

**Control Banding Tools: Advanced Regulated Evaluation and Authorization of
Chemicals Tool and Agreement with Professional Judgment**

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Introduction:

One workplace risk assessment strategy that has emerged in recent years is control banding. This strategy has gained momentum within the safety and health community, especially in Europe, but many questions surrounding the various control banding models remain. This research focused on one of those tools, the Advanced REACH Tool. Specifically, this research examined agreement of the mechanistic model and its results with a professional's approach to exposure and risk assessment.

Chapter I: Background and Significance:

History of Exposure Limits:

Traditional worker protection began in the late 19th century with the first set occupational exposure limit (OEL) values established in Germany (NIOSH 2009). The method for analyzing airborne contaminants involved air sampling and comparing the resulting concentrations with OELs. In the 1940s the American Conference of Governmental Industrial Hygiene released their first set of Maximum Allowable Concentrations, later named Threshold Limit Value (TLV), which covered 148 chemicals. An increasing number of industrialized nations adopted this method of quantitative analysis for risk management in an effort to reduce work related illnesses. These efforts were likely integral in the improvement of working conditions that has lead to an increase in the quality of life for workers, and decrease in workers' compensation costs (NIOSH 2009). With the promulgation of the Occupational Health and Safety Act, the incidence of injuries and illnesses has decreased over the past 30 years, according to the U.S. Department of Labor, Bureau of Labor Statistics. However, the proportion of injuries and illnesses associated with chemical exposures is unknown. Despite past success, strict reliance on sampling and quantitative data for air contaminants has become a daunting task with the ever increasing number of newly developed chemicals used in the workplace and cost of exposure assessment and analysis.

Limitations of Conventional Chemical Exposure Assessment:

With the number of potentially hazardous chemicals increasing far more rapidly than OELs could be established, many nations promulgated regulations to shift the burden of proof of safety from the employer to the manufacturer (NIOSH 2009). However, this shift didn't solve the inherent difficulties caused by the rapidly increasing number of hazardous chemicals, and

furthermore, it introduced new difficulties associated with the limited resources of individual, particularly small companies. One such difficulty in protecting workers solely using quantitative data was the inherent variability in representative sampling of workers. The day to day variability in a task performed by a single worker and among workers performing similar tasks was propagated into the sampling results. Engineering controls, personal protective equipment, training, medical exams, and housekeeping requirements are based on sampling results with unknown, and potentially significant, variability. Furthermore, traditional airborne contaminate monitoring is done by safety and health professionals and required quantitative laboratory analysis. Many companies lack the resources, such as on-site safety and health professionals, to perform traditional monitoring, or lack the funds to hire consultants.

Companies without the ability to quantify exposures were unable to compare exposures to regulatory limits and ensure compliance and workplace safety. Additionally, some industries, such as the pharmaceutical industry, had to provide protection for new chemicals, which lacked any regulatory limits or epidemiological data for health effects on workers. Faced with the challenge of providing adequate protection for workers with limited resources and exposure data, many companies, industries, and agencies in Europe are pioneering new methods for assessing worker protection (NIOSH 2009; Zalk, Nelson 2008). One strategy at the forefront of this effort is control banding.

Origins of Control Banding Strategy:

The United Kingdom developed the Control of Substances Hazardous to Health (COSHH) regulation which was intended to increase emphasis on risk assessment. However, implementation led to many struggles. Shortly after promulgation, a survey of companies revealed “widespread ignorance of the regulations and their implications” (Zalk, Nelson 2008). In an attempt to understand the challenges of complying with COSHH, Health and Safety Executives (HSE) conducted market research to understand companies’ perception of OELs, and the extent to which OELs affect decisions on control measures. The research indicated larger companies with safety and health professionals understood COSHH requirements, but smaller companies were not aware of COSHH, did not understand OELs, and “wanted to be told exactly what they need and do not need to do” (Topping 2001). Furthermore, the research indicated small companies could not afford occupational safety and health specialists, and measurements of workers’ exposure to chemicals typically was not possible due to cost, lack of resources, and difficulty interpreting exposure measurements. With the challenges indicated,

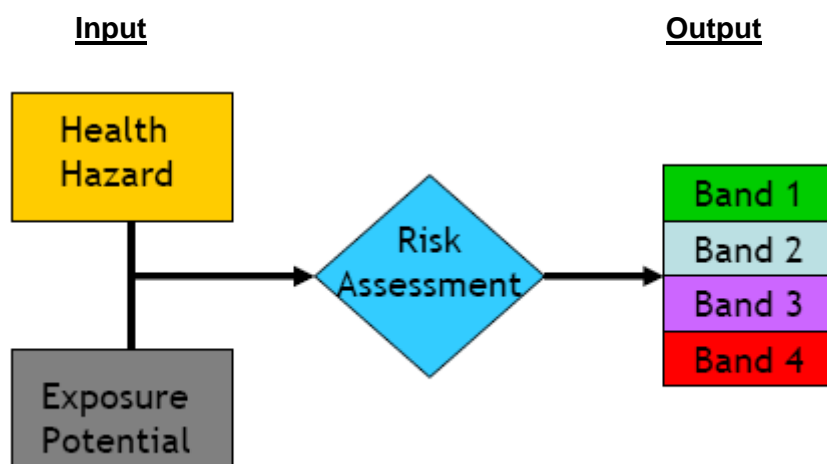
there may be little practical use for OELs in small companies (Oldershaw 2003). Given the prevalent lack of understanding of the meaning and application of OELs, promulgating new OELs for chemicals would not prove cost effective (Topping MD et al. 1998) or improve workplace safety in small companies. As a result, the researchers concluded new OELs should be limited to ubiquitous chemicals of concern, and furthermore, recognized the traditional OEL system could be renovated to couple chemical information with OELs to provide control measure guidance. This concept was the origin of control banding.

Control banding is a simplified approach derived from the pharmaceutical industry and adapted for use by non-safety and health professionals for addressing worker exposures (NIOSH 2009). In the late 1990s this general concept was developed:

Health Hazard + Exposure Potential → Qualitative Risk Assessment → Control Strategy

Data surrounding the health hazard and exposure potential of the chemical are combined to give a generic risk assessment, which guides the control strategy (NIOSH 2009). This strategy creates a process to group workplace exposures into control strategies (control bands) based on the health hazard and exposure potential of the chemical and the process. The earliest strategies evolved under the assumption that although workers may be exposed to a plethora of chemicals, only a few categorical approaches exist to protect workers. Originally, the control banding strategy was not intended to be a predictive exposure model (NIOSH 2009), but rather a way to sort work processes into bands, or buckets. Simply stated, it was a way to link hazards to general control plans.

Figure 1: "Generic Control Banding Strategy," adapted from AIHA TeleWeb Virtual Seminar "Update on Control Banding: Fundamentals, Issues, Applications and Strategies for Implementation." March 26, 2009. Copyright Exposure Assessment Solutions, Inc



Early Models of the Control Banding Strategy:

The cornerstone of any control banding model was accuracy and consistency in results. Other pillars included:

- Clear communication of the concept so workers understood and assisted in the risk evaluations
- User-friendly strategy which can be used by non-safety and health professionals
- Readily available process and chemical information required for the model
- Practical, easily understood guidance
- Training for the use and application of the tool
- Clear, consistent, and transparent presentation of advice
- User confidence in the model's output (NIOSH 2009)

A variety of control banding models were constructed by various countries to assist in risk assessment and worker protection. Many models were built on their predecessors and each has strengths and limitations. Those models are reviewed as follows.

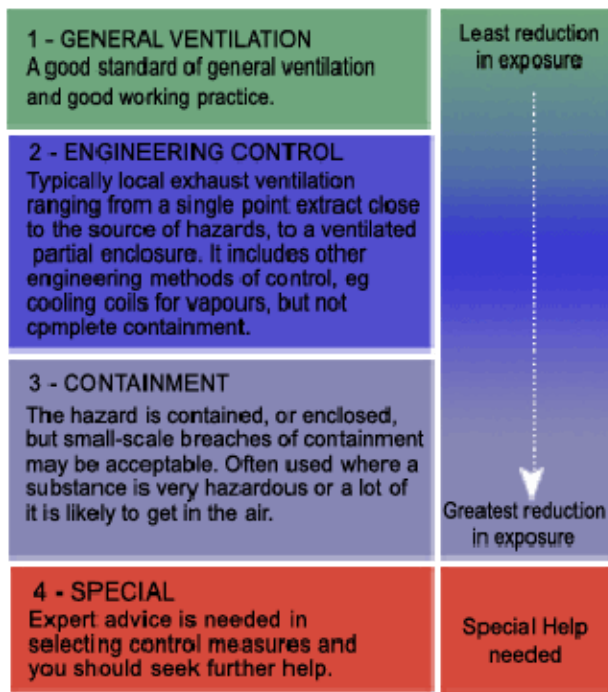
COSHH Essentials

The pioneering control banding tool was COSHH Essentials which was developed in the United Kingdom by the HSE to guide compliance with the COSHH regulation (Zalk, Nelson 2008). At the time of its release, COSHH Essentials was the most developed strategy for chemical risk assessment. It selected the appropriate control band based on four elements:

- type of task
- chemical hazard band
- volatility or potential of the chemical to become airborne
- quantity of chemical used

The resulting risk management level (control band) was presented in a one page format, and had one of the following control approaches (NIOSH 2009).

Figure 2: “COSHH Essentials Control Approaches” chart, HSE, COSHH Essentials, 5 May 2012. <http://www.coshh-essentials.org.uk/help/introduction2.htm>



The primary limitation of COSHH Essentials was it lacked applicability to pesticides, pharmaceuticals, and process generated hazards (dust generation or welding fumes). This tool did not address dermal exposures.

Risk Potential Hierarchy

The French-derived strategy used information from Material Safety Data Sheets (MSDSs) and chemical labels to assign a hazard class to the chemical based on three criteria: 1) hazard classification, 2) frequency of use, and 3) quantity used. The frequency and quantity of use are combined to give an exposure potential, which is then combined with the hazard classification, which results in a numerical score for the process. That score corresponded to one of three priority bands: elevated, middle or weak. Although this strategy is a simple and clear triage method, internal validation studies indicated it overestimated in 19% of cases and underestimated in 1% (NIOSH 2009). It was determined this strategy should be used in conjunction with another method.

Chemical Management Guide

The Chemical Management Guide tool was developed by Germany with the intent of assisting third world countries in risk assessment. The early version of this control banding tool was called the GTZ Chemical Management Guide which had three steps. The first step identified portions of the process where inefficient storage, handling, use, and disposal were observed. These portions were “hot spots.” The next step was a detailed chemical inventory and the final step used one of the following control strategies: basic risk assessment, description of control strategies, MSDSs, safety phrases for hazardous substance, or symbols for labeling hazardous materials. This tool seemed to be too sophisticated for many small companies, but could be beneficial for larger enterprises with more MSDSs on site. This strategy expanded to an easy-to-use workplace control scheme for hazardous substances called EMKG as a means to provide practical guidance for workplace risk assessment in small and medium companies. After the information from the MSDSs was applied to the workplace, EMKG could derive control strategies to minimize inhalation and dermal exposures. EMKG was similar to COSHH Essentials, but EMKG assessed dermal exposure. Like COSHH Essentials, EMKG provided non-regulatory guidance for controlling exposure, but was well supported by regulations. An enhanced version of EMKG (EMKG 2.0), connects substances with legal OELs. The user began the risk assessment with the OEL which aligned to a hazard band and then two possible control schemes. For hazard groups above the OEL, the employer must perform workplace measurements, but for hazard groups below the OEL, the employer could waive workplace measurements (NIOSH 2009).

