of the thesis

The following definitions and clarifications present the central and related concepts of the thesis.

**Air contaminant:** Substance or mixture of substances in the air over a certain level of exposure that can cause illness among human individuals (The Swedish Work Environment Authority [SWEA], 2015a).

**Control measures:** Industrial hygiene measures that control risks to human health by reducing or removing exposure (Plog, 2002). These may include substituting materials that are toxic or harmful, changing work processes, installing exhaust ventilation systems, wearing personal protective equipment, or good housekeeping, such as improving methods of waste disposal (Plog, 2002). Control measures can also be defined as, “All possible means to control health hazards” (Lumens, 1997 p. 1).

**Organization:** Organization, in this thesis, is used as an umbrella term for various types of companies and industries. The focus of the thesis is on companies from the manufacturing industry, such as the wood industry.

**PIMEX (Picture Mix Exposure):** A method where air contaminant exposure is measured and shown in real time, together with video filming. The results are presented in a computer software as a video and graph (Rosén et al., 2005).

**Safety attitudes:** “An ideal safety attitude is an attitude contributing to enhancing the safety, i.e. safe behaviour and lowering the frequency of accidents and near-accidents. A non-ideal attitude is one that contributes to the opposite” (Rundmo & Hale, 2003 p. 559).

**Safety motivation:** The term safety motivation refers to an “individual’s willingness to exert effort to enact safety behaviors and the valence associated with those behaviors” (Neal & Griffin, 2006 p. 947).

**Safety training:** OSH/safety training in the present thesis refers to an activity related to the workplace focused on increased knowledge about safety and health among workers, safety professionals or management. OSH training, in this thesis, is used synonymously with safety training.

**Solvent:** Commonly referred to as liquids that can dissolve gaseous, liquid or solid substances (National Encyclopedia, 2017).

**Source:** “Possible cause of exposure” (Buring, 1992 p. 348). Sources can be divided into work environment, agents, work practices, processes, and appliances (Buring, 1992). Source can also be understood as the emission of a dangerous substance (Lumens, 1997).

**Wood dust:** Wood dust is defined as any wood particles arising from the processing or handling of woods (The National Institute for Occupational Safety and Health, 1988 p. 1).
**Fundamental Abbreviations**

**AFA:** Labour insurance company

**AM:** Arithmetic mean

**EU-OSHA:** The European agency for safety and health at work

**GM:** Geometric mean

**GSD:** Geometric standard deviation

**HES:** Health, environment and safety

**HSE:** Health and Safety Executive

**ILO:** International Labour Organization

**LEV:** Local exhaust ventilation control

**LO:** The Swedish Trade Union Confederation

**Maximum/AM:** Maximum exposure divided by arithmetic mean

**mg/m³:** Milligrams per cubic meter

**OSH:** Occupational safety and health

**ppm:** parts per million

**PIMEX:** Picture Mix Exposure

**SAF:** The Swedish Employers Association (present Confederation of Swedish Enterprises)

**SOU:** Swedish Government Official Reports

**SWEA:** The Swedish Work Environment Authority

**SWEM:** The Swedish Work Environment Management
**Introduction**

Even though as long ago as antiquity attention was given to occupational risks, such as air contaminants which Rose and Cohrssen (2011) describe, limited attention has been directed towards control measures to reduce air contaminants in the research areas of safety science and occupational hygiene, as confirmed by Swuste (1996), Kromhout (1994) and Roelofs et al. (2003). Control measures to reduce air contaminants in the workplace that have been carried out over the years and have been commonly used in research are technical measures, such as ventilation (Säämänen, 1998; Flynn and Susi, 2012). The European Agency for Safety and Health at Work (EU - OSHA) (2017) states that EU workers have to handle dangerous substances, such as liquids, gas and solids every day in their work, and 15% of EU workers have reported inhalation of fumes, powder, smoke or dust at work (EU - OSHA 2017). About half of all occupational illnesses resulting in death in European workplaces are related to exposure of air contaminants (Bohgard & Albin, 2010). Although there are laws and regulations in Sweden about work safety, there are still workers who are daily exposed to harmful levels of air contaminants (SWEA, 2016a). In the past six years, over 8,000 occupational diseases in Sweden were reported to SWEA (2016a) due to air contaminants, and AFA Insurance (2016) shows that the manufacturing industry is the most vulnerable occupational group in Sweden for work-related respiratory illnesses.

Exposure to air contaminants in the workplace can destroy workers’ health in the short- and long-term (Stellman et al., 1998; Schlunssen et al., 2001; Harms-Ringdahl, 2013). Air contaminants may have negative acute- or long-term medical effects on human health, as confirmed by SWEA (2015c), Occupational Safety and Health Administration (OSHA) (2015), and EU – OSHA (2017). Acute health effects, such as respiratory symptoms from exposure to formaldehyde, or depressive impact on the central nervous system from exposure to toluene have been shown in a study by Persoons et al. (2012). Exposure to wood dust has been discovered to increase the risk of cancer (Stellman et al., 1998), asthma, cough symptoms, eye and nose irritation (Douwes et al., 2001; Swedish Government Official Reports (SOU), 2012). Solvents can cause respiratory problems, nervous system disorders, learning disabilities, headaches, skin problems, and memory, as well as concentration dysfunction (SWEA, 2008).

SWEA is authorized to decide on the regulation of air contaminant substances or particles that can lead to ill health or safety risks (SOU, 2007), which may involve work conditions or work products. SWEA (2015b) developed the Work Environment Act, which is a framework designed to prevent ill health or safety risks at work, including air contaminants. SWEA (2015a) has also established a regulation that describes in detail the hygienic exposure limits in organizations. The Swedish Work Environment Act and regulation of internal control increased the requirements for work environment safety in the early 1990s (SWEA, 2015a). The requirements included the measurement and management of work environment risks (SWEA 2001; SWEA 2015b). Antonsson et al. (2005) have shown that there are deficiencies in how work environment laws and rules are obeyed in Swedish organizations, for instance, the regulation of systematic work environment management in SMEs.
A risk assessment and measurement of air contaminant risks includes quantifying or describing air contaminant work processes, as well as chemical substances, according to Covello and Merkhoher (2013). SWEA (2016b) states that air contaminants can be more or less visible to the human eye, not visible at all, or odorless (SWEA, 2015c). According to SWEA (2015b), air contaminants are regulated to be measured by individuals with knowledge of how to measure, interpret and analyze data, as well as knowledge of how to execute an air contaminant measurement report. To be effective, SWEA (2015) recommends that measurements of air contaminants are performed in the worker’s breathing zone, by collaboration between employers and employees. The measuring equipment for air contaminant exposure is recommended to be placed as close to the worker’s mouth and nose as possible (i.e. breathing zone). The purpose of air contaminant measurements is to obtain as reliable as possible exposure data during the working day. In Sweden, the average exposure and the time weighted mean/average are regulated so as not to exceed the limit value set by The Swedish Work Environment Authority of the air contaminant in question during the working day. The objectives of air contaminant risk assessments, control measures and preventive work are performed according to SWEA (2015b) so as not to exceed limit values, not even for short periods of time. Rose and Cohrssen (2011) explain that risk assessments generally include observations, epidemiological measurements, qualitative analyses, and statistical or mathematical modelling methods. Epidemiological measurements are to relate the specific health aspects to air contaminant exposure value (Rose & Cohrssen, 2011), or to measure worker variability of air contaminant exposure (Ramachandran, 2005). Screening measurements of the workplace are described by OSHA (1985), and by Rose and Cohrssen (2011) as work with identifying air contaminant sources or risks. A screening measurement can be performed by asking employees in organizations which air contaminants are used in their workplace, by measuring air contaminants by directly reading instruments, or analyzing air samples in the workplace (OSHA, 1985).

In Sweden, laws and regulations have established that providing workers with information on safety issues is important when decreasing health issues, as confirmed by SWEA (2014). In addition, SWEA (2015b) states that employers are obliged to inform their employees about possible exposure to air contaminants and to ensure that correct work environment conditions are observed at work. The Swedish government aims to improve the workers’ knowledge of the safety risks in the work environment, according to Bornberger-Dankvardt et al. (2003), SOU (2012) and SWEA (2014), in order to, for instance, reduce the rate of early retirement among workers (SOU, 2012). By investigating and analyzing obstacles and opportunities for a longer work life, and by use of reference groups, systematic reviews, research, meetings and discussions, it has been found that Swedish employers and employees need to have more knowledge disseminated about the work environment (SOU, 2012). To reduce air contaminant exposure, workers and students in vocational programs, according to my understanding, may benefit from participating in occupational training programs early in their careers, to gain knowledge about how air contaminants can be avoided in a simple, effective, and time-saving manner. Workers may benefit from being made aware of their exposure level to air contaminants to ensure safety (SWEA, 2011b).
Rosén et al. (2005) show that effective implementation of control measures is a question of knowledge, motivation, and engagement. For example, even though welders have access to local exhaust ventilation of air contaminants in the workplace, they lack the motivation and knowledge of how to use it properly. Consequently, if workers lack motivation and knowledge in the use of ventilation, they become exposed to air contaminants. Thus, by using visualization methods in the workplace, employees may improve awareness, safety motivation and commitment about how to control air contaminants and avoid risks (Rosén et al., 2005).

Safety training is considered one of the most important control measures to ensure safety in the workplace, as demonstrated by Tweedy (2005). The research areas of safety training and air contaminants have been covered in studies (Hale et al., 1986; Rosén, 1993; Rosén et al., 2005), to a minor extent, compared to areas, such as risk assessment of air contaminants (Hallenbeck, 1993; Steenland & Brown, 1995; Ramachandran, 2005; Rose & Cohrssen, 2011). However, as many workers do not receive the training required, Tweedy (2005) argues that by managing safety in workplaces, organizations benefit from making safety training a priority. Workers benefit from receiving training about usage of protective respirators, the type of air contaminant risks they face, their level of exposure to air contaminants, and why they should use a respirator to protect them from air contaminants (Tweedy, 2005). Reese (2015) explains that providing safety training in workplaces is an important part of accomplishing increased productivity and reducing safety incidents by allowing learning about, for instance, how to reduce accident rates and promote the creation of a healthy workplace.

This thesis is limited to the study of human aspects, knowledge and training in the workplace to decrease and control air contaminants, which are issues that have received limited attention in the research area of air contaminants. The focus in the present thesis is the reduction of air contaminant values, not just specifically for eight-hour average limit values, also short-term values on a second- and minute-level in work situations. In Swedish legislation, there are short-term limits including 15-minute and 5-minute limits. The air contaminants of wood dust, fumes from solvents, medicine dust, stone dust and welding smoke are studied in the papers of this thesis. The thesis examines how workers and students in handicraft programs can avail of safety training in order to decrease and control air contaminant exposure. Young workers aged 16-25 have been shown by AFA Insurance (2013) to be more vulnerable to safety risks at work than workers aged 26-64. By performing safety training with students, they can be prepared early on in their career for safety at their future workplace. Students can also disseminate their new safety knowledge to work colleagues. As workers in industries suffer from occupational diseases due to air contaminant exposure, there is a need for more research and knowledge about available control measures in the industrial workplace.
Aim and research question
This thesis contains three related research questions based on one general aim of developing and analyzing safety measures for air contaminant exposure in industrial work situations, focusing on human aspects.

A) What possibilities and limitations have existing safety measures aimed at for decreasing air contaminant exposure in workplaces?

B) In what way do safety attitudes and safety motivation influence human willingness to participate in decreasing air contaminant exposure in work situations?

C) How can safety training contribute to decreasing air contaminant exposure in work situations?

Disposition
This thesis comprises four papers and the aim is to answer the above-mentioned research questions. The thesis includes sections on Theory, Results, Methodology and Discussion, related to the four papers and aim of the thesis.

This thesis begins with a presentation of the theoretical framework, after which a discussion of the methodology is presented, followed by the Results and Discussion sections.

The theoretical framework includes societal and organizational progress of work environment safety, legal obligations with regard to air contaminants in the workplace, and control of air
contaminants to prevent exposure. This is followed by research on safety motivation, safety attitudes and safety training. Each theoretical section ends with a summary of the theory.

The methodology section presents methods used in the papers of the thesis. These include: 1) qualitative and quantitative research, 2) interviews, 3) questionnaire, 4) statistical analysis, 5) PIMEX, 6) literature search, 7) safety training material and method, 8) QR codes, 9) participants and sampling, 10) research process of thesis, and 11) trustworthiness in qualitative and quantitative research.

The results include summaries of the papers presented in the thesis, as well as an analysis and summary of the results. This is followed by a discussion, organized on the basis of the aim and research questions of the thesis, its contribution, methodological discussion, and limitations, as well as future studies.

**Theoretical framework**

The theoretical framework examines the different concepts in the literature and research related to 1) societal and organizational progress of work environment safety. This is followed by 2) legal obligations about air contaminants in the workplace, and 3) research concerning control of exposure to air contaminants. Research regarding 4) safety motivation, 5) safety attitudes and 6) safety training is then presented. Lastly, these theoretical sections are summarized in each section, and in a summarizing analysis last in the theoretical framework.

**Societal and organizational progress of work environment safety**

Muntz (1932) and SWEA (2015) claim that industrialization brought new work environment risks that employees were exposed to in industries. The labor market and working life has changed over time, from having a high proportion of work at home, such as farming, to a large-scale market situation that includes service occupations (Sundqvist, 2012). At the end of the 1800s, Swedish companies focused on preventing accidents in the workplace. At the start of the 1960s, attention moved to chemical hazards in the workplace. In the 1980s, people started to talk about the psychosocial issues related to safety and the work environment. In Sweden, an understanding to combine human, organizational and technological factors to control safety risks in the work environment was raised among employers. Despite an increased perception in workplaces about physical work environment problems and air contaminants, SWEA warns that in organizations physical risks still exist, and that knowledge about physical risks, such as air contaminants has stagnated in organizations. This means that many physical work environment risks go unnoticed in Swedish organizations (Sundqvist, 2012).

SWEA (2016c) states that it was shown already 1890 that the Swedish government reacted to safety risks, and a Labor Inspectorate was created in Sweden to monitor safety, and advise on safety risks in the work environment. There was also a first edition of The Swedish Work Environment Law, at that time. In 1906, higher requirements were initiated by the Swedish government to report accidents at work to employers. A new edition of the Work Environment Law was introduced in 1912. In addition, an enhanced supervision of safety risks in the
workplace was introduced by the Swedish government, with a total of 49 supervision agents. Workers were also legally entitled to appoint their own representatives for safety to consult with the Labour Inspectorate Institute (now SWEA). Law on insurance about accidents at work was obligatory in organizations, and introduced in 1918 by the Swedish government.

The National Board of Occupational Safety and Health was created in 1949 and became the governing authority of the Labour Inspectorate Institute. In 1949, it was established that safety representatives were obligatory at workplaces of at least five employees, and a safety committee was declared mandatory when employers had fifty employees, or more. In 1973, the 40-hour work week was initiated as obligatory, according to Swedish regulations. Stronger regulations and supervision to prevent silicosis, the occupational lung disease caused by inhalation of crystalline silica dust, was introduced in 1964, when the long latency period for the disease was becoming evident. As Muntz (1932) describes, disease symptoms do not always occur directly on exposure to chemical substances, and it can be difficult to relate diseases caused by chemical substances to the specific work itself. The first symptom experienced by workers is often a headache, which cannot be directly related to the actual source (Muntz, 1932). In 1961, a Chemistry Agency was established in Sweden (SWEA, 2016c), and in 1969, projects were started by the Swedish government to control the use of asbestos, which was legally forbidden at workplaces in 1982. In 1972, the Work Medicine Institute was included in the National Board of Occupational Safety and Health, and the hygienic limit values list, consisting of 120 substances (SWEA, 2016c), was created in 1974.

In 1974, a regulation was introduced whereby safety representatives could legally stop the work if safety risks occur at the workplace. The Swedish Work Environment Law was established as a framework law in 1978, and psychosocial and organizational factors, as well as self-determination among workers about their work were given more focus in the new framework law than in previous editions of the Work Environment Law (SWEA, 2016c). The framework law included complementary, and more specific, regulations than in the Work Environment Law about how to work with safety (SWEA, 2015b). An example of such a regulation is chemical work environment risks (SWEA, 2015a). In 1985, regulations were introduced with regard to computer screen work. Later in 2014, the number of Swedish regulations was 140, but decreased to 81 regulations. Regulations about internal control were created in 1993, and, in 2001, the name was changed to Systematic Work Environment Management (SWEM) (the earlier regulation internal control). SWEM requires every employer to investigate work environment issues of an ergonomic, physical and, consequently, chemical nature, as well as psychosocial conditions (Sundqvist, 2012). The Labor Inspection Institute and the National Board of Occupational Safety and Health became SWEA in 2001 (SWEA, 2016c). The National Institute for Working Life, which focused on Swedish work environment research, was closed down in 2006-07. In addition to the supervisory work regarding safety regulations that companies are obligated to follow, in 2011, SWEA was sanctioned to disseminate knowledge about the work environment and safety risks, as well as control, and prevent health issues at workplaces in Sweden (SWEA, 2016c).
Summary of societal and organizational progress of work environment safety

The Swedish Work Environment Law recommending employee safety was greatly influenced by the establishment of SWEA and the introduction of regulations regarding safety at work. The result of these regulations and influence of SWEA has created safer workplaces in Sweden from the 1800s up to today.