Stoffenmanager:

The Stoffenmanager tool developed in The Netherlands was a compilation of the preceding control banding tools. The tool calculated a risk score using a similar chemical classification as COSHH. Stoffenmanager “supports the requirements for maintaining inventory of hazardous substances, assessing and controlling risk in a risk inventory, obtaining a plan for control measures, making instruction sheets for the workplace, and helping to store chemicals according to guidelines” (NIOSH 2009). This tool was generic, but the Dutch plan to modify the tool to be industry specific.

KjemiRisk:

Norwegian oil industry was integral in the development of KjemiRisk which used chemical and process information such as:

- physical properties
- handling methods
- personal barriers
- duration of exposure
- frequency of task

Chemicals were grouped into one of five health hazard categories, and processes fall into one of fifteen predefined common tasks. All the information listed above was used in the risk assessment which was divided into two phases: potential risk and final risk. The risk was influenced by the reliability and effectiveness of the control measures in place, and the task’s potential for illness to the lungs, internal organs, and skin. When used by production managers or safety and health generalists, KjemiRisk was a rough risk assessment tool, but when used by an industrial hygienist it becomes an expert tool (NIOSH 2009).

Regetox and SOBANE:

The Belgium tool Regetox was a two-stage assessment strategy which was developed in response to the European Chemical Agents Directive and combines COSHH Essentials and the Estimation and Assessment of Substances Exposure (EASE) model. This directive required companies to assess and manage chemical risks in the workplace. To reduce the number of chemicals requiring assessments, and thereby reduce cost, the first phase was used to rate chemicals based on the risk and the quantity used. Only those products with a rating of medium or high move forward to the second phase which used COSHH Essentials or EASE. Regetox attempts to address the challenge of evaluating mixtures, and exposure where the process

generates the contaminants. A feasibility study of the tool which was done at two facilities revealed lacking or inadequate MSDSs (NIOSH 2009). In one case, the model failed to identify a need for improvement. Overall, Regetox was believed to be helpful for companies not prepared to comply with the European Chemical Agents Directive. However, it did require training, planning, and involvement from employers.

A second tool developed out of Belgium is the Screening, Observation, Analysis, Expertise (SOBANE) method. This strategy consists of four phases, the first of which was the screening phase. The purpose of the screening stage was to identify the major problems on the worksite, and solve the simple problems immediately. The more complex problems identified in the screening phase are examined in greater detail, with the help of a nine page tool, during the observation phase. Those problems remaining after the previous two stages are analyzed by a safety and health practitioner. Finally, in the Expertise phase, an expert designs more complex solutions, as needed.

Semi-Quantitative Risk Assessment:

The foundation of the Semi-Quantitative Risk Assessment (SQRA) tool is a three stage method for exposure evaluation: monitoring personal exposure, selecting exposure factors, and estimating exposure. SQRA was developed in Singapore; however, it has been compared to COSHH Essentials. SQRA consisted of five control levels that paralleled COSHH Essentials control strategies.

The first control level in SQRA was classified as negligible risk and level two was low risk with suggested periodic reassessment and personal air monitoring. These first two levels in SQRA were comparable to the general ventilation control strategy in COSHH Essentials. Level 3 (medium risk) parallels the engineering control strategy of COSHH Essentials. This third level suggested controls and reevaluation of the process every three years. Training and personal air monitoring may be necessary. The fourth level of SQRA was high risk and indicates a need engineering controls, personal air monitoring, training, personal protective equipment and reassessment after all controls are in place. The guidance of this fourth level aligns with the containment control strategy of COSHH Essentials. The final level of SQRA was very high risk and directs the user to seek guidance from a specialist, which paralleled the “special” control strategy of COSHH Essentials.

Korean Control Toolkit:

Korea Occupational Safety and Health (KOSH) Agency developed a web-based tool for small and medium companies called the Korean Control Toolkit (KCT). The tool was a semi-quantitative assessment strategy which produced guidance on controlling hazards associated with 12 specific chemicals. Like SQRA, KCT was a modification of the COSHH Essential.

Users selected one of the twelve chemicals from a menu online and then entered information related to the chemical use and workplace conditions (quantity used, duration and frequency of use, and physiochemical properties). The KCT then used the COSHH Essential algorithm to give a risk grade, band class, and process-specific control guidance. The user then selected the specific control tool and the tool provided process-specific control guidance.

KOSH has plans to expand coverage to include a total of thirty chemicals in KCT. An additional element of the KCT project is modifying MSDS to better communicate health hazards using less technical terminology (NIOSH 2009).

Advance REACH Tool (ART):

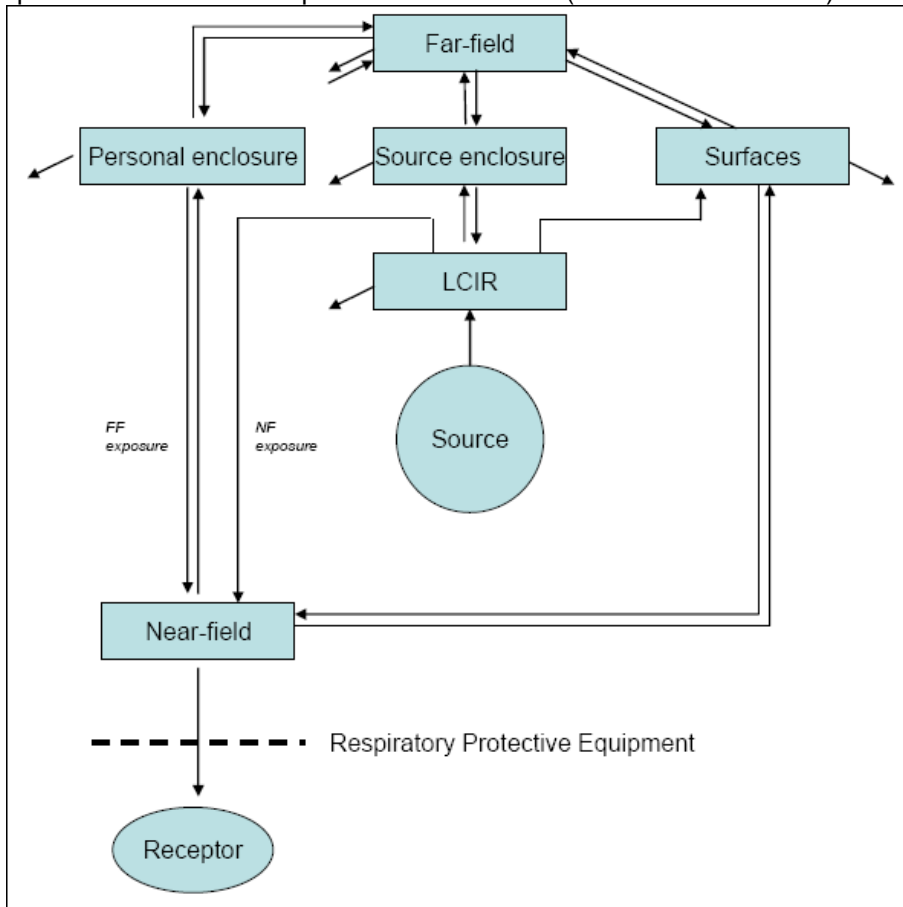
A new chemical management policy, Regulated Evaluation and Authorization of Chemicals (REACH), requires a chemical risk and exposure assessment. Exposure scenarios describe the conditions in which a substance is used. These scenarios form an essential basis for the chemical risk assessment reports required by REACH to show a chemical can be used safely (Fransman et al. 2009). Although some exposure scenarios may be easily ruled out as not posing a risk to human health, others require more data. This additional data can take the form of either specific quantitative exposure data or a generic exposure assessment tool that is capable of predicting exposures in a large variety of scenarios (Fransman et al. 2009). With no scientifically accepted generic risk assessment tool available, those cases for which specific quantitative exposure data did not already exist required exposure measurements on a case-by-case basis. Exposure monitoring on such a scale would be impractical, expensive, slow, and would greatly decrease the cost-effectiveness of REACH. The need for a robust, scientifically accepted, and generic risk assessment tool was clear, and a collaborative effort was made to develop a mechanistic model to assess risk (Fransman et al. 2009). This effort was called the Advanced REACH Tool (ART) project.

Many groups collaborated on the ART project and the resulting tool is structured as both a mechanistic and an empirical model (Fransman et al. 2009). The empirical portion allows a user, if he or she desires, to upload analogous data to calibrate the mechanistic model and give a more accurate estimate for the specific exposure scenario (Fransman et al. 2009). ART 2.0, which is under development, will include an exposure database to make the empirical portion as robust as possible. The current model combines the different sources of information using Bayesian statistics and provides a “separate estimate of the central tendency and variability of the exposure distribution” (Fransman et al. 2009) for the specific exposure scenario. The prediction of exposure variability is based on the among- and within-worker variability in similar exposure groups. This analysis and research will focus on the mechanistic model which is explored in more detail in the following section.

Conceptual Model of Inhalation Exposure

The mechanistic portion of ART uses the concept outlined in Figure 3 to describe the transfer of a contaminant from the source to the receptor.

Figure 3: “Conceptual model for inhalation exposure including sources, compartments and receptor and transport between these components.” Flow chart (Fransman et al. 2009)



The transport of contaminants between the compartments is indicated through the arrows. Those arrows leaving one compartment without leading to another signify a loss of contaminant in the system. For example, the arrow leaving the local control influence region (LCIR) compartment without leading to another compartment indicates a loss of contaminant mass due to the local control measures. The model components of Figure 4 are described in greater detail as follows.

- Source:

The “source” component of the figure above represents the activity, or task, during which the contaminant is released into the air. Although the source may be stationary or mobile, ART imposes virtual boundaries around the source. By defining the limits for the source, a LCIR can be established.
- LCIR

The LCIR is the region affected by local controls such as local exhaust ventilation systems, or physical barriers.

- Near and far field:

The near-field (NF) zone is defined as the volume of air within 1 meter, in any direction, centered on the worker's head. Centering the NF zone on the worker, rather than the source places the emphasis on the personal exposure which differentiates ART from other mechanistic models. Far-field (FF) zone is the remainder of the space in the room where the worker is located. ART assumes the concentration of airborne contaminants decreases as the distance from the source increases, and then simplifies the concentration gradient into two regions, NF and FF. Additionally, ART assumes perfect mixing within, the two regions and contaminant transfer between the two regions (Fransman et al. 2009). Airflow in workrooms is usually turbulent with eddies resulting from obstacles, room shape, room size, general room ventilation, and movement of equipment and workers. The assumption of "perfect mixing may lead to substantial error in exposure assessment where workers are positioned very close to the source. Moreover, the perfect mixing assumption does not consider local disturbance in the flow field very close to the worker" (Fransman et al. 2009). Factors influencing the concentration of airborne exposure in the NF are convections resulting from body temperature, arm movements and current formation surrounding the body. Although fluid dynamic computations can be developed for the aforementioned factors, such calculations cannot be integrated into a generic mechanistic model such as ART. Modifying factors (discussed below) are used to characterize factors influencing the NF and FF zones.

- Source Enclosure Personal Enclosure:

A source enclosure is anything which isolates the source from the work environment.

- Personal Enclosure:

A personal enclosure isolates the worker from the work environment.

- Surfaces:

Surfaces such as workbenches, machinery, and clothing may become contaminated.

The deposition may become resuspended or evaporated into the NF or FF of the worker.

In contrast, deposition of the contaminant onto a surface may result in a permanent removal of contaminants due to housekeeping practices.

- Receptor:

The receptor component is the respiratory tract. Respiratory protection can create a barrier reducing or preventing uptake of the airborne contaminants by the receptor. ART 1.0 exposure estimates do not take respirator protection into consideration. However, ART 2.0 will account for it.

Modifying Factors for the Model Components

To capture the specific exposure scenario, modifying factors are applied to the model components in Figure 4. The modifying factors used by ART are listed in the Figure 5 (Fransman et al. 2009).

Figure 4: “Components of the conceptual model and related principal Modifying Factors.” Table. (Fransman et al. 2009)

Model component	Principal MF	Description
Source	Activity emission potential (H)*	Describes the potential of the activity to generate exposure and is determined by the following characteristics: type and amount of energy transfer, scale (e.g. amount product used), and product to air interface (e.g. level of containment).
	Substance emission potential (E)	Determines the intrinsic emission potential of a substance, i.e.: dustiness for particulate agents and volatility for liquids.
Local control influence region (LCIR)	Localized control (LC)	Control measures in close proximity of the source intended to remove emissions, e.g. local exhaust ventilation (LEV), airborne capture sprays.
Source enclosure	Segregation (Seg)	Isolation of sources from the work environment without containment of the source itself, e.g. separate drying room.
NF and FF zone	Dilution (D)	Natural and mechanical ventilation characteristics, determining the dilution of air contaminants through the room: i.e., between NF - FF zone, and FF - outside.
NF zone	Personal behavior (P)	Orientation and distance of the worker to the source in the near-field, determining the potential exposure, e.g. worker positioned at very close distance during precision work, overhead work.
Personal enclosure	Separation (Sep)	Providing a worker with a personal enclosure within a work environment, e.g. air conditioned cabin.
Surfaces	Surface contamination (St)	Emission related to release of deposited contaminants on surrounding surfaces (including worker clothing) due to natural means or general workplace activities (e.g. moving equipment / vehicles).

*Discussion of the activity emission potential can be found in Marquart H, Heussen H, le Feber M et al. (2008)

The modifying factor assigns a numerical value to the corresponding model component, which in turn determines the weight each model component carries in the overall exposure calculation. For example, an exposure scenario in which local exhaust ventilation is used will result in a different modifying factor value for the localized controls (LC) than a scenario in which only general room ventilation is used. The different values for the LC modifying factors will cause different weightings of the LCIR model component in the overall calculation of exposure.

Quantifying Exposure:

The total personal exposure level (C_t) is the sum of exposure levels from the near field (C_{NF}) and far field (C_{FF}).

- $C_t = C_{NF} + C_{FF}$ Equation 1 (Fransman et al 2009)

The personal exposure from C_{NF} and C_{FF} are both multiplicative functions.

- $C_{NF} = (E_{NF} * H_{NF} * LC_{NF} * P_{NF} + S_{UNF}) * D_{NF}$ Equation 2 (Fransman et al 2009)

- $C_{FF} = (E_{FF} * H_{FF} * LC_{FF} * Seg_{FF} * S_{UNF}) * D_{FF} * Sep_{FF}$ Equation 3 (Fransman et al 2009)

The personal exposure for the near and far fields both involved the substance emission potential (E), activity emission potential (H), localized control (LC), surface contamination (Su), and dilution (D). The near and far field functions differed in three terms: segregation (Seg), separation (Sep), and personal behavior (P). The separation and segregation terms were only relevant in the far field and the personal behavior term only applies to near field. Equations 1-3 can simply be applied once for stable exposure conditions. However, for multiple sources in both the NF and FF with varying strength, the contributions of each source should be calculated separately. In the case of a person performing distinct consecutive tasks during a period of time, the personal exposure for each task should be assessed separately and then used to calculate a time-weighted average. The final exposure range produced by ART is in units of concentration (e.g. mg/m³). The substance emission potential is assigned a unit of emission rate (mass per time unit), and the dilution term has a unit of the reciprocal of a ventilation rate (time unit per volume) (Fransman et al. 2009). The remaining MFs are dimensionless. Exposure data is continually being collected from a variety of industries and companies to validate the ART model and the weighting calculated by the modifying factors.

A major limitation of ART is it cannot be used to assess fibrous material, solid objects (excluding wood and stone), gases, fume producing hot process such as welding, and low-volatile liquids with high viscosity. ART is a compliant exposure assessment method under the REACH

requirements, but its usefulness is greatly hindered by its lack of applicability to so many common processes.

General Limitations of Control Banding Tools

The most significant challenge in the development and implementation of control banding tools is the accuracy of the decision log (NIOSH 2009). Under prescription of controls can lead to hazards resulting in serious injuries, illnesses, or deaths. In contrast, over prescription of controls can result in unnecessary expense. The variables that must be considered in validation studies of control banding strategies are:

1. Prediction of Exposure: The exposure data used to validate the decision log methodology needs to characterize the entire range of exposure for the work process under consideration. The measurements must account for interworker, intraworker, and interworkplace variation. Repeat measurements on each worker are required. For processes with engineering controls, the use of those controls needs to be discontinued, assuming acceptable risk, for testing purposes.
2. Hazard Prediction: The toxicological endpoint of a chemical is typically used to define the specific risk level of that chemical. However, risk levels do not capture the relative severity of different chemicals in the same risk level. Where toxicological data, such as with OELs and TLVs, exist, they can be used to further assess the hazard.
3. Control Recommendations: The recommendations from control banding strategies can be compared to those of experts, preferably for scenarios where the exposure and hazard predictions of experts have already been tested and determined to be accurate.
4. Training: Control banding tools are intended for non-experts in the field of industrial hygiene. Therefore, an understanding of the tool and the methodology of the strategy is vital to proper implementation. The training on how to use the tool should be evaluated to ensure that it is appropriate for the target audience, offered frequently by a credible source, and effective. Because most control banding tools are accessible online, delivering and measuring effectiveness of training remains a challenge.
5. Control Implementations: Follow up is needed to validate proper implementation of controls, and periodic evaluation of controls is required to maintain effectiveness.

Research Proposal

Validation of all the proposed control banding tools with respect to the five factors above is crucial to determining the credibility of the control banding methodologies.

Although some have embraced the control band strategy, many believe reliability and accuracy (safety) have been compromised for simplicity (Bracker, 2009). To address these concerns, workplace scenarios with known quantitative exposure data are continually being used to validate ART's exposure predictions. However, little effort has been made towards validating ART's approach to exposure estimation with the decision-making process of a safety and health professional. Validating ART's approach is important because the quantitative data used to validate ART's predictions would come from a skewed sample. ART is intended to cover a wide range of industries and companies, but only large companies would have the amount of quantitative data needed to validate ART's predictions. These larger companies would likely have safety and health professionals on site who validate effectiveness of controls. Therefore, the quantitative data these companies would provide to use for ART validation would not cover the range of exposure situations for which ART is intended. Understanding the agreement of the model's approach to estimating exposure with a professional's approach to estimating exposure will assist in validating the ART model. Research on professional judgment has shown an association between professional certifications and an increase in accuracy of judgment of exposure (Vadali 2011). Additional factors, such as education and years experience in the field have also shown a similar association. Finally, this research will contribute to the growing research evaluating control banding tools.

This research will examine ART exposure estimates and professional judgments through the following hypotheses:

1. There is no difference between the subjects' exposure banding and Advanced REACH Tool's (ART's) exposure banding.
2. There is no difference in agreement of exposure banding between subjects who are Certified Industrial Hygienists, and subjects who are not Certified Industrial Hygienists.
3. There is no difference in how ART uses process information to determine exposure bands and how the research subjects use process information to determine bands.

Chapter II: Study Design and Data Analysis Methods

Overview of Data Collection Method:

The overall aim of this study was to compare ART's and professionals' estimates of personal airborne exposure in a hypothetical process. Subjects watched a thirty second video of a spray painting operation, and then opened an online questionnaire, which provided elementary information on ART along with all the information used by ART to estimate the exposure of the scenario. Subjects used the provided information and their professional judgment to estimate the airborne exposure relative to regulatory limits. Subjects indicated on the questionnaire what of the provided information they found the most beneficial in their assessment and any additional information they wanted. Finally, subjects were asked a series of questions related to their work experience, academic credentials, and uses of ART.

Exposure Scenario Development:

Each of the four questionnaires corresponded to an exposure scenario. All four scenarios were regarding exposure to Methyl Ethyl Ketone (MEK) during a spray painting process. The four exposure scenarios varied in conditions that were consistent with those expected among workplaces and industries (i.e. exposure time, ventilation controls, and housekeeping practices). The scenarios were assessed through ART and the exposure estimates that resulted were 16 ppm (<<16 ppm), 94 ppm (<PEL), 217 ppm (~PEL) and 949 ppm (>> PEL). The researcher identified the most significant modifying factors driving the overall exposure calculation for each scenario. The identified modifying factors were not reported to subjects, but were used in the data analysis. The information inputted into ART for each scenario was the information in the questionnaire for that scenario.

Subject Recruitment:

To examine the agreement between ART's estimates and the safety and health community's estimates, two pools of subjects were used. The pool of professional or practitioner subjects were certified industrial hygienists (CIH) recruited through the Pacific Northwest Section of the American Industrial Hygiene Association (PNS-AIHA). The PNS-AIHA administrator sent an email to members soliciting participants in a graduate student's research on control banding tools. Those members interested in participating responded to the email. The email addresses

of those members who indicated they were willing to be approached were sent by the PNS-AIHA administrator to the researcher.

The pool of non-practitioners consisted of people who had completed the University of Washington OSHA Education Center “521- OSHA Guide to Industrial Hygiene” course (OSHA-EC). These subjects were students who had completed the OSHA 521 course and also indicated they were interested in future information from OSHA-EC.

The randomized list of emails from PNS-AIHA and OSHA-EC were divided into quartiles and each quartile was assigned one of the four scenarios questionnaires.

Survey Development and Details:

The information provided in the questionnaire that described the exposure scenario included the information used by ART. The second portion of the survey focused on the subjects’ work experience and academic credentials which are variables research associated with accuracy in professional judgment (Valdali et al., 2011). The survey instrument was developed by the researcher and committee members and then piloted with a small group of practitioners. The pilot group provided feedback on the information in the introduction and instruction section, the format of the questionnaire, the video used, and the wording of the questions. Feedback from the pilot group was incorporate into the questionnaire and then retest with the same group. The final four questionnaires can be found in appendices A-D.

All the information used by ART for the specific scenario was provided to the subjects along with a video of a spray painting operation. All the subjects saw the same video. The following information was provided for the conditions of the exposure scenario.

The chemical information:

- The chemical name
- The CAS number
- The physical state of the chemical

- The temperature of the process
- The vapor pressure of the chemical
- The weight fraction of the chemical (MEK) in the overall composition of the solution (paint)
- Activity coefficient--Activity coefficient is the deviation from Raoult Law as a result of the chemicals within a mixture having different interactions when compared to an ideal mixture where all chemical species interact equally

The operational/process conditions:

- Process application type (e.g. spray application of liquid)
- Emission source in relation to breathing zone (NF or FF)
- Application rate
- Direction of the paint being sprayed
- Whether compressed air is used

The risk management measures:

- The use of localized ventilation
- Whether the process is fully enclosed
- Whether housekeeping practices are in place
- The ventilation in the workroom
- Whether a secondary emission source is present
- Process exposure time

Survey Implementation:

An introductory email was sent to potential subjects, which included how their emails were acquired and the scope of the research. Background information on control banding tools and ART was also provided. Within the email was a link to the questionnaire in SurveyMonkey Tool. Each link was unique to each subject and each research subject only asked to estimate the exposure for one exposure scenario. The questionnaire opened by stating the subjects would

be asked to view a video and consider information provided to estimate airborne exposure to MEK. The video was password protected and the password was on the introductory screen of the survey tool. The video showed a painter using a spray gun to spray small parts on a table top. After watching the video, subjects were prompted to return to the questionnaire and were presented with all the information related to the scenario. The information was divided into three sections: chemical information, operations/process information, and risk management measures. The subjects were asked to indicate the two pieces of information within each sections they found the most beneficial in their estimation of exposure. Subjects used the aforementioned information, along with the video, to qualitatively assess the personal airborne exposure relative to the Permissible Exposure Limit (PEL) for MEK.