However, many risks still exist, such as air contaminants, and there is a need for more knowledge that can increase safety in the workplace. One reason for raising awareness about workplace risks is that knowledge about air contaminant risks is limited in Swedish organizations. As air contaminant risks may not be detected until much later after the time of exposure, raising awareness of the possible risks is essential to protect workers. Control measures developed to decrease and prevent risks are discussed in the next section of this theoretical framework.

Legal obligations with regard to air contaminants in the workplace

SWEA (2015a) describes the Swedish regulations that include laws concerning air contaminants, in the form of smoke, dust, gas, mist, or vapor in the workplace. There is a regulation about how to control risks with systematic work environment management (SWEM) (SWEA, 2001). SWEM declares that Swedish employers are regulated to work systematically, identifying and controlling safety risks in the workplace (SWEA, 2001). According to Swedish air contaminant regulations, employers are obligated to ensure minimal air contaminant exposure to prevent health issues for workers (SWEA, 2015a). Air contaminants can be replaced with new substances that meet higher limit values. Work processes can also be separated from air contaminants by performing the work from an encapsulated control cabin. Control is performed to reduce air contaminants based on hygienic limit values. First, an assessment of the air quality is performed in relation to other interests, such as ventilation or surrounding areas of individual work situations. It is also important to assess the diffusion extent of air contaminant sources from the work premises to the offices. Direct reading instruments are effective in finding high-exposure risks, and the effect of the measures taken (SWEA, 2015a). Control of air contaminants can also be discussed in safety committees, or with safety representatives in Swedish organizations, which support cooperation between employers and employees in safety and work environment issues (SWEA, 2015b).

The Swedish Work Environment Law states that employers and workers should collaborate regarding work environment safety issues (SWEA, S2015b). With five employees, or more, at a workplace the organization is obligated to have a safety representative. If there is more than one safety representative, a chief safety representative is obligatory. If there is no safety representative in a workplace, a regional safety representative is required to be available, according to the Swedish Work Environment Law. At a workplace of 50 employees, or more, Swedish organizations are obligated to have a safety committee, according to SWEA. Additionally, employees should communicate risk situations to safety representatives or the employer. An essential factor for safety in Swedish organizations is safety information (SWEA, 2001), and knowledge about how to reduce air contaminants among workers, according to
Rosén et al. (2005), as well as Andersson and Rosén (2014). In accordance with SWEA (2015b) and the Work Environment Act, safety information and knowledge are obligatory in Sweden. Employers have a responsibility to handle safety training and inform employees about work environment risks (SWEA, 2015b).

Summary of legal obligations with regard to air contaminants in the workplace
For effective safety and control of air contaminants, it is important to identify air contaminant risks and use control measures. Safety representatives and safety committees can support employees and help organizations to implement procedures for general safety work that is required by law. Safety training and awareness regarding safety for air contaminants is an additional important legal factor addressed by the Swedish regulations and air contaminant research.

Control of air contaminants to prevent exposure
According to Swuste (1996), one reason for the need of more research on control measures may be the ad hoc approach that air contaminant control research has taken, whereby studies have addressed a specific problem, making them less generalizable. A review study by Zalk and Nelson (2008) states that air contaminant control, such as control banding, can have weaknesses, an example being that control banding works better with dust than vapor (Zalk and Nelson, 2008). Control banding is described as simplified solutions and strategies for controlling worker exposures to constituents often encountered in the workplace (Zalk & Nelson, 2008). Control banding can include approaches, such as hazard containment, engineering controls (local exhaust ventilation), or occupational hygiene practices that include personal protective equipment (Eastlake et al., 2016). Control banding is a method that includes workplace evaluation of air contaminant exposure risks to make a basis for the control measures implemented, based on, for instance, the level of dust in the workplace (WHO, 1999).

There is previous research on ventilation and control measures concerning air contaminants (Thorpe et al., 1999; Watson et al., 2001). Use of ventilation to deal with air contaminants is discussed by Bohgard and Albin (2010), who point out that ventilation has been commonly used to reduce exposure to air contaminants. Studies, such as Buring et al. (1992), showed that air contaminant control can be implemented systematically. A systematic approach towards control measures is also supported by Swuste (1996). Additionally, in the rubber industry, workers in the study by Dennis and Mortazavi (1995) used internal shielding gas around a welding arc to reduce ozone exposure. Vermeulen et al. (2000) investigated the effectiveness of control measures over nine years in the rubber industry. Between 1988 and 1997, 57 different control measures were identified that led to a reduction in air contaminant exposure, including inhalable and dermal exposure to air contaminants. The majority of control measures were directed toward preventing the inhalation of air contaminants among workers, and most control measures in the study by Vermeulen et al. (2000) were implemented in the production process within the organizations. The production process included tempering, molding, compounding, and mixing processes. Personal protective equipment was used by about 5% of the workers.
About 80% of the control measures involved changing existing equipment (so-called ‘add-on,’ or ‘retrofit’), which had effects on air contaminant control. Most of the control measures tested in the study showed a reduction to exposure (Vermeulen et al., 2000).

Automatization of work methods is one control measure used in workplaces to reduce air contaminant exposure, as the worker can be separated from the air contaminants, according to Vermeulen et al. (2000). Removing the air contaminant source was shown to be the most effective control measure, (72% reduction of dermal and inhalable air contaminant exposure). Another control measure that was effective in the study was dust-free chemicals. Removing anti-tacking agents and replacing them with liquid anti-tacking agents, or anti-tacking foils in the workplace, was also an example of a control measure in the study. One factor that explained 14% of air contaminant reduction was the number of years in service, where seniority workers with more experience showed a reduced air contaminant exposure (Vermeulen et al., 2000).

Enander et al. (1998) planned risk reduction and demonstrated a number of technology changes, material changes, and improved operating practices in the automotive refinishing industry that characterized environmental and industrial control of air contaminants. The study by Enander et al. (1998) was largely related to behavior and training. The modified enclosed spray gun cleaners, compliant coatings, and high-volume, low-pressure spray guns were effective for creating safety motivation to control air contaminants in the organization. Enander et al. (1998) also showed that better methods of professional licensing requirement, targeted training, compliance, technical assistance, and risk communication can help to reduce air contaminant risks.

Flynn and Susi (2012) state in a literature review on specifically local exhaust ventilation (LEV) control, that additional work practice and training are important factors in the control of air contaminant exposure, for instance, standing in the correct position at work (Flynn and Susi, 2012). The World Health Organization (WHO) (1999) describes how work practice and training are important in controlling air contaminants. This may include caretaking about the transfer of dusty materials among workers (WHO, 1999).

Research regarding air contaminants includes studies about how control measures that concern safety at work should be prioritized (Antonsson, 1991; Eurenius, 2000). First, essential factors in any control measure in industries is that knowledge and acceptance of the work environment and safety problems, such as air contaminants, exists among employees. Second, it is important to find the cause of the problem and identify the suppliers of control measures. The industry in question benefits from assigning capital for solutions and control measures, implementing solutions, as well as evaluating the results (Eurenius, 2000). Including workers in air contaminant risks and control measures at work has proved to be an effective approach in increasing safety awareness and reducing exposure to air contaminants at work (Rosén et al., 2005).

WHO (1999) has shown that control measures can be based on different stages of action. First, the process and method include elimination and substitution of air contaminants, or the change
of work process. Secondly, engineering methods include workplace design, redesign or modification of work process material, as well as enclosure. Engineering methods can include local exhaust ventilation (LEV), or general ventilation. Third, personal measures include materials handling (manual) and keeping the workplace clean. Fourth, administrative measures include personal protective equipment, work practices, safety training, safety information, safety instructions, restricted areas and work situations, reduction of exposure time or workers’ exposed, and decontamination, as well as personnel hygiene arrangements (WHO, 1999).

As implementation of control measures may decrease production speed, and production quality, according to Swuste (1996), it is essential to be aware of how air contaminant control measures can be implemented effectively, to avoid problems of production speed. Control measures are shown by Swuste (1996) to be implemented using a trial and error approach, where changes are made gradually. Once the problems have been controlled, i.e., the adverse effects have been eliminated, new problems may arise. Nevertheless, increased interest has been placed on research creating a more systematic approach to control air contaminant risks, and predicting the possible effects of implementing control measures (Swuste, 1996). To create a further understanding of control measures for air contaminants, models have been developed in research about air contaminant control.

Lumens (1997) explains that a possible method to find and use control measures effectively is to use models. A model can solve a problem, such as the model of an individual’s safety where the problem is to explain an individual’s behavior (Hägg & Weidersheim-Paul, 1994). Models can also be described as a simplification of reality (Hägg & Weidersheim-Paul, 1994; Lumens, 1997). The following models are grouped to display how they contribute to the research and work with air contaminants control. Exclusively, mathematical equations and tables are not included in the models below. The concepts used in the models are immission, which is the exposure, inhalation or uptake of an air contaminant by a worker (Swuste, 1996). Emission is the source and risk of air contaminants exposure, release or point of discharge towards the air contaminant, and transmission is the spread of the air contaminant through the air (Swuste, 1996).
Table 1. Air contaminant control models

<table>
<thead>
<tr>
<th>Model</th>
<th>Source and risk (Emission)</th>
<th>Exposure and dose (Immission)</th>
<th>Transport/spread (Transmission)</th>
<th>Control &amp; Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>The dynamic model of exposure, susceptibility, and effect (Van Dijk, 1988)</td>
<td>Identify sources</td>
<td>Influence of exposure</td>
<td>Influence of transmission</td>
<td>Prevention of exposure &amp; intervention of work methods</td>
</tr>
<tr>
<td>Multiply source model /diagram (Boleij et al., 1995, in Lumens 1997)</td>
<td>Identify sources</td>
<td>Influence of exposure</td>
<td>Influence of transmission</td>
<td>Control strategy to decrease exposure</td>
</tr>
<tr>
<td>Factors affecting styrene exposure (Säämänen, 1998)</td>
<td>Exposure potential &amp; hazard band relation</td>
<td>Influence of exposure</td>
<td>Influence of transmission</td>
<td>Identified factors that affect exposure to control styrene</td>
</tr>
<tr>
<td>Approach used to develop control predictive model (Maidment, 1998)</td>
<td>Source in relation to exposure</td>
<td>Characterize exposure potential</td>
<td>Factors affecting transmission</td>
<td>Work approach to develop model to characterize control strategies</td>
</tr>
<tr>
<td>Factors governing Exposure to an air born contaminant (Andersson, 1995)</td>
<td>Source Characteristics</td>
<td>Influence of exposure</td>
<td>Influence of transmission</td>
<td>Basis for control used in discussions on how to reduce exposure &amp; factors affecting exposure</td>
</tr>
<tr>
<td>Sequence for aerosol particles to induce negative health effects (Nilsson, 2016)</td>
<td>Source related to exposure, dose and effect</td>
<td>Exposure and dose related to effect and source</td>
<td>Not focused on transmission</td>
<td>Basis for control with health effects related to process from source, exposure and dose</td>
</tr>
<tr>
<td>Stages of control measures (WHO, 1999)</td>
<td>How to prioritize risk and source control</td>
<td>How to prioritize exposure control</td>
<td>Not focused on transmission</td>
<td>Basis to understand priority of control measures</td>
</tr>
</tbody>
</table>

Table 1 presents a number of models related to control measures developed to decrease air contaminants. (Van Dijk, 1988; Andersson, 1995; Boleij et al., 1995 in Lumens, 1997; Säämänen, 1998; Maidment, 1998; WHO, 1999; Nilsson, 2016). Maidment’s (1998) model predicts substance exposure potential, relative to the control strategy. Nilsson (2016) describes sequences for aerosol particles with the outcome of negative health effects, including exposure, dose and effect (Nilsson, 2016). Säämänen’s (1998) model shows the factors that affect air contaminant exposure and suggests making changes to factors located close to the source, such as replacing the styrene, changing the work processes, and using low emission styrene resins. The model then addresses the local, as well as general ventilation (near the worker and the
source), work processes, execution, cleaning, personal protective equipment, monitoring, work schedule, training and education. Andersson (1995) describes factors, such as work practices, source characteristics, and the amount of ventilation air affecting the exposure of air contaminants. The model of exposure, susceptibility, and effect, by Van Dijk (1988), includes influencing factors that are related to air contaminant exposure dose and effect, such as health effects. The model visualizes interrelated phases, from the point of the air contaminant source to the final effects. The final effects include biological effects, such as behavioral or health changes that are affected by factors, such as work or personal hygiene. Another model that has been tested and used (see Lumens, 1997) is the multiply source model by Boleij et al. (1995), further analyzed by Lumens (1997), with inspiration of Buring et al. (1992). This model lists air contaminant sources of inhaled exposure for the worker. Lumens (1997), who compared the models of Buring et al. (1992) and Van Dijk, (1988), explained that it is essential to find the main source of air contaminants and attack it with the best possible approach to control the air contaminants.

Summary concerning control of air contaminants to prevent exposure

Although control measures for air contaminant exposure have received less attention than the risks involved, some previous studies are developed. These control measures include making changes to machines or purchasing specific control equipment, such as ventilation systems. In addition, the literature on air contaminant control shows that control measures, such as control banding may have flaws. Control banding works better when preventing dusts in comparison to vapor. Trends can also be seen in the studies about criticized control measures being too focused on one specific factor, such as dust, or too complex for generalization within workplaces, such as the control measures focusing on one specific risk context.

To date, models that control and reduce air contaminants have focused on the source or the exposure process. Factors, such as safety training and safety behaviors, including safety motivation, have been mentioned in research of the air contaminant control studies, and have not been in focus. This thesis focuses on conducting safety training in order to change safety attitudes and on safety motivation to reduce air contaminants.

Safety motivations in work situations

In a review of the safety motivation literature, Scott et al. (2014) describe how employee safety motivation research has been studied, mostly since 2000. However, there have been earlier
studies, such as Andriessen (1978), showing that safety motivation is determined by the safety standards of a leader and the leadership. Safety motivation research has been mainly focused on the amount of safety motivation related and linked to worker safety and safety behavior in an organization (Scott et al., 2014). In studies on work environment and safety motivation, there is limited research carried out on the measurement of safety motivation, as pointed out by Åteg et al. (2006), and Li and Poon (2015). Earlier safety studies focus on accidents and the costs involved, while literature on safety motivation is scarce (Åteg et al., 2006; Li & Poon 2015). Since little has been written on how to influence individuals’ safety motivation (Job et al, 2010; Bluff, 2011), some studies have highlighted the need to study safety motivation (Åteg et al., 2005; Åteg et al., 2006; Reese, 2015; Hedlund et al., 2010; Bluff, 2011), for increased safety in the workplace. Hedlund et al. (2010) describe worker’s safety motivation as being essential for effective safety investments in organizations. The motivation of the workers to actively participate in the invested safety measures contributes to the outcome of the safety investments. Hedlund et al. (2010) state that safety investments in organizations have a reduced effect due to the absence of interest among workers to use safety investments.

Safety in the workplace can include knowing how to control chemical risks through knowledge and safety motivation (Scott et al., 2014). Safety motivation is rarely a priority in organizations (Bornberger Dankvardt et al. 2003; Scott et al. 2014; Bluff, 2011). Bornberger Dankvardt et al. (2003) state that small organizations with fewer than 50 employees lack sufficient motivation for implementing health and safety measures. Despite the safety tools available for the work environment, it is difficult to get small organizations to start using the safety tools (Bornberger Dankvardt et al., 2005). Employers search for a quick resolution when safety problems arise (Scott et al., 2014), and seldom plan in depth how to motivate workers to manage safety issues, despite the fact that workers affect the result of the safety in organizations (Scott et al., 2014; Reese, 2015). Data indicates that 85%–90% of all accidents are caused by poor safety behavior among workers, according to Reese (2015). It is essential for safety motivation among workers to implement a health and safety program that demonstrates the importance of safety. If workers do not understand the importance of health and safety, they cannot be motivated to behave in a safe manner at the workplace, as shown by Scott et al. (2014) and Reese (2015).

Lingard (2002) confirms the essentiality of awareness regarding safety, and describes how safety training helps to increase safety motivation and prevent various forms of illness and injuries at work. When safety training was used in the organization, workers took fewer unnecessary safety risks than before the safety training. Worker behavior with regard to the avoidance of illness and injury in the workplace increased with safety training in the organization. Lingard (2002) concluded that safety training also helps to increase workers’ awareness about safety, and that workers’ behavior with regard to safety measures is essential for spreading beliefs, perceptions, and experiences of safety among workers.

Safety motivation, safety climate, and safety behavior
Åteg et al. (2005) state that a common factor and starting point in work strategies with safety and work environment issues is safety motivation. Leadership and encouragement tactics
towards workers, safety climate, safety goals, safety compliance, as well as safety participation in organizations, are related to safety motivation (see Neal et al., 2000; Neal & Griffin, 2006; Hedlund et al., 2010; Zohar, 2014). A positive safety climate within work groups increases individual safety motivation, according to Neal and Griffin (2006). In addition to safety climate, safety motivation is related to increased safety participation in organizations. Past studies have indicated that when workers understand the importance of prioritizing safety, they want to perform a higher quantity of safety activities. Neal and Griffin (2006) have found that a higher participation in safety activities can increase safety motivation among workers. The study indicates that the safety of an organization does not benefit from punishing workers who do not follow the safety rules. Leaders benefit from motivating and engaging workers to participate in safety activities (Neal & Griffin, 2006). Another example of the interplay between participation and safety motivation is when the worker participates in the selection of safety equipment in the organization (SWEA, 2001). Worker participation in the selection of safety equipment can raise the employees’ motivation to use the safety equipment in question (SWEA, 2001).

Two aspects of safety behavior are safety initiative and carefulness in the work environment (Bluff, 2011). Safety motivation and safety behavior are affected by cohesion in the work group and group norms, as pointed out by Bluff (2011). A safer behavior among employees reduces the number of accidents in the workplace (Andriessen, 1978; Reese, 2015). It has been shown that workers who underestimate safety risks have less motivation to adopt the necessary safety procedures (Helander, 1991).

Bluff (2011) claims that various forms of safety motivation exist. Controlled safety motivation is when workers feel obliged to carry out safety measures because of pressure from the management, society, colleagues, or individual pressure from one’s self, or the environment (Scott et al., 2014). Controlled safety motivation can be classified as external or internal pressure to perform a safe behavior or safety tasks. Extrinsic motivation is dependent on the performance or reward of an outcome (Scott et al., 2014), which can relate to Probst and Brubaker’s (2001) definition of safety motivation, which is “an employee’s degree of incentive to adhere to their organization’s safety regulations, as they understand them to be” (Probst & Brubaker’s 2001 p. 140).

Intrinsic motivation includes enjoyment of the safety task in question in an organization (Scott et al., 2014). Personal protective equipment may be perceived as less relevant within the organization because it is not created to generate individual satisfaction Scott et al. (2014) This became apparent when individuals in the workplace did not want to use protective equipment and complained when protective equipment was a requirement. To overcome the problem of not having satisfying safety measures, organizations use rewards (Scott et al., 2014; Reese, 2015). Scott et al. (2014) shows that the rewards can include financial bonuses, to increase safety motivation in the workplace and encourage workers to identify risks and measures to manage safety risks. The rewards of safety fall within the scope of what can be called controlled motivation, which includes a demand or pressure, compared to autonomous motivation (Scott et al., 2014).
Scott et al. (2014) point out that organizations may benefit from a greater focus on autonomous motivation, including expanding and developing workers’ skills related to safety. Employees are more likely to follow safety procedures and rules if they understand the importance of safety, according to Scott et al. (2014). Workers can benefit from having the chance to become experts in various fields related to safety through safety training, because they are more likely to follow safety procedures and rules. For example, with regard to chemical risks, instead of focusing on the established organizational safety rules, safety knowledge can be provided to the workers. Thus, the workers can better develop their safety skills and independence in safety issues because they learn why it is important to comply with safety rules (Scott et al., 2014).

**Safety motivation, management and organization**

Åteg et al. (2005) state that there is a need to create safety motivation, in order to improve work environment efforts in organizations. Åteg et al. (2005) describe the importance of safety motivation at all levels of an organization to create desirable changes in work regarding safety and work environment issues. Desirable changes consist of safety issues, including managers’ needs to get employees to work with safety, such as safety awareness (Åteg, 2005). Desirable changes with safety and work environment issues can include employers who need awareness to create interest in safety and work environment issues. If employers have a greater understanding of safety and work environment issues, employees can more easily implement safety suggestions for improvements in the work environment (Åteg et al., 2005).

Safety motivation among employees is influenced by the leadership in organizations (Hedlund et al., 2010; Bluff, 2011). Zohar’s (1980) reasoning, confirmed by Bluff (2011) and Hedlund et al. (2010), states that safety motivation among employees is affected by leadership, and that commitment to safety by management in organizations is important for the outcome of safety programs. The fact that management and leadership involvement is essential for safety can be related to a study by Kvorning et al. (2015), which shows that financial support assets affect safety motivation to participate for the organization in safety work.

Managers need to perceive OSH programs as profitable and meaningful (Kvoring et al., 2014). Contextual factors, such as workplace culture, manager’s attitude toward authorities, as well as the access that companies have to technical safety equipment, also affects managers’ motivation to participate in OSH programs (Kvorning et al., 2015). According to Bluff (2011), motivation to improve safety and health issues in organizations can be related to financial, legal, and social pressures or consequences for the individual and organization, such as reputational damage and financial penalties. Financial, legal, and social pressures can mean a sense of moral duty or obligation to perform safely (Bluff, 2011). Other safety motivation literature by Job et al. (2010) states that workers’ main motivation to consider safety and health actions is to perform the work more easily and efficiently. The study by Job et al. (2010) demonstrates that one reason for increased safety motivation among employees was decreased responsibility for worker injuries. In addition, the costs of an injury were one reason for safety motivation, which can be compared with single action to prevent illness and, consequently, injury costs in an organization. Safety motivation among workers could also increase when safety requirements arise from the
management and supervisors (Job et al., 2010), which can be related to the extrinsic or controlled safety motivation, described by Scott et al. (2014), whereby pressure is applied by the management on the worker to perform a safety task.

Probst and Brubaker (2001) show that the conceptions and perceptions of job insecurity among workers reduce safety motivation, which leads to decreased safety in the workplace, and, consequently, an increased number of injuries and accidents. This is because uncertain work situations affect workers’ safety motivation and safety attitudes, leading them to ignore safety policies. Workers may focus instead on trying to increase their production in order to keep their jobs (Probst & Brubaker, 2001).

Reese (2015) argues that providing clear goals and expectations of the safety procedures are important for increasing workers’ safety motivation in an organization. Clear goals and expectations of the safety procedures include displaying information on a noticeboard when an employee has been injured at work, and providing feedback to workers when they have followed safety processes. Clear goals and expectations of the safety procedures can also help employees feel part of safety at work, and motivate them in performing safety procedures more regularly. One method that shows the organizational values of health and safety procedures in the workplace is to explain the consequences of not following safety procedures, such as being suspended without pay (Reese, 2015).

Reinforcement in the form of a reward or verbal feedback when a worker has performed a task in a safe manner is recommended by Reese (2015), and can occur more than once a year. Giving a reward for increased safety motivation in the organization has become a topic of debate within work safety research. The reason for the debate is that rewards benefit from being used only to complement health and safety initiatives. The rewards are not a quick fix for safety issues, or a replacement for failed safety and health programs. Rewards may help maintain a focus among workers, or strengthen safety efforts. However, rewards, such as money, can be quickly forgotten by the employee (Reese, 2015).

In a review of safety motivation literature, Åteg et al. (2007) describe how participation in safety and work environment activities among employees can create safety motivation. Thus, employees are given encouragement for performing work environment and safety activities, a finding which is also supported in studies by Scott et al. (2014), and Reese (2015). To create an environment, where employees feel motivated to increase safety, the employees’ physical needs benefit from being met by providing them with effective tools for worker safety (Reese, 2015). According to Reese (2015), it is difficult to develop a work environment in which every individual feels the stimulus for safety motivation; thus such an environment is something to strive for.

**Summary and understanding of safety motivation in work situations**

Previous literature states that safety behavior and motivation are important for organizational safety. More efforts are needed to make safety procedures more available in training, and
focusing on work relating to safety motivation and safety behavior among workers in organizations to increase safety.

The area of safety motivation requires more examination, according to the research literature. Earlier safety motivation studies focused on accidents or the costs of safety issues, but research on how to influence safety motivation is scarce. Safety motivation is related to a branch of studies to create safety behavior among workers, and can be understood as extrinsic, meaning that employees are willing to follow safety regulations in an organization for a reward. This can be compared to the fact that smaller companies have difficulties following safety regulations because it can be a lack of funds. Safety motivation is complex and can be increased from an organizational perspective by financial support, and from a worker perspective with verbal feedback, or an increased safety climate in the work group.

Existing literature emphasizes the importance and advantages of developing safety motivation among employees. If the risks are underestimated, safety motivation is lowered and the workers fail to follow the safety procedures. Workers who believe that safety is important are more likely to continue to perform safety activities. In terms of air contaminant safety, such workers are more likely to use protective equipment and increase safe behaviors.

According to the literature, as safety measures are rarely created for purposes of individual satisfaction for workers, the will to perform safety measures is often difficult to establish. Providing safety training will help workers to become more aware of risks, to understand the importance of safety, and develop their safety motivation. To create internal safety motivation among employees, organizations can benefit from disseminating safety knowledge and skills among their employees. An additional essential factor for safety and air contaminant control is, as further described below, safety attitudes.

**Safety attitudes in work situations**

Studies have been carried out about managing workplace risks, health and safety, as well as workplace culture (Job et al., 2010). There is a lack of knowledge and studies on socio-psychological factors, such as motivation, knowledge, attitudes and how these affect work health and safety (Job et al., 2010). Written studies, by Malfetti (1963), on employee safety attitudes in the past, related accidents to workers’ safety attitudes. Malfetti (1963) also highlighted how safety attitudes can be developed, by using safety training that is implemented by using film strips and that can engage the observer to see the risks and find individual measures to manage them. Malfetti (1963) found that the closer the safety training is to the work activity in organizations, the better the increase in safety attitudes. More recent literature by Sokas et al. (2009) showed that safety attitudes improved after an hour of safety training on risk awareness. Malfetti (1963) states that attitudes and experience can affect the interpretation and storage of information: workers fail to predict the risk, or they predict the risk, but ignore it. It is important to improve workers’ knowledge and experience of safety to change safety attitudes, according to Malfetti (1963). Later literature on safety attitudes research focuses on measuring safety attitudes (e.g., Donald & Canter, 1994; Lee et al., 2010; Haynes et al., 2011).
Safety attitude literature has also been related to safety climate or culture (e.g., Diaz & Cabrera, 1997; Siu et al., 2004), traffic safety (e.g., Ulleberg & Rundmo, 2003; Lund & Rundmo, 2009), and accident prevention in the workplace (e.g., Malfetti, 1963). Safety attitudes have been used in organizations within the health sector (e.g., Flin et al., 2006; Sexton et al., 2006; Carruthers et al., 2009), and in school contexts (e.g., Morronigello et al., 2008). Literature is limited on safety attitudes related to the control of air contaminants in industries. The present thesis aims to contribute to the understanding of safety attitudes related to air contaminant control.

**Safety attitudes, behavior, culture, and climate**

Malfetti (1963) defines attitudes as the “accumulation of information and experience that predisposes an individual to certain behavior” (p. 477). All individuals have attitudes that can respond either positively or negatively toward an object, message, situation, or person/persons (Malfetti, 1963). Safety attitudes are considered a way of thinking, or feeling, about safety or health, according to Bluff (2011). This differs from safety climate, which is defined by Sokas et al. (2009) as an “individual’s perception of how the organization in which he or she is working values safety” (p. 165). According to Goldmund (2000), attitudes are focused on abstract factors, such as safety or policies, and include concrete factors, such as risk-taking and personal protective equipment. Rundmo and Hale (2003) describe an ideal safety attitude as “an attitude contributing to enhancing the safety, i.e. safe behaviour and lowering the frequency of accidents and near-accidents. A non-ideal attitude is one that contributes to the opposite” (Rundmo & Hale, 2003 p. 559).

Increased positive safety attitudes are related to safety behavior within organizations (Mearns & Flin, 1995; Rundmo & Hale, 2003; Henning et al. 2009; Channing, 2013). According to Channing (2013), increased positive safety attitudes can increase the use of personal protective equipment. Individual factors can contribute to safety attitude, such as agreeableness, fatalism, and focus on prevention (Henning et al., 2009). Safety attitudes can affect how workers perceive risks and safety issues in the workplace. Additional to safety attitudes, factors that can affect perceived risk are work environment quality, how satisfied workers are with safety measures, (Mearns and Flin, 1995), and knowledge of safety risks, as well as safety measures among employees (SWEA, 1980; Mearns & Flin 1995).

Safety attitudes in an organization among employees are related to safety culture (Mearns & Flin 1995; Guldenmund, 2000), or safety climate (Niskanen, 1994; Guldenmund, 2000). According to The Swedish Work Environment Authority (2014), safety culture can be understood as common attitudes, values, and beliefs that employees and managers possess in relation to occupational health and safety. Safety culture is described as having a significant impact on the work of employees and management in a safe work environment. For example, it is essential for the management in an organization to prioritize safety issues, in order to anchor the safety issues among workers (SWEA, 2014). Niskanen (1994) states that a safety climate contains safety attitudes, teamwork, feedback and appreciation, safety in production work, and changes in work demands.
**Safety attitudes among leaders and management**

Safety attitudes have proven to be important for managers’ safety, intentions, and behavior in organizations, according to the reasoning by Rundmo and Hale (2003). Attitudes, such as high management commitment, low fatalism, high safety priority, and high risk awareness, are important for behavioral safety intentions and behavior in the organization (Rundmo & Hale, 2003). It has been shown, according to Njå and Fjelltun (2010) that out of 106 managers who participated in a study on health, environment, and safety (HES) measures, one third described the HES as too costly and not worth investing in. Another third of the managers in the study were of the opinion that the measures already in place in the organization were sufficient, and more investment in health, environment, and safety issues was not needed (Njå & Fjelltun, 2010).

A previous study from Mearns and Flin (1995) on safety attitudes indicates that safety attitudes can vary in different parts of the organizational hierarchy, such as at worker or management level. Workers without a leader position believed that there was more pressure when production was prioritized over safety, compared to managers and leaders. Behavior and safety attitudes among management have proven to be crucial for safety. Management at a higher organizational level can have limited contact with workers. Mearns and Flin (1995) consider line managers can have a responsibility to translate decisions and policies of higher level management into safety behaviors in the workplace.

Guldenmund (2000) describes hardware and software attitudes related to safety. Hardware attitudes refer to personal protection equipment, safety measures, or safety arrangements. Software safety attitudes refer to safety procedures, safety training, or safety knowledge. Attitudes toward people refer to attitudes toward groups or individuals within organizations, such as management or colleagues. Attitudes toward behavior are actions which include work safely, taking responsibility, and communicating that can include more negative attitudes, such as skepticism (Guldenmund, 2000).

**Summary and understanding of safety attitudes in work situations**

Safety attitudes have been related to, and used within, safety areas, such as the safety climate or culture in the organization. A limited amount of literature focuses on the area of air contaminants. Safety attitudes are a way of thinking and approaching safety among workers or managers that can be changed through implementation of safety information and safety training for workers. Increased safety attitudes can improve safety behavior. Providing information through safety training can affect employees’ safety attitudes and safety behavior. Safety training may encourage workers to use protective equipment in the case of air contaminant control. The following sections describe safety training and have been found to be important and helpful in earlier literature in developing or affecting safety attitudes.
Safety training in work related situations

As mentioned previously in the present thesis, safety training is shown in the literature to be essential in improving safety attitudes, safety motivation and safety behavior, or safety and health among employees and management in organizations. According to Swedish law, training and providing information about safety risks is an essential part of safety in the work environment (SWEA, 2015b). Stuart (2014) states that safety training plays an important role in promoting safety culture and reducing accidents in the furniture industry in Europe and Ireland. Safety training has also been shown to increase safety climate at construction sites (Jafari et al., 2015). Swedish regulations stipulate that it is obligatory to make information on safety risks and preventive safety measures available at work (SWEA, 2015b). According to Swedish regulations, managers and workers are obliged to be made aware of specific work task risks and how to work with safety to avoid ill health (SWEA, 2014). In accordance with Swedish laws on safety training, one essential factor for building a safe work environment is safety training (Reese, 2015). A well-written safety and health program, together with safety training, can be positive in decreasing accidents in the workplace, and companies that neglect safety and health programs and safety training have higher accident rates (Reese, 2015). Job et al. (2010) have demonstrated that lack of safety training is the main cause of work-related injury and illnesses among workers, while Burke et al. (2006) have shown that safety training increases knowledge among employees and reduces the number of injuries and illnesses within the organization. As Job et al. (2010) have pointed out, safety training is a central source of information relating to work safety and health in Australian workplaces (Job et al., 2010).