After viewing the video, reviewing the work conditions and controls, and indicating which information was the most beneficial to their decision-making, subjects estimated whether the worker's airborne exposure was above or below the PEL for MEK of 200 ppm. After indicating their exposure "band" (above or below the PEL), ART's exposure estimate for the specific scenario was revealed to the subject. Finally, subjects were asked to respond to questions about academic credentials, work experience, and likelihood of using ART.

The questionnaire, questionnaire implementation, and subject recruitment methods were reviewed and approved by the University of Washington Institutional Review Board.

Data Analysis:

Subjects' survey results were stratified based on reported certification status (CIH or non-CIH). Certification status was self-reported by subjects based on their responses to the question in the survey. Survey responses were used to address the focus of this research: agreement with ART estimations among practitioners. More specifically, agreement was explored through the following three hypotheses.

Hypothesis 1:

There is no difference between the subjects' exposure banding and Advanced REACH Tool's (ART's) exposure banding.

Data analysis for the first hypothesis was done by pooling all the subjects' responses to the question regarding estimation of exposure relative to the PEL for MEK. ART's quantitative estimate was categorized as either above the PEL, or below the PEL. A kappa statistic of agreement was calculated for all the pooled data.

Hypothesis 2:

There is no difference in exposure banding between subjects who are Certified Industrial Hygienists, and subjects who are not Certified Industrial Hygienists. Education and experience in the field do not affect agreement.

The second hypothesis was tested by assessing the agreement between the subjects' estimates and ART's estimates. The kappa calculations were repeated, but this time after stratifying on certification status (CIHs and non-CIHs). Subject response were compared to corresponding ART assessment and coded as "agree" with each other or "disagree" with each other. An odds ratio (OR) was calculated comparing the agreement according to certification status. Additionally, odds ratios were adjusted for education and work experience. To account for the different scenarios, Scenario 3 was used as the baseline for the other scenarios in the logistic analysis. Scenario 3 was selected as the reference because it was banded by ART as the closest to the PEL.

The variables and coding used in the analysis for hypothesis one and two are described in Table 1.

Table 1: Description of Variables

Variable	Description	Type	Coding
Band (independent)	Estimation of exposure, above or below PEL	Nominal	0=below 1=above
Agreement (dependent)	Agreement between the band variable for ART and the Subject	Nominal	0=no 1=yes
Certification (independent)	Certified Industrial Hygienist	Nominal	0=no 1=yes
Experience (Exp) (independent)	Years of experience working in the safety and health field	Continuous	None
Education (Edu) (independent)	Years of education	Nominal	0=less than 18 yrs 1= 18 yrs or more
Continuing Education (CE) (independent)	Frequency of attendance at continuing education courses	Ordinal	1=once a yr 2=once every 1-3 years 3=once every 3 yrs
Control Banding (CB) (independent)	Attendance at a course on control banding	Ordinal	0=no 1=yes
Scenario (independent)	Estimate of exposure by ART for the conditions of the scenario	Categorical	1=16 ppm 2= 94 ppm 3= 217 ppm 4= 949 ppm

Hypothesis 3:

There is no difference in the information ART uses to estimate exposure and the information practitioners use to estimate exposure. There is no difference how that information is weighted by ART and by subjects

The third hypothesis addressed what information used by ART is used by subjects to estimate exposure. As noted previously ART, uses modifying factors to determine the influences each model component has on the calculation of exposure. The information indicated by the subjects as being the most beneficial in estimating exposure was compared to the modifying factors in ART. Those were determined for each scenario prior to implementation of the survey. The final portion of the questionnaire aimed at identifying how likely, in practice, a subject would be to

use ART to estimate exposures. The analysis of this portion of the questionnaire was qualitative in nature.

Chapter III: Results

Questionnaire responses were summarized (Table 2) for all subjects and for each certification strata (Table 3). Responses were grouped by scenario. For each scenario, the sum of subjects who banded (or categorized) exposure above the PEL or below the PEL totaled the number of responses for that scenario. Similarly, the sum of the total number of subjects who agreed with ART and the total number who disagreed with ART totaled the number of responses for the scenario. The percentages calculated are based on the total number of responses for the scenario. The percentages in the “Total” column are based on the total number of responses.

The responses indicate, in general subjects agree with ART and as often as they disagree (Table 2), and they band above the PEL as often as they band below the PEL. However, CIHs tend to band below the PEL more often than above, and non-CIHs tend to agree with ART more than CIHs (Table 3).

Table 2: Summary of Responses for All Subjects

		Scenario 1 <<PEL	Scenario 2 <PEL	Scenario 3 ~PEL	Scenario 4 >>PEL	Total
ART	Exposure Estimate	16 ppm	94 ppm	217 ppm	949 ppm	N/A
	Total Responses (% based on total responses for all subjects)	9 (17.3%)	11 (21.2%)	18 (34.6%)	14 (26.9%)	52
All Subjects	Banded above PEL (% based on all subjects responses for the scenario)	0 (0%)	6 (54.5%)	10 (55.6%)	6 (42.9%)	22 (42%)
	Banded below PEL (% based on all subjects responses for the scenario)	9 (100%)	5 (45.5%)	8 (44.4%)	8 (57.1%)	30 (58%)
	Agree with ART (% based on all subjects responses for the scenario)	9 (100%)	5 (45.5%)	10 (55.6%)	6 (42.9%)	30 (58%)
	Disagree with ART (% based on all subjects responses for the scenario)	0 (0%)	6 (54.5)	8 (44.4%)	8 (57.1%)	22 (42%)
	Mean Yrs of Education	17.1	15.8	16.75	16.7	16.8
	Mean Yrs of Experience	20.4	16.1	15.3	19.9	17.6
	Attend Continuing Education courses once per year (% based on total number of respondent for the scenario)	89%	73%	83%	86%	83%
	Completion of a Control Banding course (% based on total number of respondents for the scenario)	66%	18%	11%	14%	17%

Table 3: Summary of Responses Stratified by Certification Variable

		Scenario 1 <<PEL	Scenario 2 <PEL	Scenario 3 ~PEL	Scenario 4 >>PEL	Total
ART	Exposure Estimate	16 ppm	94 ppm	217 ppm	949 ppm	N/A
	Total Responses (% based on total responses for CIHs)	6 (25%)	4 (16.6%)	6 (25%)	8 (33.3%)	24
CIH	Banded above PEL (% based on total CIH responses for scenario)	0 (0%)	2 (50%)	1 (17%)	2 (25%)	5 (21%)
	Banded below PEL (% based on total CIH responses for the scenario)	6 (100%)	2 (50%)	5 (83%)	6 (75%)	19 (79%)
	Agree with ART (% based on total CIH responses for the scenario)	6 (100%)	2 (50%)	1 (17%)	2 (25%)	11 (46%)
	Disagree with ART (% based on total CIH responses for the scenario)	0 (0%)	2 (50%)	5 (83%)	6 (75%)	13 (54%)
	Mean Yrs of Education	18	16.5	18.3	18	17.83
	Mean Yrs of Experience	24.5	28.75	21.6	25.9	24.96
	Attend Continuing Education courses once per year (% based on total number of respondent for the scenario)	83%	100%	83%	100%	92%
	Completion of a Control Banding course (% based on total number of respondents for the scenario)	50%	50%	17%	25%	33%
	Total Responses (% based on total responses for non-CIH)	3 (10.7%)	7 (25%)	12 (43%)	6 (21.3)	28
	Banded above PEL (% based on total non-CIH responses for the scenario)	0 (0%)	4 (57.1%)	9 (75%)	4 (66.7%)	17 (61%)
Banded below PEL (% based on total non-CIH responses for the scenario)	3 (100%)	3 (42.9%)	3 (25%)	2 (33.3%)	11 (39%)	
Non-CIH	Agree with ART (% based on total non-CIH responses for the scenario)	3 (100%)	3 (42.9%)	9 (75%)	4 (66.7%)	19 (68%)
	Disagree with ART (% based on total non-CIH responses for the scenario)	0 (0%)	4 (57.1%)	3 (25%)	2 (33.3%)	9 (32%)
	Mean Yrs of Education	19.3	15.4	15.9	14.7	15.54
	Mean Yrs of Experience	12.3	8	12.1	11.8	11.25
	Attend Continuing Education courses once per year (% based on total number of respondent for the scenario)	100%	67%	83%	57%	75%
	Completion of a Control Banding course (% based on total number of respondents for the scenario)	0%	0%	8%	0%	4%

Agreement between ART and Subjects (Hypothesis 1 & 2):

The first two hypotheses focused on examining agreement between ART and subjects' banding. To examine agreement, a kappa statistic and odds ratio were calculated. The first hypothesis examined overall agreement between ART and the subjects, while the second hypothesis looked at agreement for CIHs and non-CIHs. A kappa greater than 0.75 represented excellent agreement beyond chance and a kappa below 0.40 represented poor agreement. A kappa between 0.4 and 0.75 was considered intermediate to good agreement (Gordis 2009). Agreement between subjects and ART is poor. The results of the kappa statistic were as follows.

Table 4: Kappa Statistic of Agreement between Subjects and ART

	Kappa	Level of agreement
All subjects	0.21	Poor
CIH	0.08	Poor
Non-CIH	0.32	Poor

Agreement and Certification Status (Hypothesis 2):

To further examine agreement, a logistic regression was done to calculate an OR comparing likelihood of agreement between ART and CIHs compared to ART and non-CIHs. The ORs reported (Table 5) represent the likelihood of agreement between ART and CIHs compared to ART and non-CIHs. The OR calculation is adjusting for years of experience in the field (Exp), highest level of education (Edu), and exposure scenario (Scen). Due to sample size, education was categorized as less than eighteen years or more than eighteen years. As noted previously, Scenario 3 (approximately at the PEL) was used as the baseline for the Scenario variable. Due to sample size, Scenarios 1 and 2 (both below the PEL) were pooled as one category.

Table 5: Agreement between subjects and ART comparing CIHs to non-CIHs--accounting for Independent Variables

Variable Adjusted for	Odds Ratio of Agreement and Cert	Standard error	95th Confidence Interval	p-value
--	0.40	0.23	0.13-1.24	0.11
Exp	0.15	0.13	0.02-0.89	0.04
Edu	0.77	0.56	0.18-3.21	0.72
Scen	0.38	0.15	0.11-1.24	0.11

Based on the odds ratios calculated (Table 5) for this study, when adjusting for other variables the odds ratios change dramatically indicated both the ORs and the model are highly unstable.

Information Used to Assess Exposure (Hypothesis 3):

The final hypothesis addressed what chemical information, process conditions, and risk management measures are used by subjects to estimate exposure. Subjects were asked to indicate the information they found most significant in determination of exposure. The most commonly selected items (chemical information, process conditions, and risk management measures) are indicated (Table 6). ART’s modifying factors identified for each scenario are tabulated (Table 6). To determine the most significant modifying factors, the coefficients for each modifying factor were identified using literature on ART (Fransman 2009). Those which drove the most significant change in ART’s estimate of exposure were identified (Table 6). ART does not use chemical information when estimating exposure.

Table 6: Most Influential Data in Estimating Exposure

	CIH	Non-CIH	ART (Modifying Factors)
Chemical Information	Weight fraction in overall paint composition	Weight fraction in overall paint composition	N/A
Operational/Process Conditions	Process application	Emission source in relation to breathing zone	Application rate
Risk Management Measure	Use of localized ventilation	Use of localized ventilation	Air exchange rate and housekeeping practices

CIHs and ART were in agreement that information on application method (process and rate) was the most influential in the estimation of exposure. Subjects and ART both indicated information related to ventilation to be the most influential risk management measures. However, ART weighted housekeeping practices equal with ventilation.

This study considered the possibility that some information influential in the professionals’ estimates may not be included in the ART model. The survey instrument only presented the information that is used by ART. So, to capture additional information used in exposures

estimations, subjects were queried for any additional information they would have liked to have had to estimate exposure. The responses were aggregated (Table 7).