Workplace health and safety can have more than one definition, according to the study by Job et al. (2010). It can include safety in the workplace, following safety procedures, prevention, work injuries, work accidents, safety of self and other individuals, as well as rules or regulations (Job et al., 2010). In this thesis, safety training is used as a general term for OSH training and safety training. The definition for safety training is thus an activity related to the workplace, focused on increased knowledge regarding safety and health among workers, safety professionals, or management.

Providing training for employees may reduce and prevent risks that cannot be completely excluded through other measures (SWEA, 2013a). Safety training can prevent employees from behaving unsafely (Burke et al., 2006; Robson et al., 2012; Taylor, 2014; SWEA, 2014), and, as Sari (2009) shows, it can have a positive and improved mental and physical effect on the safety and health of workers in an organization. In addition, the positive effects of safety training with regard to decreased air contaminants risk and increased control and safety have been confirmed by Andersson (1995) and Säämenen (1998).

Safety training is essential for workers, as they may become more cautious in the work environment towards risks (Sari, 2009). Furthermore, safety training can encourage workers to take care of, and reflect on, their health (Sari, 2009). Safety training has also been proven to have a positive influence on workers’ perception of safety and adoption of safety procedures, as well as on injury prevention (Leiter et al., 2009). How workers see, or perceive, risks can
largely depend on contextual and psychological factors, in other words, knowledge of the risks and risk consequences that affect how risks are perceived by workers (Bluff, 2011).

Effective safety training means that it is presented in a way that is effective for changing safety attitudes (Sari, 2009). This is in accordance with HSE (2015), which emphasizes the importance of understanding and prioritizing safety training in an organization. By participating in safety training, employees can learn how to reduce health and safety risks and ensure employee health. Meeting legal safety regulations is also beneficial for the development of a good safety culture in an organization. With effective safety training, the organization can avoid unnecessary costs for damaged products, non-motivated workers, or lost production, and can therefore avoid unnecessary distress (HSE, 2015).

**Challenges and safety training**
The literature on safety training has been reviewed by Robson et al. (2012). The most studied area was ergonomic hazards which comprised 22 studies. The second most studied science area relating to safety training was healthcare and office workers. It was shown that lectures were the most frequent form of training. Safety training lectures were used for 20 training interventions (90 %). Printed materials were used for 14 training interventions (38,8%), while hands-on practice was used for 14 training interventions (38,8%). Feedback in 12 training interventions amounted to 33,3 %. It was demonstrated in literature about safety training that 23 interventions (63,8%) consisted of one training session. Eight training interventions (22,2%) consisted of two training sessions. One training intervention (2,7%) consisted of three, five, or seven training sessions. Robson et al. (2012) described that in 28 sessions where the duration of training was observed, twelve (42,8%) lasted less than one hour, nine sessions (32,1%) lasted for one, or two, hours, while seven sessions (25%) lasted three hours, or more.

One reason for lack of safety training in organizations may be, as Hendrick (1990) points out, organizations the unavailability of sufficient resources for the amount of training required. It is more difficult for smaller companies to carry out safety training because the costs are problematic for organizations with smaller budgets (Worsfold & Griffith, 2003). A manager’s lack of safety training can affect the workers’ safety attitudes unfavorably (Worsfold & Griffith, 2003). Swedish research shows that organizations may lack sufficient safety training among employees, as shown by Bornberger-Dankvartd et al. (2003). This lack of safety training is confirmed by Worsfold and Griffith (2003), who highlight the poor availability of safety training courses in Wales.

**Implementation of safety training**
Malfetti (1963) describes how work-specific safety training can increase safety attitudes among workers. The work specific safety training can be related to the concept of training transfer conditions that includes sustainability in trained skills and generalization of learned training materials to the job in question (Baldwin & Ford, 1988). Generalization refers to the extent to which trained skills and behaviors are shown in work, after the training has been performed.
Research on training transfer discusses the trainee (training ability, personality factors, skills and motivation), training design (training content/materials and principles of learning), as well as work environmental factors (opportunities to perform trained behaviors, supervisory and support at work) (Baldwin & Ford, 1988).

The implementation of training towards the workplace for the worker may, as Baldwin & Ford (1988), discuss be affected by more than one factor, such as skills, personality factors, supervision and support of perform training. The affecting factors in training, as highlighted by Baldwin & Ford (1988), correspond with Laberge et al. (2014), who found ambient workplace factors, such as respect for the training and work, which can affect learning from the training. Social relationships and supervision of workers in the workplaces can also affect the process of increasing knowledge among workers (Laberge et al., 2014). In addition, workers interpret safety knowledge differently (Bluff, 2011). As Bluff (2011) discusses, workers ways of absorbing knowledge may depend on whether employers deal effectively with safety issues, or whether the workers receive information that increases their chances of absorbing safety knowledge.

To identify a strategy for implementing safety training, it is essential to consider factors that are unique in an organization (Hendrich, 1990). When resources are limited, safety training materials could be created and published online to ensure that workers can access the safety material (Bluff, 2011). Hendrich (1990) demonstrates how some companies may choose traditional classroom-type training sessions, other strategies can be considered based on the participants’ willingness to be trained, the content to be taught, and the participants’ ability to increase their knowledge (Hendrick, 1990).

**Summary of safety training**

Safety training is an approach to teaching and training workers how to perform a task safely. Laws and existing literature clarify the importance of safety training and knowledge dissemination in an organization to prevent work risks. Workers have the right to receive information on safety to ensure optimum health by reducing the effect of the risks present in the workplace, such as air contaminant exposure. Safety training can change workers’ behavior and perceptions about safety by getting them to use protective equipment, such as protective masks. Safety training can also have an effect at company level by reducing costs gained from unmotivated employees or lost production. To create awareness and prevent workers avoiding work risks in the work environment, safety training is important. There is a clear demand for, and profit from, safety training, and many organizations still lack sufficient safety training measures. Future studies benefit from including the development of methods to avoid problems, such as ineffective safety training, or high costs incurred by safety training. Workers can add reflectiveness about workers own health through safety training. Safety training affects how the worker sees and perceives safety risks, such as air contaminant exposure.

As workers may need to be motivated to participate in safety training, they benefit from being involved, and the training content benefits from being related to the worker’s practical work. It
is also essential for an effective safety training to have an effective method that is individually adapted. Workers understand safety information that is presented in training differently, depending on the method used. Audiovisual equipment is effective for classroom-style training sessions. Publishing training materials online is considered particularly effective for companies with limited financial resources. Safety training benefits from being evaluated regularly to ensure its effectivity for change of safety behavior and creation regarding safer work practices.

Safety attitudes, training, and motivation for control of air contaminants

The theoretical framework used in this thesis is demonstrated by studies, such as those showing the importance of conducting safety training in the control of air contaminants (see Buring et al., 1992; Brosseau et al., 2002; Lazovich, 2002), and improving motivation to work more frequently to reduce air contaminants (Buring et al., 1992; Rosén et al., 2005). In line with this, Scott et al. (2014) describe knowledge and training as an important step for workers in handling chemical risks. Safety training creates a deeper understanding of why safety is essential. If safety training and understanding of safety are not exercised among workers, they may fail to use the safety equipment or follow the safety rules, and it becomes a necessary evil (Scott et al., 2014). Nevertheless, providing safety training for air contaminant control has received limited attention in the literature, compared to topics, such as air contaminant risk assessments.

![Figure 2. Focus areas of theory and analytical reference frame in the thesis (arrows represent “leads to”, among employees in organizations).](image)

Health factors from air contaminant risks and the impact from individual exposure can be discovered later, after the illness has developed. For instance, cancer can be developed by exposure to wood dust after long-term exposure for the worker (Stellman et al., 1998). Workers benefit from being trained how to identify and control air contaminant risks. Behavior and human factors have received limited attention in the air contaminant control measure literature, and behavior and human factors are considered important for air contaminant control. Air contaminant control measures need to be kept simple to be effectively implemented and used.
in organizations. Using, primarily, a questionnaire, interviews and developed safety training methods, I have attempted to understand safety motivation, as well as safety attitudes in relation to safety training and air contaminant control, as described in the methodology section.

**Methodology**

The thesis process has involved methodological and theoretical stages. The intention in the thesis process was to find safety measures to reduce air contaminants from industries and develop theoretical knowledge in the field of air contaminants control in the workplace. Based on understandings and restrictions that have emerged over the research time of this thesis, safety training was chosen as a tool for decreasing air contaminants. The focus of the safety training was on developing workers’ safety knowledge, attitudes, and motivation to increase air contaminant safety and decrease air contaminant exposure at work.

With inspiration from Small (1995), Hansson (2007) and Bernard (2011), research was established to create a basis for actions, which in the thesis includes air contaminant control measures. A methodological approach has been described by Hansson (2007) as principles for the planning of measurements, experiments, and research source criticism. The methodology of this thesis is presented in this chapter.

Bernard (2011) has shown that two kinds of knowledge have been distinguished within science research. Knowledge from human senses that individuals are exposed to by experiences were called empiricism, and knowledge from reasoning rationalism (Bernard, 2011). Aristoteles (384-322 BC) distinguished between factual knowledge, called episteme, that includes a confident and universal truth, as well as knowledge by techne (action based knowledge), for instance, practical skills to perform an act (Nonaka & Toyama, 2007; Hansson, 2007).

In earlier literature and studies, research toward action has included theories about practical solutions to problems (Small, 1995; Hansson, 2007). The theoretical basis for solutions/control measures, and the testing of practical solutions (knowledge towards action), were undertaken in this thesis, using methods to increase safety knowledge, while safety attitudes and safety motivation were tested and analyzed to increase air contaminant safety. Wigblad (1997) as well Alvesson and Sköldberg (2009) described research towards an empirical perspective on theory as an inductive approach, and research from theory as deductive. Abductive research changes between inductive and deductive, and, consequently, between theoretical and empirical approaches (Wigblad, 1997; Alvesson & Sköldberg, 2009). This thesis has an abductive approach as its theory, and empirical data is gathered and analyzed simultaneously, with elements of both deductive and inductive approaches (see Table 2).

Research methods debated in science have included epistemology, ontology and human nature, according to Morgan and Smirchich (1980). The question of ontology (what the world could include), was described by Hansson (2007), as being related to the view that reality is independent of the human senses and is mutual to humans. Hofer (2000) and Bernard (2011) described how epistemological factors include how individuals create knowledge, as well as
theories and beliefs among individuals about knowledge. Epistemology (what humans could know) includes a view from the author in this thesis that people can benefit from approaching both an authentic or mutual reality. From the point of view of scientists, safety representatives, workers and managers, a mutual reality can contribute to different perspectives to create effective methods, for instance, for controlling air contaminants in organizations. The reasoning regarding mutual reality was confirmed by Hansson (2007), who described proper science as when knowledge disciplines all work towards a universal, general and mutual knowledge.

The research of this thesis aimed at reaching inter-subjectivity (Hansson, 2007), which means a common truth to all people. This thesis aimed at studying and reaching knowledge objectively, since it is a requirement for research and knowledge towards action (Hansson, 2007), and a norm in research (Bernard, 2011). Objectivity was handled by performing confirmability in accordance with Guba and Lincoln (1994), as well as Shenton (2004) (see Confirmability). To achieve objectivity and inter-subjectivity, this thesis and the articles included in the thesis have undergone seminar presentations, conference reviews, comments from researchers within the area of safety and work environment, as well as comments from supervisors and colleagues. In addition, the articles have undergone a review process when submitted to the journal in question, where more than one researcher has reviewed the research of every article. The research in this thesis was based on previous theory from studies in methodology, test methods for the increase of knowledge regarding safety in the work environment, and by analytically examining the results and relating these to previous studies.

**Qualitative and quantitative research**

This thesis has been based on qualitative and quantitative approaches in the methods used. It included the PIMEX method (see central concepts and PIMEX section) to engage the worker in seeking solutions to reduce air contaminants in work situations (Rosén et al., 2005). The PIMEX method is an effective tool for developing safety training material (Papers II, III), or as a methodological basis for identifying air contaminant risks and control measures (Papers I, II, III), as it is a combination of quantitative and qualitative methods, which included observation and numerical data.
Table 2. Method and design of Papers I-IV, lower case x shows small parts in the study design and method, capital X indicates the main method part of the study (e.g. Paper I in majority Quantitative method & qualitative fragments).

<table>
<thead>
<tr>
<th>Method &amp; Design</th>
<th>Paper I</th>
<th>Paper II</th>
<th>Paper III</th>
<th>Paper IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantitative</td>
<td>X</td>
<td>X</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>• PIMEX</td>
<td>X</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>• Questionnaire</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Qualitative</td>
<td>x</td>
<td>x</td>
<td>X</td>
<td>x</td>
</tr>
<tr>
<td>• PIMEX</td>
<td>x</td>
<td>x</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>• Interviews</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An advantage of qualitative research has been described by Silverman (2006) as a favorable method for researchers to understand psychological factors and thoughts from a group of individuals, and to find distinctive or unique results (Zikmund et al., 2012). Using both quantitative and qualitative methods was described as essential for a greater assuredness in the results, as quantitative and qualitative methods together can add new perspectives to anticipate research problems (Jick, 1979).

The four papers of this thesis had qualitative elements. Three papers had both qualitative and quantitative elements (Papers I, II, III). Knowledge is gained and passed on from qualitative and quantitative traditions to evaluate results and findings. In Papers I, II and III, empirical material was obtained from workers, students, and safety representatives through interviews, questionnaires, and exposure measurements (see Table 2).

Paper I obtained quantitative measurements in terms of statistical analysis concerning variation among 10 individual workers and their exposure within the engineering, pharmaceutical, printing, stone, and wood industries. Paper II obtained quantitative measurements from workers in print shop, metal, paper mill and municipality organizations to measure air contaminant exposure and safety motivation. Paper III included semi-structured interviews with students of senior high schools (aged 16-18) to analyze safety attitudes among students after safety training. Paper IV included semi-structured interviews with safety representatives from the carpentry industry in order to analyze safety training as a control measure to decrease air contaminant exposure in carpentry work situations.

**Interviews**

Interviews have been described as an effective method for analyzing social phenomena, human groups, human experiences, or human practical and professional experience from daily life
situations (Kvale, 2008). Interviews may help when gaining knowledge of why human beings act in a certain manner within a specific situation. Interviews can also be a key component in understanding human interactions and individual attitudes to various factors, such as work situations, according to Kvale (2008).

The interviews in Papers III and IV were transcribed and analyzed using value coding (Miles et al., 2013). Similar statements in the interview material were sorted into themes and coded to reflect the participants’/safety representatives’ values, attitudes, and beliefs. The values of participants have been coded into themes related to the aims of Papers III and IV. Values have been defined as the “importance we attribute to ourselves, another person, thing or idea”. The concept attitude was not used with the same meaning as safety attitudes (see central and related concepts). Attitudes have been defined as “the way we think about oneself, another person, thing or idea”, and beliefs have been defined as “part of a system that includes values and attitudes, plus personal knowledge, experiences, opinions, prejudices, morals, and other interpretive perceptions of the social world” (Miles et al., 2013 p. 75). Value coding was used to obtain the respondents’ clear perceptions, attitudes, and approaches to the safety training, air contaminant safety, and control measures in typical work situations. Values and beliefs were coded into common codes, with names, such as QR learn, or knowledge increase, to get an overview and clear analysis of the codes. Thereafter, themes were created (see Table 3).

**Table 3.** Example of analysis in coding processes, and themes from statements and questions in Paper III, words within brackets are interpreted by the researcher [].

<table>
<thead>
<tr>
<th>Paper III</th>
<th>Question</th>
<th>Statement</th>
<th>Code</th>
<th>Theme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>What do you feel that you may have learned?</td>
<td>“Yes, but first, that you have seen how much dust that you were exposed to, because it is not something I thought about before [before the training] so much, yes, but above all, that we are exposed to quite a lot of dust, and that it is good with extraction that absorbs it [dust]..”</td>
<td>QR - learn.</td>
<td>Knowledge Development</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Paper IV</th>
<th>Question</th>
<th>Statement</th>
<th>Codes</th>
<th>Theme</th>
<th>Main theme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>What is a good training material?</td>
<td>“Simple [training material], not excessive [short], easy to understand, and not too much [short and tangible], really only one A4 with front and back, not a folder, possibly that you can link [web link] on to something else if you want to read more, a web page or something like that”</td>
<td>Train. Short. Tang.</td>
<td>Short, tangible and consequent</td>
<td>safety training routines</td>
</tr>
</tbody>
</table>
In Papers III and IV, paper statements were coded first, where a statement could include multiple codes, see Table 3. A theme could have more than one code, for example, codes where 1) training benefits from being 2) short, and 3) concrete (see Table 3, Example Paper IV). In Paper IV, the theme process when coding the interviews included semi-themes that were divided into a main theme, to simplify and concretize results. The semi-themes were divided, based on consistency and similarities between the semi-themes. The codes in Table 3 were analyzed according to the questions and statements, which could demonstrate that the respondent in question was talking about a specific factor, such as training material.

The abductive approach was used as a basis for avoiding misunderstandings or subjectivity, while gathering empirical data in Papers III and IV, and, consequently, get an understanding of the target group and problems of the study in question. For example, a model was created based on theory in Paper IV, from which an interview template was created, and in Paper III a pre-study was performed. The analysis of the interviews was related to theory about interview analysis, interview methodology, safety training, safety attitudes, safety motivation, and air contaminant safety, to prevent subjectivity. The coded process was followed by analyzing the empirical material with previous theory about safety training, safety attitudes, safety motivation and air contaminant control. Seventeen telephone interviews were performed in Paper III with secondary school students. In Paper III, an interview template (see Appendix B) was organized in themes (see Table 4)

Table 4. Themes of interview template in Paper III.

<table>
<thead>
<tr>
<th>• Work environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>• QR codes in general and linked to PIMEX videos as a safety training tool</td>
</tr>
<tr>
<td>• Mobile phones as a safety training tool</td>
</tr>
<tr>
<td>• Work environment and safety training in general</td>
</tr>
</tbody>
</table>

In Paper IV, face-to-face interviews were performed with nine safety representatives. The interview template (see Appendix C) was created with inspiration from the model developed in Paper IV, and sent to respondents prior to the interview. Based on theory, the discussion basis was used in terms of a model that explained safety training in Paper IV (Buring et al., 1992; Rosén et al., 2005; Paper I; Paper II; Paper III). The model was created from theories within air contaminant exposure research. Themes (see Table 5) were included in the interview template (see Appendix C) of Paper IV.

Table 5. Themes of interview template (see Appendix C) of Paper IV.

| • Create safety training material |
| • Identifying risks as well as measures, and safety training |
| • Implementation and safety training |
| • Evaluation and safety training |
| • Attitudes and motivation towards safety in relation to safety training |
| • Cooperation and safety training |
**Questionnaire**

Mitchell and Jolley (2012) argued that questionnaires have been shown to gather information on a large sample, in a short space of time about human behavior, beliefs and attitudes. Questionnaires have shown to be an effective method for anonymity and improvement in validity in answers from respondents in research. In compatibility with interviews, respondents should not be influenced by body language or responses from an interviewer that may affect answers from respondents (Jones, 2014). In Paper II, a previously validated, safety motivation questionnaire was used (Hedlund et al., 2010), which may benefit the method as a reduced number of biases could occur if the questionnaire is well-designed, as shown by Jones (2014).

In Paper II, measurement of safety motivation was performed before and after six safety training methods in workplaces. Questionnaires were administered to the employees before and after the safety training to evaluate and compare their levels of safety motivation. The questionnaire comprised 26 statements about safety motivation in the work environment and included five themes (see Table 6).

**Table 6. Themes included in the questionnaire for Paper II.**

| • Importance of safety improvement |
| • Interest and resources in safety by workers |
| • Perception of management involvement in safety |
| • Safety improvements |
| • Your involvement in safety issues |

**Statistical analysis**

In Paper I, a relative cumulative exposure variation analysis was conducted, in accordance with Andersson and Rosén (1995). The PIMEX method was used in Paper I to characterize exposure variation and frequency of peak exposure in various work tasks. An analysis was performed with Excel version 2010, by dividing every data measure of the workers with the arithmetic mean (AM) of the data set, and multiplying it by 100 to normalize data. The calculated AM in every work situation was 100, to facilitate comparison of the variation in exposure within work situations. The exposure data was analyzed in terms of geometric mean, geometric standard deviation (GSD), the ratio between geometric and arithmetic mean (GM/AM), and the ratio between maximum value and arithmetic mean (Maximum/AM). Percentage of time with exposure over AM, Percentage of exposure explained by levels over AM, and percentage of time explaining 50% of exposure were also analyzed. The values were used as they represent more than one perspective towards air contaminant variation. It gave the opportunity to analyze exposure in relation to the time of the work task, and the peak exposure relative to the arithmetic mean.
A low ratio between GM and AM can show a high variation of exposure during the work process. By including the measures/values percentage of time during which exposure exceeds the AM, and the percentage of exposure accounted for by levels over the AM, the time in relation to exposure was analyzed above average exposure, which indicates more, or fewer, peaks of exposure. Maximum value related to the AM showed the highest peaks in work situations. High background level indicated reasons why the peaks did not occur frequently, as the exposure was generally high.

The work situation background level of the air contaminants in the premises was analyzed, as well as work tasks, and air contaminant risks to find control measures that reduce the air contaminants. The exposure measurements were performed in 10 organizations in the following industries: engineering (1), pharmaceutical (1), printing (2), stone (3), and wood (3).

In Paper II, statistical analysis was performed by using SPSS version 21 to evaluate and analyze the data. The results in Paper II were presented by showing significant changes on a factorial and item level. The questionnaire created by Hedlund et al. (2010) was used to evaluate safety motivation, which was validated using a test-retest method and internal consistency reliability, as well as factorial structure that was explored in the study.

The data from the safety motivation questionnaires was analyzed by finding significant changes on a factorial and item level. The answered questionnaire in Paper II was analyzed by parametric or nonparametric tests because of sample size. Nonparametric tests were used to compare results as respondents were small-size samples that included fewer than 30 individuals/participants. Nonparametric data tests have been shown to fit sample sizes under 30 respondents (Hinton et al., 2004; Burt et al., 2009; Ryan, 2013), for instance, sample levels of 10-15 participants (Burt et al., 2009).

**PIMEX**

The PIMEX method (JBR Consulting, Germany) was an essential part of the safety training material in Papers II and III, as well as a central part of Paper I to analyze exposure variation in typical work situations. PIMEX has been used in research (Andersson, 1995; Rosén et al., 2005; Beurskens-Comuth, Verbist, Brouwer, 2011). Air contaminants, such as gases, vapors, dust, smoke, mists, aerosols, enzymes, fibers and radon can occur in workplaces. This thesis included mainly wood dust, fumes from solvents, medicine dust, stone dust and welding smoke (SWEA, 2015a).

Air contaminant exposure data and measurements were collected from the work situations in Papers I, II and III using the PIMEX method. The PIMEX method included synchronized filming and measurement in air contaminant exposure of workers in real time (Andersson, 1995; Rosén et al., 2005; Beurskens-Comuth et al., 2011). Real-time recordings of workers were made with a video camera and synchronized with a Mini RAE 2000 instrument, and a dust track that was used to perform air contaminant exposure measurements. Mini RAE used a photoionization detector to measure air contaminants. The Dust track used light scattering as a method to
measure air contaminants. Light scattering was a direct reading instrument that detected particles in the air by identifying scattering of light by a photodiode (Rose & Cohrssen, 2011). The scattering has been shown to be depended on dust particle size and amount. Photoionization was another air contaminant assessment method. UV radiation was used to ionize contaminants which were detected by the instrument, and ions are produced which are detected by electrodes, and a concentration of air contaminants can be read (Rose & Cohrssen, 2011).

Telemetry measurement signals were sent to a receiver connected to a computer. Video and measuring signals were synchronized using PIMEX software for computers; and exposure variability appeared on the computer screen together with the work process. The videos were recorded in the computer software with an exposure scale next to the work situation in the video. The videos made it possible to watch the work situations and the worker exposure, together with researchers, workers, students, and safety representatives in the industries, to find risks and control measures for air contaminants. In Papers I, II and III, observations as part of the method PIMEX were performed in work situations.

This thesis explored which workers in the studied organizations were exposed to air contaminants, and how air contaminant exposure could be avoided with the help of PIMEX assessments. Based on findings in Paper I, short-term exposure became the focus to reduce a large percentage of the total exposure in organizations that are especially vulnerable to air contaminants, such as print shop or wood industries. A recommended use of the PIMEX method is to produce safety training material, as stated in a study by Rosén et al. (2005).
Based on findings of Paper I, PIMEX videos were selected to be used in safety training with the aim of decreasing air contaminant exposure among workers. Safety training was used to improve safety attitudes and safety motivation. In order to prevent short-term exposure, knowledge about air contaminant risks and control solutions was intended to make workers aware of the risks and how to avoid them.

Literature search
Literature searches were conducted in each paper, focusing mainly on: safety training, short-term exposure, safety motivation, safety attitude and air contaminant control. The concepts above have been paired and applied together with each other, and other associated terms and synonyms, for instance, “safety motivation after safety training”, or similar terms “work environment motivation after training of safety”. The databases used were mainly Web of Science, Google Scholar, ERIC, Oxford Journals, and Science Direct.

Safety training material and method
In Paper II, managers, safety representatives, employees, and team leaders performed safety training interventions. In one of the safety training methods in Paper II, safety representatives visualized air contaminant risks and control measures in a presentation to print shop workers. The employees watched PIMEX videos in visualization presentations (see Figure 5), which showed how peak exposure risks could be decreased and controlled. The graphs in the safety training material were related to work situations, aiming at pedagogically showing the increase and decrease in exposure, and not specifically at measuring values, such as ppm or mg/m$^3$. The presentation in Paper II was followed by a group discussion. Similar methods to the visualization presentation have been seen as effective, since it has been shown that it was easier for those with learning and reading disabilities, or language difficulties, to learn by watching videos rather than by reading (Xin & Rieth, 2001; Hasselbring & Baush, 2005).

In the second work setting and safety training in Paper II, a safety training measure was performed in which the welding workers were trained by PIMEX measurements, assessments and discussions (see PIMEX description & central concepts). The training process was followed.
by discussions with employees. To compare the air contaminant safety training settings and methods, four safety training methods were performed.

The third work setting and safety training included training of managers, team leaders, safety representatives, and training about systematic work environment management (SWEM). The safety training included classroom sessions with training, risk assessment, and test questions, during six months.

In the fourth work setting and safety training, safety representatives, team leaders, and managers were trained about systematic work environment management, during three days. Physical and psychosocial risks, ergonomic risks, risk assessments, drugs, as well as laws and regulations were included in the training.

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a) Air contaminant risk – cleaning with ethyl acetate

![Image](image1)

b) Control and reduce air contaminants – cleaning with ethanol

![Image](image2)

Figure 5. Example of safety training using PIMEX videos visualizing air contaminant exposure a) risks before the control measure, and b) after control measure when changing solvents to clean the machine.

The fifth safety training was performed in an office environment, consisting of classroom training, individual training in an office, and follow-up meetings, where employees exchanged
experiences. The training and a review of each employee workstation was performed by a physiotherapist and a safety engineer who worked in occupational health services.

In the sixth safety training, 15 managers received training about work environment and safety in a classroom format for over two years, in a municipal agency (Municipal Department 1). Eleven employees in the studied organization received individual function health assessments. The individual health assessments encouraged workers to take part in fitness exercises and individual feedback (Department 2). All the managers and workers were given an individual function assessment, health examination and individual feedback (Department 3).

**QR codes**

In Paper III, a new form of safety training was used involving QR codes and PIMEX videos (see Figure 3), which were placed in classrooms with wood processing machines, among secondary school students in handicraft programs. By linking QR codes to internet linked videos, the information and training were accessible at the wood work situations, such as wood machines, for the secondary school students. QR codes were linked to PIMEX videos that showed how short-term exposure could easily be avoided (see figure 3 and figure 6). By using QR codes linked to PIMEX videos, the students could get direct information (direct response) and training that included quick and easy information.

![Figure 6. Placement of QR codes at the work station.](image)
**Participants and sampling**

From inspiration of a strategic sample method (Finlay & Evans, 2009), participants were chosen based on their experience, perspective and air contaminant risk situation at their workplace. The strategic samples of this thesis were based on sample relevance to the research question in this thesis, as Bryman (2015) describes as essential. To gain a deeper understanding of safety training to reduce air contaminants, Paper IV was conducted to obtain data from in-depth interviews with safety representatives. The strategic sample in Paper IV is based on experience of the safety representatives. As Finley and Evans (2009) have shown, the target group of a strategic sample was based on participants that have experience and a broad perspective within the phenomenon studied. In Papers I and II, the strategic samples were made with the intention of finding participants who had air contaminant risks typically of their workplace and work situations. In addition to air contaminant risks, Paper II included samples with general work environment risks, such as ergonomic risks. The intention in Paper II to include organizations that had additional risks other than air contaminant risks was to obtain a broader research perspective of safety training and safety motivation.

In Paper III, the strategic sample was made with secondary school students as they had experience of air contaminant risk situations from the perspective of 16-18-year old vocational students, with air contaminant risks in their daily work/school situation. Secondary school students were asked to participate in Paper III because, as the future workforce, they can transfer their knowledge and skills after the safety training to the workplace and thus help promote a safe approach towards air contaminant risks and control. Students were also selected because younger workers are more vulnerable to safety risks (AFA Insurance, 2013; Laberge et al., 2014), and more receptive and adaptive to new knowledge than older workers (see Isla Diaz & Cabrera, 1997). The samples were selected for all papers in this thesis by identifying industries that were typical of air contaminant exposure. The samples were selected in conversation with union representatives, senior high school teachers, researchers with experience within air contaminant research and management in industries. In summary, the strategic sample method was intended to widen perspective and knowledge of air contaminant safety and safety training, since workers, students, as well as safety representatives, were included in the thesis (see Figure 7).

![Figure 7. Focused sampled target groups in thesis Papers I-IV.](image-url)
Research process of thesis

A research strategy was developed to create knowledge and understanding of the safety training methods in Papers II and III, by different stages that were modelled and entitled the Four-Step Model (see Figure 8). In Papers II and III, the first step of the research process was to contact the schools and industries. The second step involved discussing and measuring air contaminant risks and control measures with the workers and industry management using PIMEX. Step three included the editing of PIMEX videos for use in safety training. Step four included evaluation of safety training by using safety motivation questionnaires (Paper II), and interviews (Paper III).

In Paper I, the first and second stage of the Four-Step Model was included in the research process, followed by a statistical analysis. Paper IV, included the first and the second step in the research process of the Four-Step Model, followed by interviews.

During the thesis process, regular communication and discussion was held with managers, leaders, workers, safety representatives, supervisors and colleagues, regarding the research in this thesis. In addition, communication was held with other PhD students in PhD education, and discussed at conferences about work environment science, and research in general. The feedback received, as well as doctoral education in the dissertation process, has given new perspectives and knowledge of how this thesis research should be written and understood.

Trustworthiness in qualitative and quantitative research

In this thesis, a discussion of quantitative concepts of reliability and validity was added, interwoven with corresponding concepts in qualitative research from Shenton (2004). Credibility, transferability, confirmability and dependability were described by Shenton (2004) as essential for trustworthiness in qualitative research. Shenton’s (2004) factors of trustworthiness have been used in qualitative studies, such as Rydell (2015). The choice of discussing and converging the quantitative terms of reliability and validity with credibility,
transferability, confirmability and dependability was based on the fact that the methods used in this thesis include both qualitative and quantitative elements. The discussion within the research to distinguish between quantitative and qualitative method was described by Åsberg (2001) as meaningless, as no method is simply quantitative or qualitative. My approach in this thesis was that a method can benefit from including both qualitative and quantitative elements, as a broader perspective may add objectivity and understanding to the results in the thesis (see Table 2).

**Credibility and validity**

The counterpart of internal validity purpose in positivistic research has been to measure with study methods factors intended to be measured (Shenton, 2004; Bryman, 2009; Burt et al., 2009). An equivalent factor to internal validity was qualitative research credibility. To achieve credibility in research, methods that have been used previously can be included in studies (Shenton, 2004). In this thesis, commonly used semi-structured interview methods were included, and coding from transcribed data (see Kvale, 2008; Miles et al., 2013). Semi-structured interviews have been a commonly used method in development research, as stated by Raworth et al. (2012). Semi-structured interviews were described by Raworth et al. (2012) as an essential method for learning about motivation behind behavior and choices among individuals, as well as human beliefs and attitudes.