Table 7: Number of Requests for Additional Information to Use in Exposure Estimation

Additional Information Category	CIH	Non-CIH	Total
Chemical Information	4	1	5
Operational/Process Conditions	4	2	6
Risk Management Measure	6	4	10
Quantitative Data	3	1	4
Worker Information	3	0	3
Exposure Time	2	4	6
None	6	9	15

The type of additional chemical information requested included the complete composition of the paint, or more specifics on MEK (molecular weight, specific gravity etc.). The most commonly requested addition for the operational/process conditions was related to the application method of the paint. Additional ventilation information was the most requested risk management measure. Some subjects indicated they would want exposure data (labeled “quantitative data” in Table 7), and others requested information on the worker’s training and experience (“worker information”). Some subjects requested additional information on worker “exposure time,” including length of time the worker remains in the area after the end of the process. Most subjects did feel additional information was needed.

Finally, subjects were asked about how they might use ART in the future. Subjects rated likelihood out of five possible choices: very likely, likely, somewhat likely, unlikely or highly unlikely.

Table 8: Likelihood of Using ART

ART Use Scenario	CIH	Non-CIH
As a screening tool	Somewhat	Somewhat/Likely
For compliance with REACH	Likely	Likely
In remote locations	Somewhat/Likely	Likely
When quantitative data is not available	Likely	Likely

Subjects were only marginally likely to use ART when assessing workplace exposures.

Chapter IV: Discussions

Summary of Research and Conclusions

The aim of this study was to examine agreement between ART and subject's estimation of exposure and how certification status affects likelihood of agreement. This study also examined what information was used by subjects when estimating exposure.

First, agreement was determined by calculating a kappa statistic. Based on the kappa results for all subjects (Table 4), we conclude for this study there is poor agreement between all subjects and ART on banding exposure into broad categories under the conditions presented.

Second, the question of agreement between ART and certification status was further examined by calculating odds ratios and adjusting for education, work experience and exposure scenario. Based on the odds ratios calculated (Table 5) for this study, CIHs are 40% as likely as non-CIHs to agree with ART. When adjusting for work experience, CIHs are 15% as likely as non-CIH and agree with are and when adjusting for education, CIHs are 77% as likely as non-CIHs to agree with ART.

Third, the information subjects use in estimating exposure was examined. Subjects were in agreement on the need for additional information beyond what ART used (Table 7). Though ART does not use chemical information in its estimation of exposure, subjects were in agreement on the need for chemical information (Table 7). Of the information used by ART, CIHs and ART were in agreement that information on application method was the most influential process information in the estimation of exposure. Subjects and ART both indicated information related to ventilation to be the most influential risk management measures. However, ART weighted housekeeping practices equal with ventilation (Table 6).

Finally, this study qualitatively examined ART uses. Based on responses (Table 8), subjects are marginally likely to use ART in scenarios that are not conducive to quantitative exposure monitoring.

Discussion of Results

The kappa statistics (Table 4) revealed poor agreement overall between subjects and ART. One cause for the observed disagreement may be due to the video misleading subjects. The video was intended to be a visual aid, but was not tailored to the exposure conditions of the

described scenarios. It is possible some subjects primarily relied on the visual in their decision-making process. If subjects disregarded the scenario information and relied on the video, they would have estimated the exposure of a scenario that was not estimated by ART or part of this study. Subjects were instructed to use the video only to understand the process, but, nonetheless, it is possible the visual representation influenced subjects in aspects of the exposure situation in which video was not meant to be instructive.

The odds ratios calculated (Table 5) indicated CIHs are less likely to agree with ART than non-CIHs. It is worth highlighting that CIHs estimated exposures above the PEL 20% of the time where ART's estimates of exposure were above the PEL 58% of the time for the same distribution of scenario responses. This difference was noteworthy because one of the primary design requirements of all control banding tools is to guide employers in worker protection decisions, but without overestimating exposure. Estimating an exposure above a PEL triggers many other requirements such as the implementation of medical health exams, periodic exposure monitoring, training, use of personal protective equipment and engineering controls. In addition to being costly, these requirements can be difficult to properly and effectively implement. Because these four scenarios were hypothetical exposures, there was no quantitative data to validate if the personal exposure was above, or below the PEL. However, this lack of agreement between CIHs and ART, and the tendency of CIHs to band below the PEL, merits further study.

Comparison to Literature on Professional Decision-Making

A recently published study examined accuracy in professional judgment and factors affecting the decision-making process (Vadali 2011). The study hypothesized a need for cognitive thinking (enjoying complex problem-solving) was related to accuracy in professional judgment of exposure. Among the variables tested as indicators of a need for cognitive thinking were years of experience and professional certifications. Vadali et. al. found both those variables were associated with increased accuracy in judgment. In contrast, our study found experience and a CIH were associated with decreased agreement with ART. Though both studies considered experience and certification variables, those variables were defined differently. Vadali et. al. included more professional certifications than just a CIH and years of experience was more specifically defined as years of experience in assessing exposure. Though testing different hypothesis, Vadali et al's conclusions highlight a need for further validation of ART's mechanistic model with professional decision-making and quantitative data

Direction of Future Research

This study should be done with a much larger sample to ensure adequate power, and to validate kappa and OR values. The study design should ensure even distribution of response for all scenarios. In addition, subjects should be recruited from more diverse sources.

The questionnaire asked subjects to identify what information was the most beneficial in their exposure estimates, and what additional information they would have wanted, but the questionnaire did not capture how the information was used. How the information was used would identify if the disagreement between ART and subjects was because the two groups used different information or because they weighted the same information differently. Research is currently underway to verify the accuracy of the ART estimates with quantitative exposure data. Quantitative data coupled with a better understanding of the factors practitioners use to estimate exposure and what weight they place on exposure factors, would guide further revisions of ART.

European companies and agencies have been utilizing control banding models for many years and are integrating ART into exposure estimation methodology. Additional research exploring agreement between ART and European practitioners and U.S. practitioners would be interesting as it would examine how academic credentials and work experience affect agreement particularly given European practitioners familiarity with control banding in general.

Limitations of Study

When considering the results presented in this research some limitations must be acknowledged. Power calculations for this study indicated a minimum of seventy two subjects, thirty six CIHs and thirty six non-CIHs were needed. Fifty-two subjects participated in this study, twenty four CIHs and twenty eight non-CIHs. This shortage of subjects hindered the power of this study to find significant differences. The limitations of the sample size became even more magnified when we attempted to stratify the data into smaller subsets.

ART is capable of estimating exposure for a variety of operations. This study only examined agreement for a spray painting process. Agreement between subjects and ART may depend on the type of operation being assessed. As previously noted, the video was not accurate for any of the scenarios. As a result, some subjects may have estimated exposure for the conditions in the video, rather than the conditions described in the questionnaire. Though instructed to disregard the use of any personal protective equipment, the individual in the video was wearing

an air-supplying respirator which may have misled many subjects. The use of the respirator could cause practitioners to assume high contaminant levels in the work area, but lower exposure levels to the worker due to the respirator.

To address the issues surrounding the video and to align with professional practice, the exposure scenario could be presented to subjects as a walkthrough of a facility. By seeing the actual facility, process, and work conditions, subjects would have a better understanding of the exposure scenario and this would likely provide an exposure estimate that truly represents their professional judgment.

A final limitation of the study design was the source of subjects. All the non-CIHs had completed the University of Washington OSHA Education Center "521-OSHA Guide to Industrial Hygiene". Consequently, this may have contributed to a lack of variability in the non-practitioner subjects. The CIH subjects were all members of the PNS-AIHA which could indicate similar interest in current research, attendance to continuing education courses, and approach to exposure assessments. All of these similarities indicated a lack of variability within the pool of practitioners.

Conclusions and Contributions of Research:

In conclusion, this research indicated a lack of agreement between our research subjects and ART in estimating exposure to a hypothetical scenario. CIHs were more likely than non-CIHs to disagree with ART's exposure estimates. Due to sample size, this disagreement was not significant at the five percent level. However, when adjusting for education and years of experience, the odds ratios do change significantly and indicate CIHs are not as likely as non-CIHs to agree with ART.

The major contribution of this study was actually testing agreement between ART and professionals. Although other studies have had professionals review control banding mechanistic models, few have had professionals and ART estimate exposure of the same process and then quantified the level of agreement (NIOSH 2009). Moreover, few other studies have attempted to concurrently capture the factors, such as education, training and work experience, which may influence the subjects' estimates. However, this study exposes questions about agreement between professionals and ART, which in itself is a significant contribution. This study indicates certification status is associated with a decrease in the

likelihood of agreeing with ART. Vadali et al. has found certification status is associated with an increase in accuracy of professional judgment. The findings in the study contribute to the growing body of research surrounding control banding tools, but also shed light on the need for further research comparing ART and professional's estimates of exposure to improve control banding tools.

References:

- NIOSH (2009), Qualitative Risk Characterization and Management of Occupational Hazards: Control Banding (CB): A Literature Review and Critical Analysis. CDC Aug. 2009
- Zalk, D., Nelson, D. (2008), History and Evolution of Control Banding: A Review. *JOEH* 2008;5:330-346
- Bracker, A., Morse, T., Simcox, N. (2009), Training Health and Safety Committees to Use Control Banding: Lessons Learned and Opportunities for the United States. *JOEH* 2009; 6:307-314
- HSE, COSHH Essentials., <http://www.coshh-essentials.org.uk/>
- Oldershaw PJ (2003), Control banding workshop 4 and 5 November 2002, London. *Ann Occup Hyg* 47(7):531–532.
- Fransman, W et al. (2009), Development of a mechanistic model for the Advanced REACH Tool (ART), TNO Report 2009
- Topping MD, Williams CR, Devine JM (1998), Industry's perception and use of occupational exposure limits. *Ann Occup Hyg* 42(6):357–366.
- Topping MD (2001), Occupational exposure limits for chemicals. *Occup Environ Med* 58(2):138–144.
- Zalk, D., Kamerzell, R., Paik, S., Kapp, J., Harrington, D., Swuste, P., (2009), Risk Level Based Management System: A Control Banding Model for Occupational Health and Safety Risk Management in Highly Regulated Environment. *Industrial Health* 2010, 48, 18-28.
- Marquart, H., Heussen, H., Feber, M., Noy, D., Tielemans, E., Schinkel, J., West, J., Van der Schaaf, D (2008), 'Stoffenmanager'. A Web-Based Control Banding Tool using an Exposure Process Model. *Ann.Occup. Hyg.*, 52(6): 429-441
- Mossink, J. (2002), Understanding and Performing Economic Assessments at the Company Level. WHO: *Protecting Workers' Health Series* .,
- Afifi, A., and Clark, V., Computer-Aided Multivariate Analysis; UK: Chapman & Hall, 1996
- Erickson, L., Hoover, M., Nelson, D., Update on Control Banding: Fundamentals, Issues, Application and Strategies for Implementation, AIHA TeleWeb Virtual Seminar, March 26, 2009

Vadali, M., Ramachandran, G., Banerjee, S. (2011), Effect of Training, Education, Professional Experience and Need for Cognition on Accuracy of Exposure Assessment Decision-Making, *Ann. Occup. Hyg.* 56(3):292-304.

Gordis, Leon (2011), *Epidemiology*; US: Saunders Elsevier, 2011

Appendix 1: Scenario 1 Questionnaire

Electronic Consent Form

UNIVERSITY OF WASHINGTON
ELECTONIC CONSENT FORM
Control Banding Tools: Advanced REACH Tool and Agreement with Professional Judgment

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1. Researchers' statement

We are asking you to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask questions about the purpose of the research, what we would ask you to do, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all your questions, you can decide if you want to be in the study or not. This process is called "informed consent." We will give you a copy of this form for your records.