In addition, according to Shenton (2004), it is essential to understand the culture of the organization early on in the research process to improve credibility in qualitative research, by, for instance, visiting the organization or studying documents that increase knowledge about the organization in question (Shenton, 2004). In this thesis, regular visits were made and contact held with employees, safety representatives or leaders at workplaces. In Papers I, II and III the PIMEX measures were performed at the workplaces. PIMEX includes an interactive contact with employees in the research process (Papers I and II), as well as students and teachers (Paper III), which created an understanding of the workplace in question. In Paper II, the safety representative and additional workers in the print shop industry were involved in the PIMEX process and safety training process. This allowed the employees and the safety representatives to contribute with their thoughts about air contaminant risks, control measures or safety training in their workplace. In Paper IV, the safety representatives described and related their experiences regarding safety for organizational culture. One example of this was that managers need to be included in the process of safety training, as they make all the decisions in the organization about safety measures.

Triangulation has been described in research as support data with additional sources of data, such as adding an interview with a respondent to the basic data (Shenton, 2004; Lincoln & Guba, 2002), or mixing quantitative and qualitative methods (Jick, 1979). When using triangulation, documents can be included that incorporate or verify details from participants in the studies, or demonstrate a background that helps to describe the behavior or attitudes of a group. Shenton (2004) describes how triangulation and credibility have been shown to be improved by documents, such as sources that are created or related to the company in question. Lincoln and Guba (2002) describe how triangulation has been shown to include additional
sources, methods or theory to verify or develop the validity and trustworthiness in a qualitative study. In Paper IV, a safety training model based on previous research was created and used in developing an interview template. The model was used as a basis in the interviews (see Interviews). Quantitative and qualitative methods have been included in this thesis. Interviews, questionnaires and statistical analyses were used, and PIMEX includes both qualitative and quantitative method characteristics (see Table 2, and PIMEX).

Participants from more than one organization may be useful in triangulation processes to create credibility regarding the impact of local factors that were characteristic for one organization, and to provide diversity (Shenton, 2004). Papers I, II, III and IV included four or more organizations. Paper I included five organizations. Paper II included seven organizations, and Paper III included, in total, three schools/organizations + one organization/school in the pre-study. Paper IV included four organizations.

To ensure honesty among participants and hence credibility in the study, each participant could be given the opportunity not to participate in the project, and therefore participants would be willing to contribute and provide data generously, according to Shenton (2004). The aim with free willingness of participation was also to ethically provide the participants with this option, and thus not force them to participate in the studies. It may be emphasized that participants, who chose not to participate in the study, could have contributed with valuable information for the results. The researcher may encourage participants to be honest, when the researcher describes that there are no right answers, so the participants can answer honestly without feeling fear (Shenton, 2004).

In Paper III, the participants, students/future workers in secondary schools, were informed and asked by their teacher about the project and study in Paper III. The students were also informed at the interview situation, before it started, about the interview in question. Information was given to the students about the included questions and interview, as well as the work environment, study project and safety training. The students were also given the chance in the interview to add information that they thought was important, directly after the interviews.

Before the study, the students also had the chance to ask questions about anything they wondered about, related to the interview or the project. Similarly, the safety representatives in Paper IV were given information before the interviews (2 weeks), and at the interview situation. The safety representatives were also given the opportunity to not participate, and were asked by both the manager and researcher about participation in the study. Students and safety representatives were also informed that they would be anonymous.

In addition to creating conditions for increased credibility through information to respondents, it was essential to reduce potential lies or misconceptions in the interview statements, by using two, or more, related questions in the interviews (Shenton, 2004). In the interviews for Papers III and IV, related questions were included (see Interview Templates in Appendices B and C, and Table 7).
### Table 7. Questions in Papers III and IV related to similar questions in the interview template

<table>
<thead>
<tr>
<th>Paper</th>
<th>Question 1</th>
<th>Similar question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper IV</td>
<td>What do you think about the factors inside the organization that may influence safety training?</td>
<td>What are your experiences of what may affect safety training: before process, early in the process, later in the process, in process</td>
</tr>
<tr>
<td>Paper III</td>
<td>What do you think of the QR Codes and training material that were attached next to the machines in the classroom?</td>
<td>Describe whether there are factors that you learned from the fact that QR codes were attached in the classroom?</td>
</tr>
</tbody>
</table>

Methods to perform double checks on the correctness of the data have been shown by Shenton (2004) as essential for strengthening the credibility of qualitative studies. The interviews in Papers III and IV were recorded and transcribed. This gave the opportunity for the researcher to listen and analyze the recorded interview data, so that misunderstandings were avoided. The interviews were analyzed further with values coding by Miles et al. (2013) (see Table 3, and Interview section), to avoid errors in the interview data.

If the definition of air contaminants quality is weak, it may be difficult to achieve validity (Burt et al., 2009). Papers I, II, III, IV contain definitions of the subject area in question, to improve validity. In Paper I, the definition of peak exposure was clearly formulated. Safety motivation was defined, problematized and related to the earlier theory in Paper II. To increase validity, in Papers III and IV, definitions of the main areas of safety attitudes and safety training were formulated and related to theory, as well as the defined central concepts in this thesis.

A peer review and analysis of abnormalities has been shown by Shenton (2004) as being essential for credibility in qualitative research. Consequently, all of the papers, included an analysis of methodological, empirical and theoretical abnormalities, and the transcribed material was analyzed more than once. During the writing process, Papers I, II, III and IV were analyzed and checked for possible problems by the researcher, colleagues, supervisors, and in seminars, as problematized in the text of each paper. In addition, Papers I, II, III and IV were analyzed and reviewed (peer reviewed) by reviewers (2, or more).

**Transferability**

External validity has been seen as generalization of the results, for example, to other individuals, target groups or situations (Rubin & Babbie, 2009). Since qualitative research has been shown to include a limited number of individuals, it could be challenging to generalize the results of any similar situations (Shenton, 2004). A comprehensive description of the phenomenon under examination was described by Shenton (2004) as increasing transferability.
Consequently, researchers and readers of the study in question, in general, could evaluate the results and relate them to their situation. The description of research has been shown to include information about the number of organizations involved in the study, or restrictions in the type of respondents who contributed to the data to increase transferability. In addition, information to increase transferability could include a number of participants, collection methods, the number and length of the data collection session, and the time period of collected data (Shenton, 2004). In Papers I, II, III and IV, the number of participants was described. The organizations included were described in the methods. In Papers I, II, III and IV, detailed descriptions have been formulated of collection methods in organizations (including schools) and the work task. Transferability can be strengthened by a description and understanding for readers about the study context, which may have comprised, for example, the organization or geographic location where the study was conducted (Shenton, 2004). There were descriptions about type of organization in Papers I, II, III and IV, and a description of the work tasks. Descriptions about organizational contexts create conditions for increased dependability, and consequently, trustworthiness in qualitative research (Shenton, 2004).

**Dependability and reliability**

Reliability in positivistic research could be referred to as techniques to show that if the research work/method is performed again, the result will be the same (Shenton, 2004). The qualitative research term for reliability has been dependability. To improve the dependability, the research process could benefit from having been described in detail, to enable future researchers to repeat the research work and gain the same result (Shenton, 2004).

For increased dependability in qualitative research, explanation of plans, and performance on a strategic level, a detailed description of data gathering, evaluation of the project effectiveness, and the method of data collected could be used in the study in question (Shenton, 2004). A description of data gathering has been carried out in this thesis (see Transferability section). For increased reliability/dependability in Paper II, the questionnaire that was used had been previously tested (Hedlund et al., 2010). In addition to a previously tested questionnaire, the interview method in Paper III had a pre-study on a similar target group as in the main study (secondary school students in vocational programs). Before each of the two interviews, methods and the interview templates were examined by two or more individuals with experience and knowledge in scientific methods. In Paper IV, the interview template was developed and performed with a basis in previous research (See Interview section)

**Confirmability**

Confirmability in research studies is essential for trustworthiness, and includes researcher objectivity. Reduced effect of researcher bias/partiality can be made by triangulation (see Credibility section), such as including additional data (Shenton, 2004), or theory (Guba & Lincoln, 1994). Confirmability can be improved by identification and discussion about method shortcomings and in-depth description of method (Shenton, 2004). The description of
shortcomings, and in-depth description of method in this thesis are described (see Credibility section, and Dependability section) (Shenton, 2004)

**Results**

This section describes the different papers/sub-studies in this thesis. This is followed by an analysis and discussion related to the purpose of the thesis, which is to develop and analyze safety measures to decrease air contaminants based on human aspects. The questions characterized in the aim and purpose include 1) existing safety measures aimed at decreasing air contaminant exposure, 2) safety motivation and safety attitudes, and the influence of participating in decreasing air contaminant exposure, and 3) safety training contribution to decrease air contaminant exposure in organizations.

**Paper I. Short-term variation in occupational exposure to air contaminants**

Karl Gummesson, Ing-Marie Andersson, Gunnar Rosén  
Journal: *Journal of Occupational and Environmental Hygiene*

The main objective of the study was to characterize the exposure variation in selected industries and analyze variation in typical work situations. Paper I contributes toward creating knowledge to control air contaminants that can be used by researchers and in workplaces.

**Method**

Paper I was based on an interactive approach, whereby empirical material was gathered using the PIMEX method and risks were identified by workers in ten industries. The data was then analyzed for each sample. PIMEX videos showing risks and exposure can be used to show what type of exposure that is a risk regarding high air contaminant exposure i.e., peak exposure, and how to avoid these air contaminant risks, by avoiding risk situations. The peak exposure of air contaminants is shown in these videos and a curve that indicates when (work position) the workers are exposed and the level of exposure. Exposure values were normalized so that the AM for each data set is 100. This normalized value of 100 is calculated by dividing each measurement by the AM for the data set, and multiplying it by 100. Data of exposure was analyzed using geometric standard deviation (GSD), the ratio between geometric and arithmetic mean (GM/AM), as well as the ratio between maximum value and arithmetic mean (Maximum/AM), and the percentage of time explaining 50% of exposure.

**Results and findings**

Ten typical work situations where air contaminant risks are commonly revealed are presented with relative exposure variation, along with relative cumulative exposure versus time. There are comments about risks, peak exposure and control measures related to each typical work situation. For example, in a stone industry workplace, the stone was crushed in a hydraulic machine outside, and the end product was paving stones. Local exhaust effectiveness was
shown to be diminished because of a missing plastic window. Working outside/outdoor gave a low background exposure level of dust for the worker, and frequently observed peaks were linked to the cutting of stones in the stone machine.

- Among the work situations in Paper I, the background level varied, and highest exposure values were seen in the print shop, stone, as well as wood industry work situation examples.

Exposure data comparisons were made between the GSD, the ratio between GM and AM, the ratio between maximum value and AM, as well as the percentage of time explaining 50% of exposure.

- High total exposure variation was shown generally in the 10 work situation examples.

The percentage of time over the arithmetic mean was shown in work situation examples to be low, at the same time as having peak exposure. In one example, it could include 20-30 peak exposure situations, and the total exposure consisted mainly of peak exposure. For instance, in the pharmaceutical industry, the time which explained 50% of the exposure was 3.2%. In the pharmaceutical industry the exposure was explained by levels over AM, more explicitly described as 83%. It was 17% with the percentage of time with exposure over AM. 17% of time and 83% of levels over the arithmetic mean indicated a high number of peaks.

- The exposure peaks were shown to account for the main part of the total exposure for the worker.

**Paper II. Safety motivation at work: evaluation of changes from six interventions**
Ann Hedlund, Karl Gummesson, Alexis Rydell, Ing-Marie Andersson
Journal: Safety Science

In Paper II, six safety training interventions were analyzed. The aim of Paper II was to evaluate whether six safety training interventions increase employee safety motivation. The contribution from Paper II was a theoretical path diagram, and data from a questionnaire related to six safety training interventions.

A path diagram based on theory was developed summarizing the relationship between actions, aspects, and effects related to safety motivation. For instance, safety motivation is related to increased safety participation. Furthermore, in two of the safety training interventions, PIMEX was used to identify air contaminant risks and solutions at 1), a print shop industry, and 2), a metal organization.
Method
Questionnaires (see Appendix A) were used to evaluate six safety training interventions which included: 1) PIMEX (see PIMEX) visualization of risks and control measures in presentations by a safety representative (in PIMEX videos and text), 2) practice of PIMEX and related discussions in a work situation, and safety training intervention, 3) Swedish regulation and work with systematic work environment management, and safety training intervention, 4) risk and control at computer screens, and 5) individual health assessment with feedback from occupational health services, and safety training intervention, 6) effective workplaces that embraced improvement work, such as lean production, systematic work environment management, risk assessment and teaching, reading and practical safety activities.

Results and findings
Safety motivation was measured before and after six safety training interventions.

- Safety motivation changed significantly at the factorial level in metal organizations with the intervention effective workplaces (decreased), a paper mill organization with the intervention systematic work environment (increased), a municipal agency with the intervention computer screen work (increased).
- It could be demonstrated that the organizations are affected by who initiated the safety training intervention. If the management initiated the training, the safety motivation effect increased.
- The high participation in safety training increased safety motivation.
- A high number of safety training occasions increased safety motivation.
- The form of the target group affected safety motivation after safety training. Target groups increased safety motivation after the safety training intervention, if the safety training was directed at improvements in the workers own work (for instance, among safety representatives).

In safety training within the print industry, there were significant changes among workers at the item level, where PIMEX videos showing risks and solutions were used.

- The results showed that the workers followed existing procedures concerning the work environment to a higher degree after the safety training.
- The workers in the print industry became more aware of work environment risks after the training.

In safety training focused on PIMEX performance in a metal company with related discussions in a work situation, a significant increase was shown.

- The results showed an increase among workers concerning to what degree a worker said they were involved in work environment improvements.
Paper III. Effective measures to decrease air contaminants through risk and control visualization – A study of the effective use of QR codes to facilitate safety training

Karl Gummesson
Journal: Safety Science

The focus area of Paper III was safety training regarding air contaminant peak exposure risks, safety, and control in senior high schools. The aim of Paper III was to analyze the effect of QR codes linked to PIMEX videos, by analyzing safety attitudes in student responses after this safety training measure.

Method
The study was conducted by first identifying and analyzing wood dust control measures and risks with students and teachers, using the PIMEX method.

In a preliminary study the PIMEX method was used in one secondary school handicraft program. To identify risks and control measures and to develop a safety training material, students were filmed in work situations and wood dust exposure was measured with PIMEX. Teachers, students and researchers together analyzed wood dust risks and effective measures before and after the filming of students in work situations. The safety training material was created by 1), performing PIMEX safety training videos with wood dust risks and control measures and, 2), QR codes were linked to PIMEX videos from real time measurements and videos. After the QR codes were linked to PIMEX videos, 3) the QR codes were displayed next to the wood machines in the classrooms. .

The effect is analyzed by evaluating safety attitudes to this safety training measure in the student responses. Seventeen telephone interviews were performed at three senior high schools, and a specific preliminary study to explore improvements of the safety training measures at two additional high schools. The preliminary study led to some changes in the actual execution of the main study, which included information posters in each classroom, with information about the function of the videos, and links to websites about PIMEX and PIMEX videos (Rosèn et al., 2005). The QR codes were enlarged and the posters were colored green to make them more visual. The QR codes were then implemented in three senior high schools. A short introduction was made by each teacher to explain the function of the safety training QR codes and the PIMEX videos.

Results and findings
By placing QR codes linked to PIMEX videos next to machines at senior high schools, the interviews showed positive statements and knowledge increase about air contaminant safety.
The positive statements from the students in the handicraft programs indicated that QR codes linked to the PIMEX videos were a good, smart, or effective safety training measure.

- The 17 students made 61 positive statements regarding the QR codes linked to the PIMEX videos, and 54 statements indicated a knowledge increase.
- The knowledge increase included air contaminant safety, such as avoiding situations where high air contaminant exposure is typical. For example, work situations using compressed air to clean the students, or machines, from wood dust.
- The results indicated that the student’s safety motivation increased, whereby the students/future workers described how they now desired to work more safely to avoid wood dust exposure after they saw the PIMEX-videos in their smartphone-or I-phone.

**Paper IV. Safety and Health Training in Managing Wood Dust – On safety representatives’ experiences**

Karl Gummesson, Alexis Rydell, Annika Vänje

Journal: Not yet decided.

The aim of Paper IV was from an abductive approach to describe safety representatives’ values and experiences towards occupational safety training to reduce wood dust.

**Method**

Values coding was used to analyze the interviews. A model based on theory of what safety training embraces was first developed. The theoretical model was sent out two weeks before the interviews to the safety representatives. On the basis of this model, the interviews with safety representatives were performed. A semi-structured interview template was based on this model (see Appendix C).