PURPOSE OF THE STUDY

Europe has developed an online tool, the Advanced REACH Tool (ART), intended to assess chemical exposures in the workplace. Information related to a process and the materials used are entered into ART, and a quantitative exposure range is produced by the tool. In Europe, ART has been accepted as a regulatory compliant method of determining workplace exposure. This research will examine the agreement between subjects' exposure assessment based on professional judgment, and ART's exposure assessments. This research will also examine potential factors (education and work experience) associated with agreement with the tool. Understanding the agreement of the model's results with the safety and health community will assist in determining how these tools can be coupled with professional assessment and applied in the field. Finally, this research will contribute to the growing research evaluating control banding tools.

STUDY PROCEDURES

Subjects will start by watch a thirty second video of a work process. They will then open the questionnaire which will provide information on ART along with hypothetical information related to the work process and materials used. Subjects will use the information and their professional judgment to estimate the airborne exposure relative to regulatory level. Subjects will indicate which of the provided information they found the most beneficial in their assessment. After indicating their exposure assessment, the exposure as assessed by ART will be revealed, and subjects will be asked to indicate if they agree or disagree with ART. After completing the surveys related to exposure estimations, the subjects will be asked information regarding their educational background and professional history. The final set of questions is related to whether a subject would use ART in various applications.

The data analysis will examine if there is a difference in how subjects and ART assess exposures. Further analysis will use the subjects' background and educational

information to determine any association between background/educational information and agreement with ART.

CONFIDENTIALITY OF RESEARCH INFORMATION

No personal identifiable information will be reported in the final results of this project. Email addresses will be linked to subject's responses in the survey but will be discarded for data analysis. Email address will only be retained in the survey tool for nine months.

OTHER INFORMATION

You may refuse to participate and you are free to withdraw from this study at any time without penalty or loss of benefits to which you are otherwise entitled.

**If you have any questions regarding this research, or your participation, please contact:
Katie Skordal
425-941-9676
skordk@u.washington.edu**

Subject's statement

This study has been explained to me. I volunteer to take part in this research. I have had a chance to ask questions. If I have questions later about the research, I can ask one of the researchers listed above. If I have questions about my rights as a research subject, I can call the Human Subjects Division at (206) 543-0098.

- I consent to participating in this survey. Click the next button
- I do not consent to participating in this survey. Click exit this survey at the top right of the page

Vapor Exposure Estimate

The information in the survey is based on the information and language used by ART. In the ART mechanistic model, information is entered in the short answer free response form (e.g. exposure time, chemical name) or selected from a drop down menu. The answers from the survey below will be used to examine the agreement between OH&S professional and ART estimates of exposure.

Below is a link to a short video of a person spray-painting parts. After watching the video, please return to this questionnaire where you will be presented with the same information used by ART to estimate the airborne exposure that might be associated with this scenario. The information is split into three sections: paint information, operational conditions, and risk management measures. After you review the information, you will be asked to indicate which pieces of information are the most beneficial to you in making your estimate of exposure. After reviewing the details of the process, you will be asked to indicate if you think the exposure is above or below the Permissible Exposure Limit for the compound of interest. You will then be presented with the ART exposure estimate and asked if you agree or disagree with the ART value. To view the video of the exposure scenario, copy and paste the link below into your web browser; you will be asked for a password, which is also listed below. Once you have viewed the video, return to this survey and consider the process information in the survey below.

For this scenario, the paint used contains methyl ethyl ketone (Permissible Exposure Limit is 200 ppm, 8-hour TWA). You will be asked to estimate the airborne exposure to methyl ethyl ketone (MEK).

Please watch the following video: <http://www.vimeo.com/24360456>
Password: Vapor

2. Below are the details ART uses related to the paint used in this process. Of the six options below, please indicate the three pieces of information most beneficial in your exposure estimate.

- The chemical is MEK/CAS: 78-93-3.
- The physical state is liquid.
- The temperature of process is 22 C.
- The vapor pressure of chemical is 9465.9 Pa.
- MEK is a main component (50-90%) of the paint.
- The activity coefficient is 2. (Activity coefficient is the deviation from Raoult Law as a result of the chemicals within a mixture having different interactions when compared to an ideal mixture where all chemical species interact equally).

3. Below are the details ART uses regarding the operational conditions of the paint process. Of the five options below, please indicate the two pieces of information most beneficial in your exposure estimate.

- This process is a spray application of liquids. ART defines this process to be activities used to atomize liquids into droplets for dispersion on surfaces (surface spraying) or into air (space spraying).
- The primary emission source is located in the breathing zone of the worker (i.e. the volume of air within 1 meter in any direction of the worker's head).
- The spraying is occurring at a low application rate: 0.03-0.3 l/minute (i.e. pest control operations).
- The paint is only spraying in a horizontal or downward direction.
- The spray application has no, or low, compressed air use.

4. Below are details ART uses regarding the risk management measures in place for the painting process. Of the six options below, please indicate the three pieces of information most beneficial in your exposure estimate.

- During the painting process, there are no localized control measures in close proximity of the near-field emission source intended to minimize emissions from the source. (No local exhaust ventilation in use).
- The spray process is fully enclosed and the integrity of the enclosure is regularly monitored.
- The spray painting process is performed in a down-flow spray room with 10 ACH
- There are no secondary sources present in the workroom in addition to the source in breathing zone of the worker.
- The total time spent spraying paint (process time) is 15 minutes.
- The total time not spraying paint (non-exposure time) is 465 minutes.

5. The 8-hour time weighted average permissible exposure limit (PEL) of MEK is 200 ppm. Based on the video and the information provided, please select what range you believe the airborne exposure to MEK to fall in at the 50 percentile for a full 8 hour shift. Do NOT include a margin of safety in your estimate.

****Disregard the use of any personal protective equipment****

- Using the information presented above, I estimate the airborne exposure to MEK for this process to be at, or above, the PEL (greater than or equal to 200 ppm)
- Using the information presented above, I estimate the airborne exposure to MEK for this process to be below the PEL (less than 200 ppm)

The 8-hour time weighed average PEL of MEK is 200 ppm. The options from the previous page are reproduced below:

Using the information presented above, I estimate the airborne exposure to MEK for this process to be at, or above, the PEL (greater than or equal to 200 ppm)

Using the information presented above, I estimate the airborne exposure to MEK for this process to be below the PEL (less than 200 ppm)

6. Using the exact same information that was provided in this survey, the ART model assess the following MEK exposure:

The predicted 50th percentile full-shift exposure is 16 ppm

ART predicts concentrations in a worker's personal breathing zone outside of any respiratory protection equipment.

Do you agree or disagree with the ART assessment?

Agree

Disagree

Background/Educational Information

The following questions relate to your academic achievements and work experience. This information will be used to examine potential factors associated with agreement with ART.

7. Do you currently, or have you ever obtained any of the following professional certifications?

- Certified Industrial Hygienist (CIH or ROH)
- Certified Safety Professional (CSP)
- Certified Hazardous Materials Manager (CHMM)
- Certified Professional Engineer (CPE)
- Certified Professional Ergonomist (CPE)
- Occupational Health and Safety Technologist (OHST)
- Certified Associate Industrial Hygienist (CAIH)
- Other
- None

8. How many years have you worked in the safety and health field?

9. What is the highest level of education you have achieved? In what field was the degree obtained?

10. How often do you attend continuing education courses?

- More than once a year
- Once every 1 to 3 years
- Less than once every 3 years

11. Have you ever taken a courses on control banding?

- Yes
- No

12. This survey presented a video of a spray painting process and only the information used by ART to estimate exposure. What additional information would you have liked to know in order to estimate the exposure?

ART Applications

ART has potential applications beyond compliance with REACH. The following questions are related to how likely you would be to use ART in various scenarios.

13. If you were assessing exposure in a large facility, how likely would you be to use ART as a screening tool to determine where to perform quantitative exposure monitoring?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

14. If tasked with achieving compliance with REACH at a workplace, how likely would you be to use ART?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

15. If you were assessing exposure in a remote location, how likely would you be to use ART?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

16. If quantitative exposure monitoring was not possible, how likely would you be to use ART to determine exposure?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

17. Any additional comments regarding ART or the applications of ART?

Appendix 2: Scenario 2 Questionnaire

Electronic Consent Form

UNIVERSITY OF WASHINGTON
ELECTONIC CONSENT FORM
Control Banding Tools: Advanced REACH Tool and Agreement with Professional Judgment

Researchers:

Katherine Skordal, MS Graduate Student in Department of Environmental & Occupational Health Sciences
skordk@u.washington.edu
425-941-9676

Faculty Advisor:

Dr. Michael Yost Ph.D, Professor Department of Environmental & Occupational Health Sciences
airion@u.washington.edu
206 685-7243

1. Researchers' statement

We are asking you to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask questions about the purpose of the research, what we would ask you to do, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all your questions, you can decide if you want to be in the study or not. This process is called "informed consent." We will give you a copy of this form for your records.

PURPOSE OF THE STUDY

Europe has developed an online tool, the Advanced REACH Tool (ART), intended to assess chemical exposures in the workplace. Information related to a process and the materials used are entered into ART, and a quantitative exposure range is produced by the tool. In Europe, ART has been accepted as a regulatory compliant method of determining workplace exposure. This research will examine the agreement between subjects' exposure assessment based on professional judgment, and ART's exposure assessments. This research will also examine potential factors (education and work experience) associated with agreement with the tool. Understanding the agreement of the model's results with the safety and health community will assist in determining how these tools can be coupled with professional assessment and applied in the field. Finally, this research will contribute to the growing research evaluating control banding tools.

STUDY PROCEDURES

Subjects will start by watch a thirty second video of a work process. They will then open the questionnaire which will provide information on ART along with hypothetical information related to the work process and materials used. Subjects will use the information and their professional judgment to estimate the airborne exposure relative to regulatory level. Subjects will indicate which of the provided information they found the most beneficial in their assessment. After indicating their exposure assessment, the exposure as assessed by ART will be revealed, and subjects will be asked to indicate if they agree or disagree with ART. After completing the surveys related to exposure estimations, the subjects will be asked information regarding their educational background and professional history. The final set of questions is related to whether a subject would use ART in various applications.

The data analysis will examine if there is a difference in how subjects and ART assess exposures. Further analysis will use the subjects' background and educational

information to determine any association between background/educational information and agreement with ART.

CONFIDENTIALITY OF RESEARCH INFORMATION

No personal identifiable information will be reported in the final results of this project. Email addresses will be linked to subject's responses in the survey but will be discarded for data analysis. Email address will only be retained in the survey tool for nine months.

OTHER INFORMATION

You may refuse to participate and you are free to withdraw from this study at any time without penalty or loss of benefits to which you are otherwise entitled.

If you have any questions regarding this research, or your participation, please contact:

Katie Skordal

425-941-9676

skordk@u.washington.edu

Subject's statement

This study has been explained to me. I volunteer to take part in this research. I have had a chance to ask questions. If I have questions later about the research, I can ask one of the researchers listed above. If I have questions about my rights as a research subject, I can call the Human Subjects Division at (206) 543-0098.

I consent to participating in this survey. Click the next button

I do not consent to participating in this survey. Click exit this survey at the top right of the page

Vapor Exposure Estimate

The information in the survey is based on the information and language used by ART. In the ART mechanistic model, information is entered in the short answer free response form (e.g. exposure time, chemical name) or selected from a drop down menu. The answers from the survey below will be used to examine the agreement between OH&S professional and ART estimates of exposure.

Below is a link to a short video of a person spray-painting parts. After watching the video, please return to this questionnaire where you will be presented with the same information used by ART to estimate the airborne exposure that might be associated with this scenario. The information is split into three sections: paint information, operational conditions, and risk management measures. After you review the information, you will be asked to indicate which pieces of information are the most beneficial to you in making your estimate of exposure. After reviewing the details of the process, you will be asked to indicate if you think the exposure is above or below the Permissible Exposure Limit for the compound of interest. You will then be presented with the ART exposure estimate and asked if you agree or disagree with the ART value. To view the video of the exposure scenario, copy and paste the link below into your web browser; you will be asked for a password, which is also listed below. Once you have viewed the video, return to this survey and consider the process information in the survey below.