**Results and findings**

The results of the interviews with safety representatives showed that more safety training can favorably be implemented at all levels in smaller organizations. Notably, smaller organizations may benefit from better and more consistently trained safety representatives because they merely receive general training when they first start their appointment. The safety representatives own training is carried out regularly, on a single occasion, over one, or a few days. From the interviews, it was shown that occasion/occasions to perform safety training may be limited in small organizations, depending on safety representatives, workers and managers.

- Meeting points at break times or organized meetings were described by the safety representatives to be training opportunities in the workplace.
Apart from the theoretical model developed in Paper IV, an empirical model was developed from the statements in the interviews by safety representatives. According to statements from safety representatives in smaller organizations, factors were identified which benefit safety training in reducing wood dust.

- Short training sessions.
- Focused training sessions.
- Smaller group sizes for trainees.
- Cooperation between managers and workers.
- Visualization of wood dust risks and control measures.
- Facilitator with reliance from the workers and experience in safety.
- Frequent training sessions.
- Group discussions and questionnaire as evaluation of the safety training.

**Analysis and discussion of thesis**

In Paper I, air contaminant exposure was measured in work situations where air contaminant was common. The results from Paper I showed that short-term exposure is essential to consider in the reduction of air contaminants in the workplace. Importantly, peak exposure could, if identified and decreased, reduce the exposure by more than 50%. To control peak exposure among workers, changes can be made, such as changing work position, changing solvent, or cleaning a room. One aspect to consider when using control measures, such as changing work position, changing solvent, or cleaning a room, is safety training. In Papers II-IV, safety training has been shown to be essential in creating awareness about air contaminant risks and control measures among workers, or students.

![Figure 9](image-url) Focus areas of theory and analytical reference frame in the thesis (arrows represent “leads to”, among employees in organizations).
In two studies (Papers II and III), safety training methods showed an effect on both the safety motivation (Paper II), and safety attitudes (Paper III). In Paper II, safety motivation increased with safety training. Air contaminant risks and control measures were visualized in videos in a safety training verbal presentation, and discussed, after being presented by a safety representative. In Paper III, safety training, with visualization of linked videos by QR codes of air contaminant risks and control actions, further showed increased positive change in values, attitudes and knowledge of how to handle/control wood dust risks among students. Paper III included students in handicraft programs at upper secondary schools. Paper IV demonstrated that safety training to reduce wood dust can be complex. Factors such as group size can improve the effectiveness of safety training to reduce wood dust.

This thesis contains three related research questions that are each discussed and analyzed below. The thesis aim is based on one general aim of developing and analyzing safety measures for air contaminant exposure in industrial work situations, focusing on human aspects. Contributions of this thesis relate to developing and analyzing safety measures to decrease air contaminant exposure for workers in work situations. The focus of the study is on human aspects, such as safety attitudes and safety motivation. Safety training was used to improve safety attitudes and safety motivation, with reference to workplace near trainings, in contrast to employees and being sent on safety training outside their own workplace, being given safety information related to workplace risks in general. Workplace near safety training sessions are related to the workers own workplace and work situations.

The safety training used in this thesis is available in the workplace, and the safety training sessions were held at locations close to, or at, the workplace, with a focus on tailoring the training to the specific industrial work practices. In Paper III, students were able to access QR codes at all times, allowing them to obtain a direct response from their smart phones in the form of information and videos in relation to the specific workplace. In Paper II, training was conducted at work, using information from the workplace, such as video footage and measurements of air contaminant risks, as well as control measures.

The target group of Paper IV was safety representatives, who have close contact with workers and are workers themselves, as well as worker representatives of safety at workplaces. It is essential to have safety representatives located near the workplaces for the purpose of raising awareness about safety to reduce air contaminants.

Based on the findings in this thesis, an increase of safety motivation and safety knowledge among employees is essential in controlling and reducing exposure to air contaminants among workers. These measures are essential because industries fail to follow safety laws and regulations. A literature review highlights deficiencies in the implementation of SWEM in Swedish workplaces (SWEA, 2013b). SWEM refers to safety routines at the workplace and aims at lowering accident rates and absenteeism resulting from sickness among workers.
Research Question One - what possibilities and limitations have existing safety measures aimed at for decreasing air contaminant exposure in workplaces?

In earlier studies, safety measures to control air contaminants have received less attention than risks, for instance, risk assessments. Previous studies that contribute toward decreasing and controlling air contaminants have focused on safety measures, such as exposure process and source. Air contaminant research has limitations, for instance, lack of focus on human factors, such as safety behavior, safety attitudes, and safety motivation in air contaminant control and safety. These limitations are shown in this thesis by a review of air contaminant research. Safety training has also received limited attention in the air contaminant literature, although studies indicate that safety training is essential for air contaminant safety in workplaces (e.g., Andersson, 1995a; Säämänen, 1998). To maintain and increase awareness and knowledge among workers about new, older, and existing air contaminant risks and measures, safety training can be essential. Research about air contaminant control includes air contaminant source removal, changing existing equipment, ventilation systems protective equipment, automatization, dust free chemicals, and replacing anti-tacking agents with a liquid anti-tacking agent, as Vermeulen et al. (2000) demonstrate. Senior workers with work experience were less exposed to air contaminants than workers with shorter work experience. The fact that experience among workers may contribute to reducing air contaminant exposure for workers may give an indication that safety training is essential in order to decrease air contaminants in the workplace, as safety experience may include safety knowledge and safety awareness.

Air contaminant risks can be shown to workers and may contribute in making them aware of peak exposures regarding air contaminants in the workplace. Paper I indicated that by increasing workers’ knowledge and awareness, the workers can understand which work situations involve air contaminant risks, and thus reduce the total exposure. For instance, peak exposure occurred when a worker leaned over the sand machine, in the wood industry workplace, and when welding arcs were lit in the engineering workplace.

Previous studies about air contaminant exposure include long-term exposure in the workplace (Creely et al., 2007). Paper I indicates that a large share of total exposure to air contaminants is peak exposure in the pharmaceutical, wood, stone, engineering, and print industries. By identifying air contaminant sources of peak exposure, developing control measures, and using safety training about air contaminant risks and control measures, air contaminant exposure among workers can decrease. Work situations with risks of peak exposure, identified in Paper I, included picking up wood pieces from a pile, and having close contact with wood machines, such as sawing machines in the wood industry. Control measures can include changing work practices among workers by working at a distance from the air contaminant source.

Research Question Two - in what way do safety attitudes and safety motivation influence human willingness to participate in decreasing air contaminant exposure in work situations?

As mentioned previously, this thesis focuses on human factors, such as safety attitudes and safety motivation. These can be improved with the help of safety training, as Papers II and III
demonstrate. Safety training sessions improved safety attitudes (Paper III), and safety motivation (Paper II). An increased desire among future workers/students in wood programs to participate in reducing air contaminants after the safety training was described in Paper III. The safety training in Paper III was QR codes linked to visualizing videos of risks and control measures at the workplace. The videos were related to the workplace. In Paper II, the workers’ safety motivation increased significantly after safety training, which included visualizing videos of risks and controlling measures, together with verbal presentations by a safety representative. The workers who were trained in Paper II reported in the questionnaire that they followed existing procedures concerning the work environment to a higher degree after the safety training than before the training. The workers placed greater importance on work environment improvements in the workplace than before the safety training. Paper II indicates, consequently, that safety motivation increases due to safety training, which has positive effects on the worker’s willingness to participate in the safety work to decrease air contaminants.

As safety motivation and safety attitudes were improved among employees by showing air contaminant risks and control measures to decrease air contaminant exposure (Papers II and III), the employees could improve their willingness to avoid air contaminant exposure. Safety training made employees aware of when risks arise and how to handle them. This is in line with Neal and Griffin’s (2006 p. 947) definition of safety motivation, and can be related to safety behavior: “an individual’s willingness to exert effort to enact safety behaviors”.

Among 14 of the 17 students interviewed in Paper III, 61 comments demonstrated improved safety attitude by using the safety training QR codes linked to visualized videos of air contaminant risks and control measures. These measures were described by the students as effective, since they found control measures in the visualizing videos for decreasing air contaminant exposure. There were 15 out of a total of 17 students who stated that the safety training had increased their safety knowledge about air contaminants in the workplace. Seven students stated that their safety motivation to improve the work environment safety had increased after participating in the safety training. The students related their safety motivation and safety attitude to video situations in the interviews, which had affected their willingness to participate in decreasing air contaminant exposure. For instance, students described that they were more aware of how they cleaned, in relation to air contaminant exposure.

According to Rundmo (2003), positive safety attitudes among workers in the workplace promote work safety, which can be related to safety behavior, or a reduced number of accidents in the workplace. This is in line with Malfetti (1963), who states that safety information determines safety behavior. Research shows that safety attitudes can improve risk behavior (Rundmo, 2000) and safety behavior among employees (Rundmo & Hale, 2003; Henning, et al., 2009). Safety attitudes may also be related to safety climate in the organization (Isla Diaz & Cabrera, 1997), and the safety climate can influence safety attitudes among workers and how they perform tasks at work (Neal & Griffin, 2004). Paper II demonstrated theoretical relationships between safety motivation, safety training, safety compliance, safety participation, safety knowledge, safety climate, leadership/influence tactics and goals in the organization.
The theoretical path diagram of the literature in Paper II found that safety training can increase safety motivation. Leadership/influence tactics, safety climate, and clear goals can affect safety motivation among workers. The theoretical path model in Paper II shows that safety knowledge can increase safety motivation, safety participation and safety compliance among workers. Safety participation increases safety motivation, and safety knowledge as well as training are shown in the path diagram to be essential in increasing safety motivation. Increased knowledge and training about air contaminant safety is central for safety in organizations. The literature describes how safety knowledge in the workplace has stagnated regarding air contaminant risks, which emphasizes the need for effective safety training in industries where air contaminants are common (Sundqvist, 2012).

The review of the literature regarding safety attitudes and safety motivation in this thesis showed that safety motivation may be associated with safety behavior and the willingness among workers to increase air contaminant safety (Malfetti, 1963; Neal and Griffin, 2006; Lingard, 2002). Safety attitudes were also seen in the research to be associated with safety thoughts (Bluff, 2011).

Safety motivation research is scarce, according to Bluff, 2011 as well as Li and Poon (2015). In addition, safety motivation is essential in increasing safety in the workplace (Åteg et al., 2005; Hedlund et al., 2010). Safety motivation is needed to create effective safety investments in the workplace (Hedlund et al., 2010). To improve safety motivation, context is an affecting factor, as group norms affect safety motivation (Bluff, 2011). Group norms, or other contextual factors, in the workplace, could be considered when planning a safety training setup.

Neal and Griffin (2006) state that workers’ safety motivation may decrease if workers are punished for not following safety procedures. Consequently, to improve safety motivation among workers it could be essential to introduce safety training that encourages the workers to help decrease air contaminants and to attend safety training. It may be important to involve the workers in the choice of safety activity, according to Neal and Griffin (2006). In addition, safety training can increase awareness of individual health among employees (Sari, 2009), improve safety culture in the organization (HSE, 2015), or increase knowledge about workplace safety (Burke et al., 2006). Additionally, managers need to be trained in safety issues, as it can affect the workers attitudes towards safety, as described by Worsfold and Griffith (2003), and confirmed by Laberge (2014).

Related to safety commitment, safety involvement and safety feedback towards the employees have been shown to increase safety motivation, according to Reese (2015). The literature review in this thesis shows that uncertain work situations affect workers’ safety motivation. Ignorance of safety policies can increase as workers try to increase production in order to keep their jobs (Probst & Brubaker, 2001). Leadership and management also affect safety motivation, for instance, how a safety activity is handled in the organization (Bluff, 2011; Kvorning et al., 2015). From safety research, it can be concluded that safety motivation is complex and essential to consider in the workplace when planning to increase air contaminant safety activities and implement safety training to reduce air contaminants.
Safety attitudes are essential for safety in workplaces, which is confirmed by research, such as Rundmo (2000), or Henning et al. (2009). It is essential to improve awareness of safety attitudes and knowledge of safety measures and risks among workers for safety in the workplace (SWEA, 1980). With this in mind, safety attitudes are important for influencing and improving human willingness to participate in decreasing air contaminant exposure in the workplace. It is shown that safety attitudes are related to improved safety climate and safety culture (Niskanen, 1994; Guldenmund, 2000), such as priority of safety in organizations (The Swedish Work Environment Authority, 2014; Rundmo & Hale., 2003). Rundmo and Hale (2003) also demonstrate that risk awareness is essential for increasing workers’ safety attitudes. The fact that risk awareness is essential highlights the importance of safety training in organizations. Despite safety training importance, safety implementations can often be seen as too costly (Njå & Fjelltun, 2010). Costly safety investments can motivate the inclusion of managers in safety training to change their safety attitudes, as can be confirmed in the study by Mearns and Flin (1995), and by safety representatives in Paper IV.

**Research Question three - how can safety training contribute to decreasing air contaminant exposure in work situations?**

The reasoning that safety motivation and safety training are vital in decreasing air contaminants is shown to be crucial. This can be related to the fact that safety training is legally an essential measure in obtaining safety rights for organizations (SWEA, 2015b), to change safety behavior, safety values or safety attitudes among workers and thus decrease safety risks (Burke, 2006; Taylor, 2014). Safety training to decrease air contaminants in workplaces is underdeveloped in smaller companies, as shown by Paper IV. It could be seen that employees and employers could use, and benefit from, more effective safety training to decrease air contaminants. According to the safety representatives’ experiences, safety training can be optimized by improving safety training routines, safety training subjects, safety training plan and safety training focus. These factors consist of visualizing air contaminant risks and control measures, including the aim of the safety training, performing short, focused and frequent training sessions, using small safety training group sizes, and implementing group discussions, or short and concrete questionnaires, for evaluation of safety training. The safety representatives also advised the use of meeting and break times for the evaluation or training sessions, and employing a facilitator that the employees trust.

Paper IV showed that it is important to adapt safety training to a specific target group, such as workers of a certain age, or with safety and work experiences, as well as safety knowledge. For example, it was stated in the interviews in Paper IV that, generally, workers of an older generation may absorb knowledge better in a classroom setting, while, generally, workers from a younger generation might respond better to online learning, computers or smartphones. The differences in absorbing knowledge in relation to context differences can depend on earlier experiences of training or contexts. In a review study regarding training transfer, Burke and Hutchins (2007) describe how work environmental and individual motivation factors affect the ability to transfer and absorb knowledge among workers who have received training. For
instance, the training outcome can be improved by support from supervisors and the organization, as well as training goals that relate or promote the training in question. The reasoning regarding how managers affect safety training can be supported by results in Paper II, which shows the importance of managers introducing safety training in the organization. It may be important in the reasoning of Paper II to consistently develop the idea that leaders and managers are included in the safety training for the workers, for example, by participating with the workers in safety training.

Furthermore, the opportunity to perform training at the work in question can be improved, in order to increase the degree of knowledge absorbed and implement it at the workplace (Burke & Hutchins, 2007). To first scan the workplace for individual or group differences can be a factor in optimizing safety training to reduce air contaminants, with the following strategy: 1) plan, 2) safety training focus, and 3) safety training routines of individuals as well as 4) tools. Consequently, it can be essential to consider participation from the workers when developing and performing safety training. Participation in safety training may be improved by creating activities where the workers express their opinions and influence how safety training is performed. For example, this can be done by discussions in relation to their specific work tasks, which can be confirmed by the results of Paper II. In Paper II, safety training that was performed and related to the workers’ work task improved safety motivation. This is also in agreement with the reasoning in similar results from Paper IV, showing that safety training can be improved by being more focused, rather than taking a general approach.

The safety training in Paper II was workplace related, as the visualizing videos of risks and control measures were created at the workplace in question, which was a print shop industry, together with print shop workers. In Paper III, the safety training was workplace related as the visualizing videos of risks and control measures were created at two wood workplaces in secondary schools, together with teachers and students. The safety training measures aimed at reducing air contaminant exposure in Papers II and III were placed at the workers’ and students/future workers’ workplace. In Paper III, the QR codes were placed at the work situation, such as a wood saw, and showed air contaminant risks and control measures related to the specific work task. In Paper II, work situation risks and control measures were shown from the workplace in question, a print shop industry. Safety representatives in Paper IV described how safety training sessions, in general, are outside the workplace where workers are employed and include general information about safety. The safety training in Papers II and III includes specific information about the workplace in question, and takes place at the workplace. The workers may relate to the safety training more if it is workplace related, as it is, specifically, about the workers’ own work situation. If the safety training is general information from work situations that are not similar to the worker’s own workplace, the training may be harder for the worker to relate to. In Paper IV, the workplace related safety training was confirmed as essential. In addition, safety training measures focused on a specific factor, such as air contaminants, were also confirmed as essential for an effective safety training. Employees and management can be involved in safety training, and relate it to their own workplace, safety opinions, and safety work as well as knowledge. In addition, both cooperation and personal
commitment and motivation of safety may be generated if the employees can be included in safety training.