For this scenario, the paint used contains methyl ethyl ketone (Permissible Exposure Limit is 200 ppm, 8-hour TWA). You will be asked to estimate the airborne exposure to methyl ethyl ketone (MEK).

Please watch the following video: <http://www.vimeo.com/24360456>
Password: Vapor

2. Below are the details ART uses related to the paint used in this process. Of the six options below, please indicate the three pieces of information most beneficial in your exposure estimate.

- The chemical is MEK/CAS: 78-93-3.
- The physical state is liquid.
- The temperature of process is 22 C.
- The vapor pressure of chemical is 9465.9 Pa.
- MEK is a main component (50-90%) of the paint.
- The activity coefficient is 2. (Activity coefficient is the deviation from Raoult Law as a result of the chemicals within a mixture having different interactions when compared to an ideal mixture where all chemical species interact equally).

3. Below are the details ART uses regarding the operational conditions of the paint process. Of the five options below, please indicate the two pieces of information most beneficial in your exposure estimate.

- This process is a spray application of liquids. ART defines this process to be activities used to atomize liquids into droplets for dispersion on surfaces (surface spraying) or into air (space spraying).
- The primary emission source is located in the breathing zone of the worker (i.e. the volume of air within 1 meter in any direction of the worker's head).
- The spraying is occurring at a low application rate: 0.03-0.3 l/minute (i.e. pest control operations).
- The paint is only spraying in a horizontal or downward direction.
- The spray application has no, or low, compressed air use.

4. Below are details ART uses regarding the risk management measures in place for the painting process. Of the eight options below, please indicate the three pieces of information most beneficial in your exposure estimate.

- During the painting process, there are no localized control measures in close proximity of the near-field emission source intended to minimize emissions from the source. (No local exhaust ventilation in use).
- The spray process is not fully enclosed.
- Demonstrable and effective housekeeping practices are not in place at the workplace. ART defines these practices as daily cleaning using appropriate methods (e.g. vacuum), preventive maintenance of machinery and control measures, and use of protective clothing that will repel spills and reduce personal cloud.
- General housekeeping practices are in place in the workplace.
- The spray painting process is performed indoors, in a large workroom with 1 ACH.
- There are no secondary sources present in the workroom in addition to the source in breathing zone of the worker.
- The total time spent spraying paint (process time) is 15 minutes.
- The total time not spraying paint (non-exposure time) is 465 minutes.

5. The 8-hour time weighted average permissible exposure limit (PEL) of MEK is 200 ppm. Based on the video and the information provided, please select what range you believe the airborne exposure to MEK to fall in at the 50 percentile for a full 8 hour shift. Do NOT include a margin of safety in your estimate.

****Disregard the use of any personal protective equipment****

- Using the information presented above, I estimate the airborne exposure to MEK for this process to be at, or above, the PEL (greater than or equal to 200 ppm)
- Using the information presented above, I estimate the airborne exposure to MEK for this process to be below the PEL (less than 200 ppm)

The 8-hour time weighed average PEL of MEK is 200 ppm. The options from the previous page are reproduced below:

Using the information presented above, I estimate the airborne exposure to MEK for this process to be at, or above, the PEL (greater than or equal to 200 ppm)

Using the information presented above, I estimate the airborne exposure to MEK for this process to be below the PEL (less than 200 ppm)

6. Using the exact same information that was provided in this survey, the ART model assess the following MEK exposure:

The predicted 50th percentile full-shift exposure is 94.92 ppm

ART predicts concentrations in a worker's personal breathing zone outside of any respiratory protection equipment.

Do you agree or disagree with the ART assessment?

Agree

Disagree

Background/Educational Information

The following questions relate to your academic achievements and work experience. This information will be used to examine potential factors associated with agreement with ART.

7. Do you currently, or have you ever obtained any of the following professional certifications?

- Certified Industrial Hygienist (CIH or ROH)
- Certified Safety Professional (CSP)
- Certified Hazardous Materials Manager (CHMM)
- Certified Professional Engineer (CPE)
- Certified Professional Ergonomist (CPE)
- Occupational Health and Safety Technologist (OHST)
- Certified Associate Industrial Hygienist (CAIH)
- Other
- None

8. How many years have you worked in the safety and health field?

9. What is the highest level of education you have achieved? In what field was the degree obtained?

10. How often do you attend continuing education courses?

- More than once a year
- Once every 1 to 3 years
- Less than once every 3 years

11. Have you ever taken a courses on control banding?

- Yes
- No

12. This survey presented a video of a spray painting process and only the information used by ART to estimate exposure. What additional information would you have liked to know in order to estimate the exposure?

ART Applications

ART has potential applications beyond compliance with REACH. The following questions are related to how likely you would be to use ART in various scenarios.

13. If you were assessing exposure in a large facility, how likely would you be to use ART as a screening tool to determine where to perform quantitative exposure monitoring?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

14. If tasked with achieving compliance with REACH at a workplace, how likely would you be to use ART?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

15. If you were assessing exposure in a remote location, how likely would you be to use ART?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

16. If quantitative exposure monitoring was not possible, how likely would you be to use ART to determine exposure?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

17. Any additional comments regarding ART or the applications of ART?

Appendix 3: Scenario 3 Questionnaire

Electronic Consent Form

UNIVERSITY OF WASHINGTON
ELECTONIC CONSENT FORM
Control Banding Tools: Advanced REACH Tool and Agreement with Professional Judgment

Researchers:
Katherine Skordal, MS Graduate Student in Department of Environmental & Occupational Health Sciences
skordk@u.washington.edu
425-941-9676

Faculty Advisor:
Dr. Michael Yost Ph.D, Professor Department of Environmental & Occupational Health Sciences
airion@u.washington.edu
206 685-7243

1. Researchers' statement

We are asking you to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask questions about the purpose of the research, what we would ask you to do, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all your questions, you can decide if you want to be in the study or not. This process is called "informed consent." We will give you a copy of this form for your records.

PURPOSE OF THE STUDY

Europe has developed an online tool, the Advanced REACH Tool (ART), intended to assess chemical exposures in the workplace. Information related to a process and the materials used are entered into ART, and a quantitative exposure range is produced by the tool. In Europe, ART has been accepted as a regulatory compliant method of determining workplace exposure. This research will examine the agreement between subjects' exposure assessment based on professional judgment, and ART's exposure assessments. This research will also examine potential factors (education and work experience) associated with agreement with the tool. Understanding the agreement of the model's results with the safety and health community will assist in determining how these tools can be coupled with professional assessment and applied in the field. Finally, this research will contribute to the growing research evaluating control banding tools.

STUDY PROCEDURES

Subjects will start by watch a thirty second video of a work process. They will then open the questionnaire which will provide information on ART along with hypothetical information related to the work process and materials used. Subjects will use the information and their professional judgment to estimate the airborne exposure relative to regulatory level. Subjects will indicate which of the provided information they found the most beneficial in their assessment. After indicating their exposure assessment, the exposure as assessed by ART will be revealed, and subjects will be asked to indicate if they agree or disagree with ART. After completing the surveys related to exposure estimations, the subjects will be asked information regarding their educational background and professional history. The final set of questions is related to whether a subject would use ART in various applications.

The data analysis will examine if there is a difference in how subjects and ART assess exposures. Further analysis will use the subjects' background and educational

information to determine any association between background/educational information and agreement with ART.

CONFIDENTIALITY OF RESEARCH INFORMATION

No personal identifiable information will be reported in the final results of this project. Email addresses will be linked to subject's responses in the survey but will be discarded for data analysis. Email address will only be retained in the survey tool for nine months.

OTHER INFORMATION

You may refuse to participate and you are free to withdraw from this study at any time without penalty or loss of benefits to which you are otherwise entitled.

**If you have any questions regarding this research, or your participation, please contact:
Katie Skordal
425-941-9676
skordk@u.washington.edu**

Subject's statement

This study has been explained to me. I volunteer to take part in this research. I have had a chance to ask questions. If I have questions later about the research, I can ask one of the researchers listed above. If I have questions about my rights as a research subject, I can call the Human Subjects Division at (206) 543-0098.

- I consent to participating in this survey. Click the next button
- I do not consent to participating in this survey. Click exit this survey at the top right of the page

Vapor Exposure Estimate

The information in the survey is based on the information and language used by ART. In the ART mechanistic model, information is entered in the short answer free response form (e.g. exposure time, chemical name) or selected from a drop down menu. The answers from the survey below will be used to examine the agreement between OH&S professional and ART estimates of exposure.

Below is a link to a short video of a person spray-painting parts. After watching the video, please return to this questionnaire where you will be presented with the same information used by ART to estimate the airborne exposure that might be associated with this scenario. The information is split into three sections: paint information, operational conditions, and risk management measures. After you review the information, you will be asked to indicate which pieces of information are the most beneficial to you in making your estimate of exposure. After reviewing the details of the process, you will be asked to indicate if you think the exposure is above or below the Permissible Exposure Limit for the compound of interest. You will then be presented with the ART exposure estimate and asked if you agree or disagree with the ART value. To view the video of the exposure scenario, copy and paste the link below into your web browser; you will be asked for a password, which is also listed below. Once you have viewed the video, return to this survey and consider the process information in the survey below.

For this scenario, the paint used contains methyl ethyl ketone (Permissible Exposure Limit is 200 ppm, 8-hour TWA). You will be asked to estimate the airborne exposure to methyl ethyl ketone (MEK).

Please watch the following video: <http://www.vimeo.com/24360456>
Password: Vapor

2. Below are the details ART uses related to the paint used in this process. Of the six options below, please indicate the three pieces of information most beneficial in your exposure estimate.

- The chemical is MEK/CAS: 78-93-3.
- The physical state is liquid.
- The temperature of process is 22 C.
- The vapor pressure of chemical is 9465.9 Pa.
- MEK is a main component (50-90%) of the paint.
- The activity coefficient is 2. (Activity coefficient is the deviation from Raoult Law as a result of the chemicals within a mixture having different interactions when compared to an ideal mixture where all chemical species interact equally).

3. Below are the details ART uses regarding the operational conditions of the paint process. Of the five options below, please indicate the two pieces of information most beneficial in your exposure estimate.

- This process is a spray application of liquids. ART defines this process to be activities used to atomize liquids into droplets for dispersion on surfaces (surface spraying) or into air (space spraying).
- The primary emission source is located in the breathing zone of the worker (i.e. the volume of air within 1 meter in any direction of the worker's head).
- The spraying is occurring at a moderate application rate: 0.3-3.0 l/minute (i.e. pest control operations).
- The paint is only spraying in a horizontal or downward direction.
- The spray application has no, or low, compressed air use.

4. Below are details ART uses regarding the risk management measures in place for the painting process. Of the six options below, please indicate the three pieces of information most beneficial in your exposure estimate.

- During the painting process, there are no localized control measures in close proximity of the near-field emission source intended to minimize emissions from the source. (No local exhaust ventilation in use).
- The spray process is fully enclosed and the integrity of the enclosure is regularly monitored.
- The spray painting process is performed in a down-flow spray room with 10 ACH
- There are no secondary sources present in the workroom in addition to the source in breathing zone of the worker.
- The total time spent spraying paint (process time) is 60 minutes.
- The total time not spraying paint (non-exposure time) is 420 minutes.

5. The 8-hour time weighted average permissible exposure limit (PEL) of MEK is 200 ppm. Based on the video and the information provided, please select what range you believe the airborne exposure to MEK to fall in at the 50 percentile for a full 8 hour shift. Do NOT include a margin of safety in your estimate.