On the basis of the reasoning of workplace related training above, it can be essential to include the workers when creating safety training material. When workers are included in creating safety training material they may create an understanding of how the training material can be efficiently developed. For instance, in Paper II, the print shop workers described what work situations were important to consider when reducing air contaminants, such as cleaning machines with solvents. It can also be relevant for the workers to be included in the work with safety training, as they may feel that they are involved in safety aspects of the workplace, and that their opinion is important for the organization in question.

The review of literature in this thesis shows that training benefits from being related to practical situations in the workplace (see e.g. Baldwin & Ford, 1988; Rosén et al., 2005), and from being cost effective (Hendrick, 1990; Worsfold & Griffith, 2003; Bluff, 2011). To improve safety training methods it can be beneficial to focus on changing safety attitudes (Sari, 2009; Laberge, 2014), to increase the workers understanding by participating in safety training and giving them relevant information. Safety training published online can be an effective solution, as financial resources can be limited in organizations, as stated by Bluff (2011). Therefore, it is important to establish organizational needs and conditions related to safety training in the organization, as there can be dissimilar needs for safety training among organizations (Hendrick, 1990; Squelch, 2001).

Younger workers, aged 16-25, have been shown to be more vulnerable to safety risks at work, than workers aged 26-64 (AFA Insurance, 2013). The author of this thesis has recognized that safety training for younger generations may be effective as they can easily adapt to new knowledge (see Diaz & Cabrera, 1997). In addition, younger generation of workers may be less exposed by earlier organizational cultures in their work life, compared to older generations. By being exposed to earlier organizational cultures the workers may learn how to think about safety. Consequently, it may be essential to continually create and offer training programs for the younger generation. The safety training for younger worker generations may also create a basis for understanding the risks and how they can be managed early in their career, to prevent years of work carried out with greater risk for air contaminant exposure. It was shown that there is a culture in the handicraft programs at Swedish secondary schools, where safety knowledge and training may, appreciatively, be offered to students and teachers, which shows a potential for creating awareness and implementing safety training there.

Safety training could benefit from being performed frequently, during short durations, and in cooperation with supervisors. Paper II showed that safety training of employees who regularly worked with safety issues can favorably increase safety motivation after safety training. This may include safety representatives, team leaders, and managers. With this in mind, safety training for managers may favorably be used effectively to increase results of safety training and air contaminant safety in the workplace. As shown in Paper II, safety training conditions can be optimized, by being decided by management, to contain high participation in safety
training, including a high number of occasions, or performed by a target group affected in their job, as, for instance, safety representatives. To perform training frequently may be essential, as demonstrated in Paper II, and it is important to follow up on training results, as described in Paper IV.

Training safety issues are presented by HSE as “Helping people to learn how to do something, telling people what they should or should not do, or simply giving them information” (HSE, 2015, p. 1). In the present thesis, safety training is an activity related to the workplace focused on increased knowledge about safety and health among workers, safety professionals, or management. Gaining knowledge can be knowledge sent from a more knowledge-rich source to a less knowledge-rich source (Bluff, 2011).

To further understand training and its sustainability, maintenance and effective implementation, as related to behavior, attitudes and motivation, the concept and perspectives of training transfer have been discussed in research (Baldwin & Ford, 1988). Positive transfer of training includes the degree that knowledge, attitudes and skills developed in training can be used and applied to the work. Baldwin and Ford (1988) understand training outcomes as the amount of “original learning that occurs during the training program and the retention of that material after the program is completed” (Baldwin & Ford, 1988 p.2). On the basis of this reasoning, it can be demonstrated as essential to have sustainable training solutions, which may include training operations that relate the training to the workplace, as performed in Papers II and III, and discussed in Paper IV. Work related training and training at work may therefore create conditions for clearly relating and applying the training in the work context. Understanding the reasoning of Baldwin and Ford (1988), for instance, about training outcomes, also emphasizes the importance of carrying out an evaluation, consistent and consequent training, as well as cooperating with management, as discussed in Paper IV.

The issue of training transfer, described by Baldwin and Ford (1988), indicates that training is essential, both on the training occasion and afterwards, which stresses the importance of a training plan, as discussed in Paper IV. For instance, supervisors affect the training transfer, by giving support and opportunities to implement knowledge received from the training into the work situation.

Consequently, the process of safety training may need attention, both during training and afterwards, by the organization in question, supervisors, workers and safety representatives. Aspects to consider in facilitating the company to perform an effective and sustainable training may therefore be placing the training at the workplace in question. In addition, effective and sustainable training may include consistently making the training available to everyone in the organization. Consistent and work related training for individuals at every level in organizations may create the conditions for more coherence between the trained individuals and their work context, as colleagues and managers have also been trained. An example can be seen in Paper III, where the students in the handicraft programs had access to training at specific workstations and could perform training consistently. In addition, the training included safety related to the work stations and work tasks in question, and was placed at the work stations which may ease
the transfer of training to the specific work situation. The training in Paper III may also be cost effective, and easy to access, as it is performed by the individuals on their mobile.

**Methodological discussion and limitations**

To generalize the results to every workplace in Sweden, or international workplaces, can be problematic as work context, work culture, safety climate, and safety culture may vary. With this in mind, external validity and credibility can decrease. Schmidt and Bjork (1992) point out that to generalize training methods it is essential to implement, relate and customize training results to the actual work context. For example, the work context can include factors, such as noise, stress, or hot work environments that may affect the use of the training method (Schmidt & Bjork, 1992). Papers I-IV are performed or related to work contexts, and the safety training methods are performed and related to the workplace and work situation in question, which may favor the generalization of the safety training methods. This reasoning can be related to the discussion by Schmidt and Bjork (1992), describing increased generalization of training results when relating and customizing training results to work contexts.

Industries particularly vulnerable to air contaminants in Sweden were chosen in this thesis, as well as future workers/students in wood work programs at secondary schools. The demarcated approach towards industrial and typical work situations were chosen to increase the generalization and practical usage of the safety training methods. Since the typical work situations that are used more frequently were discussed with workers, students, managers and safety representatives, consequently, it may increase the use of safety training methods and their advancement towards generalization.

Furthermore, Shenton (2004) argues that to increase transferability, which is a term used in qualitative research for generalization of the results, a comprehensive organizational context or study description is essential of the study in question. A reason for increased transferability by a comprehensive description is that researchers and readers can relate the results, study context and study in question to their research work. All the papers include comprehensive descriptions, both in the papers and in the method of this thesis (see Transferability).

In addition, limitations in this thesis may be the long-term effects of the safety training methods implemented. The safety training methods have focused on a period of less than 6 months, and can be further studied and progressed in future research. However, Paper IV was conducted to gain a deeper understanding of safety training and, accordingly, avoids the short-term effects of safety training. According to the understanding established in this thesis, the methods of safety training and long-term effects may benefit from understanding the transfer of training and having a systematic approach to safety training, where training is stimulated to be consistently performed.

In this thesis, an interactive approach was included by meeting with people from unions and industries to discuss safety ideas and safety work, focusing on air contaminant control. Meetings have also been conducted with teachers, industrial workers, and management staff in
industrial workplaces with air contaminant risks. These workplaces were selected in agreement with two researchers, and supervisors with experience in the air contaminant research field, and the support of workers, managers and safety representatives from the workplace in question. Safety representatives can be available as a natural support in the workers’ daily work and may be a link between workers and employers.

**Contributions and future studies**
This thesis summary contributed towards understanding safety training, safety attitudes, safety motivation and air contaminant control. The contribution of this thesis is a research review of measures to reduce air contaminant exposure, and use of safety training to change safety attitudes and safety motivation. The papers underline the importance of awareness in the workplace, where safety training measures can be used in future research about air contaminant control, safety training, safety motivation and safety attitudes. For instance, Paper I in the present thesis indicates that awareness of air contaminant risks and measures to control short-term exposure can effectively reduce a large portion of the total exposure. In addition, this thesis may create a basis for strategies to prevent health symptoms, by improving knowledge of air contaminant risks and control measures among industrial employees and secondary school students in handicraft programs. In addition, there are theoretical contributions in this thesis, and in Papers I-IV, with regard to safety attitudes, safety motivation, and safety training for air contaminant control, and how these are related.

**Paper I**
- Indicated work situations that are vulnerable in terms of air contaminant exposure risks.
- Showed control measures to avoid air contaminant risks in work situations.
- Contributed with statistical measures to identify peak exposure towards air contaminants in work situations.
- Found that by removing peak exposure, a large portion of the total exposure can be removed.
- Presented air contaminant variation in work situations.

**Paper II**
- Included positive effects of safety training on safety motivation regarding air contaminants safety.
- A theoretical model was developed that related safety motivation, safety training, safety participation, safety compliance, organizational goals, leadership, and safety climate and safety knowledge. The model was inspired by a previously developed model by Hedlund et al. (2010).
- A validated safety motivation questionnaire was used to evaluate safety training sessions in workplaces.

**Paper III**
- Developed a safety training measure.
• Established how safety knowledge and safety awareness may increase among young/future workers regarding air contaminants.
• Showed how safety attitudes may increase among young/future workers regarding air contaminants.
• Revealed how safety motivation may increase among young/future workers regarding air contaminants.

Paper IV
• Contributed with understanding of affecting factors towards safety training to reduce air contaminants exposure.
• Presented an understanding of aspects to optimize safety training processes to decrease air contaminants.
• Included an understanding of safety representatives’ experiences towards safety training to reduce air contaminants.
• Showed a proposal for a model to perform safety training to reduce wood dust.

In Papers I-IV, there are concepts that are associated. Safety attitudes, safety motivation, safety training, and safety knowledge can be related to safety behavior in organizations (See e.g. Bluff, 2011, & Paper II). It is essential to further study safety behavior to manage air contaminant risks. Research has emphasized the importance of involving the workers in workplace safety for air contaminants (Rosèn et al., 2005). Future studies can benefit from the study of how worker knowledge is affected in the long-term with the safety training measures from Paper II and Paper III. Specific safety training methods, such as QR codes linked to PIMEX videos and visualizations of risks, can benefit from being tested in work contexts, and can evolve gradually.

The safety training measures in Papers II and III were related to the workplace in question and performed at work. QR codes were placed on the typically used machines at work, which gave a direct response and availability when the worker required their safety training. The safety training videos were developed at the workplace, together with the workers. Safety training can be general and not workplace specific, and often performed on one single occasion, as stated by the safety representatives in Paper IV. The lack of workplace specific training, and non-frequent attention to the increase of safety knowledge in safety training, calls for consequent and further understanding of safety training implementation in the workplace. Consistent and further understanding of carrying out safety training is essential as managers and workers learn about advantages to carry out safety training in the form of decreased exposure, increased health and awareness of air contaminants. Studies about training transfer related to safety training to decrease air contaminants may also receive increased attention in future research, in order to understand the process of implementing safety training knowledge in the work, and maintaining knowledge from safety training among workers. In addition, in future research, additional studies of young work students can be carried out, as they may have contributed opinions and ideas on what the workforce of the next generation may see as effective safety training.
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References


## Appendix A. Questionnaire in Paper II (Hedlund et al., 2010)

<table>
<thead>
<tr>
<th>How important to you is/are...</th>
<th>Not at all</th>
<th>Completely</th>
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<tbody>
<tr>
<td>(1) work environment improvements?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(2) being involved in work environment improvements?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(3) taking the initiative to improve the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(4) having enough resources (time, financial) set aside for making changes to the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(5) having opportunities to influence changes in the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
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<table>
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<tr>
<th>To what degree would you say that you...</th>
<th>Not at all</th>
<th>Completely</th>
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<tbody>
<tr>
<td>(6) are involved in work environment improvements?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(7) take responsibility for improving the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(8) have enough resources (time, financial) to improve the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
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<tr>
<th>To what degree would you say that your co-workers...</th>
<th>Not at all</th>
<th>Completely</th>
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<tbody>
<tr>
<td>(9) take an interest in the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(10) are involved in work environment improvements?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(11) take responsibility for improving the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(12) have enough resources (time, financial) to improve the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
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<th>To what degree would you say that the management...</th>
<th>Not at all</th>
<th>Completely</th>
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<tbody>
<tr>
<td>(13) take an interest in the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(14) are involved in work environment improvements?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(15) take responsibility for improving the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(16) have enough resources (time, financial) to improve the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To what degree would you say that...</th>
<th>Not at all</th>
<th>Completely</th>
</tr>
</thead>
<tbody>
<tr>
<td>(17) the work environment needs improvement?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(18) there are demands on you to improve the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(19) your efforts to improve the work environment are appreciated?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(20) there are clear goals for improving the work environment?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(21) the goal of improving the work environment will be reached?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(22) there is a demand that decisive efforts to improve the work environment are carried out?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>To what degree would you say that...</th>
<th>Not at all</th>
<th>Completely</th>
</tr>
</thead>
<tbody>
<tr>
<td>(23) you contribute to creating a better work environment? (i.e. taking part in activities, meetings, or helping co-workers with safety issues)</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(24) your contributions to creating a better work environment are encouraged?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(25) you follow the existing procedures concerning the work environment at your workplace? (i.e. using safety equipment or anything else for working safely)</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
<tr>
<td>(26) you receive encouragement when you follow the work environment procedures?</td>
<td>1 2 3 4 5 6</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B. Interview template from Paper III.

Inform about the study and the interview!
Group:
Age:
Sex:

Work environment (5 questions)
- What is your impression about work environment issues and safety?
- Do you think the work environment is important?
- In what way is it important / less important?
- What are your rules for work environment and safety in your school?
- Do you think the work environment and safety are interesting?

QR codes in general and as linked to PIMEX videos as a safety training tool (10 questions)
- What is a QR code for you?
- Have you used QR code before it was attached in the classroom
- In what way then / Why have you not used them?
- What do you think about QR codes and risks, and measures that appear on your mobile phone?
- What do you think of the QR Codes and training material that was attached next to machines in the classroom?
- Describe if there is anything that could be improved about the use of QR codes among students in work situations?
- Describe whether there are factors that you learned from when using QR codes attached in the classroom?
- What do you think about QR codes and linking visualization videos about risks and measures as a method for learning about air contaminants in work situations?
- Is it possible to create motivation about commitment to knowledge increase with the help of QR codes?
- Describe what you think about the phone as a method at work, teaching about air contaminants?

Mobile phones as a safety training tool (6 questions)
- What is knowledge in mobiles according to you?
- What do you think about when you hear the concepts mobiles and knowledge?
- Describe if you have more ideas about how the mobile phone can be used in training work, than the ones used in classroom?
- Can social media be used for learning and training?
- Can apps contribute to learning?
- If yes, describe how apps can increase knowledge?

Work environment safety training in general (2 questions)
- What is learning, training and knowledge for you?
- Describe the best way for you to inspire and motivate individuals to increase knowledge about the work environment and air contaminant safety?
Appendix C. Interview guide Paper IV.

Initial description of the safety training in theory and the purpose of the study.
Description of the project and interview.

Age?
How long have you worked as a safety representative?
Which companies worked in?

Experience generally related to theory

- What are your experiences of this way of working (as safety training theory demonstrates)?
- What do you think about when looking at the theoretical perspective on working with safety training?
- What is your role within air contaminant safety?

Controlling factors of air contaminants

- How can air contaminants be controlled and thus effectively reduced in the workplace?
- What is workplace safety and control about air contaminants in your industry?

Risk identification of air contaminants

- How can air contaminant risks be identified?
- How can risks be handled?
- What are risks in terms of air contaminants?
- What are sources of air contaminants?

Influencing factors of safety training

- What you think about the factors outside the organization that may influence the outcome of a safety training?
- What do you think about the factors inside the organization that may influence safety training?
- What are your experiences of what may affect safety training:
  \ before process
  \ early in the process
  \ later in the process
  \ in process

- What could be influencing factors to change safety attitude to control air contaminants in safety training?
- What could be influencing factors in safety training for the degree of change in motivation to work more with air contaminant safety?

General questions about safety training

- Is there something you / we can add to the safety training theory to improve safety knowledge among workers to control air contaminants?
- Is there something you / we can remove from the theory to improve training to control air contaminants?
- How can safety training be adapted to other target groups than wood industries?
- Can you as a safety representative work as described in theory?
- What is a effective safety training to control air contaminants?