****Disregard the use of any personal protective equipment****

- Using the information presented above, I estimate the airborne exposure to MEK for this process to be at, or above, the PEL (greater than or equal to 200 ppm)
- Using the information presented above, I estimate the airborne exposure to MEK for this process to be below the PEL (less than 200 ppm)

The 8-hour time weighed average PEL of MEK is 200 ppm. The options from the previous page are reproduced below:

Using the information presented above, I estimate the airborne exposure to MEK for this process to be at, or above, the PEL (greater than or equal to 200 ppm)

Using the information presented above, I estimate the airborne exposure to MEK for this process to be below the PEL (less than 200 ppm)

6. Using the exact same information that was provided in this survey, the ART model assess the following MEK exposure:

The predicted 50th percentile full-shift exposure is 216.9 ppm

ART predicts concentrations in a worker's personal breathing zone outside of any respiratory protection equipment.

Do you agree or disagree with the ART assessment?

Agree

Disagree

Background/Educational Information

The following questions relate to your academic achievements and work experience. This information will be used to examine potential factors associated with agreement with ART.

7. Do you currently, or have you ever obtained any of the following professional certifications?

- Certified Industrial Hygienist (CIH or ROH)
- Certified Safety Professional (CSP)
- Certified Hazardous Materials Manager (CHMM)
- Certified Professional Engineer (CPE)
- Certified Professional Ergonomist (CPE)
- Occupational Health and Safety Technologist (OHST)
- Certified Associate Industrial Hygienist (CAIH)
- Other
- None

8. How many years have you worked in the safety and health field?

9. What is the highest level of education you have achieved? In what field was the degree obtained?

10. How often do you attend continuing education courses?

- More than once a year
- Once every 1 to 3 years
- Less than once every 3 years

11. Have you ever taken a courses on control banding?

- Yes
- No

12. This survey presented a video of a spray painting process and only the information used by ART to estimate exposure. What additional information would you have liked to know in order to estimate the exposure?

ART Applications

ART has potential applications beyond compliance with REACH. The following questions are related to how likely you would be to use ART in various scenarios.

13. If you were assessing exposure in a large facility, how likely would you be to use ART as a screening tool to determine where to perform quantitative exposure monitoring?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

14. If tasked with achieving compliance with REACH at a workplace, how likely would you be to use ART?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

15. If you were assessing exposure in a remote location, how likely would you be to use ART?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

16. If quantitative exposure monitoring was not possible, how likely would you be to use ART to determine exposure?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

17. Any additional comments regarding ART or the applications of ART?

Appendix 4: Scenario 4 Questionnaire

Electronic Consent Form

UNIVERSITY OF WASHINGTON
ELECTONIC CONSENT FORM
Control Banding Tools: Advanced REACH Tool and Agreement with Professional Judgment

Researchers:
Katherine Skordal, MS Graduate Student in Department of Environmental & Occupational Health Sciences
skordk@u.washington.edu
425-941-9676

Faculty Advisor:
Dr. Michael Yost Ph.D, Professor Department of Environmental & Occupational Health Sciences
airion@u.washington.edu
206 685-7243

1. Researchers' statement

We are asking you to be in a research study. The purpose of this consent form is to give you the information you will need to help you decide whether to be in the study or not. Please read the form carefully. You may ask questions about the purpose of the research, what we would ask you to do, the possible risks and benefits, your rights as a volunteer, and anything else about the research or this form that is not clear. When we have answered all your questions, you can decide if you want to be in the study or not. This process is called "informed consent." We will give you a copy of this form for your records.

PURPOSE OF THE STUDY

Europe has developed an online tool, the Advanced REACH Tool (ART), intended to assess chemical exposures in the workplace. Information related to a process and the materials used are entered into ART, and a quantitative exposure range is produced by the tool. In Europe, ART has been accepted as a regulatory compliant method of determining workplace exposure. This research will examine the agreement between subjects' exposure assessment based on professional judgment, and ART's exposure assessments. This research will also examine potential factors (education and work experience) associated with agreement with the tool. Understanding the agreement of the model's results with the safety and health community will assist in determining how these tools can be coupled with professional assessment and applied in the field. Finally, this research will contribute to the growing research evaluating control banding tools.

STUDY PROCEDURES

Subjects will start by watch a thirty second video of a work process. They will then open the questionnaire which will provide information on ART along with hypothetical information related to the work process and materials used. Subjects will use the information and their professional judgment to estimate the airborne exposure relative to regulatory level. Subjects will indicate which of the provided information they found the most beneficial in their assessment. After indicating their exposure assessment, the exposure as assessed by ART will be revealed, and subjects will be asked to indicate if they agree or disagree with ART. After completing the surveys related to exposure estimations, the subjects will be asked information regarding their educational background and professional history. The final set of questions is related to whether a subject would use ART in various applications.

The data analysis will examine if there is a difference in how subjects and ART assess exposures. Further analysis will use the subjects' background and educational

information to determine any association between background/educational information and agreement with ART.

CONFIDENTIALITY OF RESEARCH INFORMATION

No personal identifiable information will be reported in the final results of this project. Email addresses will be linked to subject's responses in the survey but will be discarded for data analysis. Email address will only be retained in the survey tool for nine months.

OTHER INFORMATION

You may refuse to participate and you are free to withdraw from this study at any time without penalty or loss of benefits to which you are otherwise entitled.

**If you have any questions regarding this research, or your participation, please contact:
Katie Skordal
425-941-9676
skordk@u.washington.edu**

Subject's statement

This study has been explained to me. I volunteer to take part in this research. I have had a chance to ask questions. If I have questions later about the research, I can ask one of the researchers listed above. If I have questions about my rights as a research subject, I can call the Human Subjects Division at (206) 543-0098.

- I consent to participating in this survey. Click the next button
- I do not consent to participating in this survey. Click exit this survey at the top right of the page

Vapor Exposure Estimate

The information in the survey is based on the information and language used by ART. In the ART mechanistic model, information is entered in the short answer free response form (e.g. exposure time, chemical name) or selected from a drop down menu. The answers from the survey below will be used to examine the agreement between OH&S professional and ART estimates of exposure.

Below is a link to a short video of a person spray-painting parts. After watching the video, please return to this questionnaire where you will be presented with the same information used by ART to estimate the airborne exposure that might be associated with this scenario. The information is split into three sections: paint information, operational conditions, and risk management measures. After you review the information, you will be asked to indicate which pieces of information are the most beneficial to you in making your estimate of exposure. After reviewing the details of the process, you will be asked to indicate if you think the exposure is above or below the Permissible Exposure Limit for the compound of interest. You will then be presented with the ART exposure estimate and asked if you agree or disagree with the ART value. To view the video of the exposure scenario, copy and paste the link below into your web browser; you will be asked for a password, which is also listed below. Once you have viewed the video, return to this survey and consider the process information in the survey below.

For this scenario, the paint used contains methyl ethyl ketone (Permissible Exposure Limit is 200 ppm, 8-hour TWA). You will be asked to estimate the airborne exposure to methyl ethyl ketone (MEK).

Please watch the following video: <http://www.vimeo.com/24360456>
Password: Vapor

2. Below are the details ART uses related to the paint used in this process. Of the six options below, please indicate the three pieces of information most beneficial in your exposure estimate.

- The chemical is MEK/CAS: 78-93-3.
- The physical state is liquid.
- The temperature of process is 22 C.
- The vapor pressure of chemical is 9465.9 Pa.
- MEK is a main component (50-90%) of the paint.
- The activity coefficient is 2. (Activity coefficient is the deviation from Raoult Law as a result of the chemicals within a mixture having different interactions when compared to an ideal mixture where all chemical species interact equally).

3. Below are the details ART uses regarding the operational conditions of the paint process. Of the five options below, please indicate the two pieces of information most beneficial in your exposure estimate.

- This process is a spray application of liquids. ART defines this process to be activities used to atomize liquids into droplets for dispersion on surfaces (surface spraying) or into air (space spraying).
- The primary emission source is located in the breathing zone of the worker (i.e. the volume of air within 1 meter in any direction of the worker's head).
- The spraying is occurring at a moderate application rate: 0.3-3.0 l/minute (i.e. pest control operations).
- The paint is only spraying in a horizontal or downward direction.
- The spray application has high compressed air use.

4. Below are details ART uses regarding the risk management measures in place for the painting process. Of the seven options below, please indicate the three pieces of information most beneficial in your exposure estimate.

- During the painting process, there are no localized control measures in close proximity of the near-field emission source intended to minimize emissions from the source. (No local exhaust ventilation in use).
- The spray process is not fully enclosed.
- Demonstrable and effective housekeeping practices are in place at the workplace. ART defines these practices as daily cleaning using appropriate methods (e.g. vacuum), preventive maintenance of machinery and control measures, and use of protective clothing that will repel spills and reduce personal cloud.
- The spray painting process is performed indoors, in a large workroom with 1 ACH.
- There are no secondary sources present in the workroom in addition to the source in breathing zone of the worker.
- The total time spent spraying paint (process time) is 15 minutes.
- The total time not spraying paint (non-exposure time) is 465 minutes.

5. The 8-hour time weighted average permissible exposure limit (PEL) of MEK is 200 ppm. Based on the video and the information provided, please select what range you believe the airborne exposure to MEK to fall in at the 50 percentile for a full 8 hour shift. Do NOT include a margin of safety in your estimate.

****Disregard the use of any personal protective equipment****

- Using the information presented above, I estimate the airborne exposure to MEK for this process to be at, or above, the PEL (greater than or equal to 200 ppm)
- Using the information presented above, I estimate the airborne exposure to MEK for this process to be below the PEL (less than 200 ppm)

The 8-hour time weighed average PEL of MEK is 200 ppm. The options from the previous page are reproduced below:

Using the information presented above, I estimate the airborne exposure to MEK for this process to be at, or above, the PEL (greater than or equal to 200 ppm)

Using the information presented above, I estimate the airborne exposure to MEK for this process to be below the PEL (less than 200 ppm)

6. Using the exact same information that was provided in this survey, the ART model assess the following MEK exposure:

The predicted 50th percentile full-shift exposure is 949.2 ppm

ART predicts concentrations in a worker's personal breathing zone outside of any respiratory protection equipment.

Do you agree or disagree with the ART assessment?

Agree

Disagree

Background/Educational Information

The following questions relate to your academic achievements and work experience. This information will be used to examine potential factors associated with agreement with ART.

7. Do you currently, or have you ever obtained any of the following professional certifications?

- Certified Industrial Hygienist (CIH or ROH)
- Certified Safety Professional (CSP)
- Certified Hazardous Materials Manager (CHMM)
- Certified Professional Engineer (CPE)
- Certified Professional Ergonomist (CPE)
- Occupational Health and Safety Technologist (OHST)
- Certified Associate Industrial Hygienist (CAIH)
- Other
- None

8. How many years have you worked in the safety and health field?

9. What is the highest level of education you have achieved? In what field was the degree obtained?

10. How often do you attend continuing education courses?

- More than once a year
- Once every 1 to 3 years
- Less than once every 3 years

11. Have you ever taken a courses on control banding?

- Yes
- No

12. This survey presented a video of a spray painting process and only the information used by ART to estimate exposure. What additional information would you have liked to know in order to estimate the exposure?

ART Applications

ART has potential applications beyond compliance with REACH. The following questions are related to how likely you would be to use ART in various scenarios.

13. If you were assessing exposure in a large facility, how likely would you be to use ART as a screening tool to determine where to perform quantitative exposure monitoring?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

14. If tasked with achieving compliance with REACH at a workplace, how likely would you be to use ART?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

15. If you were assessing exposure in a remote location, how likely would you be to use ART?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

16. If quantitative exposure monitoring was not possible, how likely would you be to use ART to determine exposure?

- Highly unlikely
- Unlikely
- Somewhat likely
- Likely
- Very likely

17. Any additional comments regarding ART or the applications of ART?