

ASSESSING THE RISK BELIEFS OF
OCCUPATIONAL WORKERS DURING SODIUM
HYPOCHLORITE TANK CLEANINGS USING A
QUANTITATIVE SURVEY INSTRUMENT

By: Eric Persaud

For: North Carolina State University

Advisor: Catherine LePrevost

TABLE OF CONTENTS

Abstract.....	3
Introduction.....	3
Literature Review.....	5
Methods.....	8
Administration of the Instrument.....	10
Results.....	11
Case Studies.....	13
Discussion.....	16
Conclusion.....	18
References.....	19
Appendix A: Pesticide Risk Beliefs Inventory.....	21

Abstract

Chemical tank cleaners' occupational illnesses and deaths are largely unknown due to a lack of monitoring and research; further, there are no federal regulations that govern chemical tank cleanings. This pilot study details the development of a quantitative instrument to assess the risk beliefs of chemical tank cleaners, focusing specifically on tank cleaners who work with sodium hypochlorite. Through research on these occupational chemical workers' risk beliefs, educators, safety engineers, and policymakers can make informed steps toward improving tank cleaner health and safety. The 18-item Likert type instrument developed in this pilot study was found to be psychometrically sound with a Cronbach's alpha of 0.772, and therefore can be a valuable tool in further studies of tank cleaner beliefs. The instrument, if properly modified, can target risk beliefs of tank cleaners working with a variety of hazardous chemicals, which can illustrate points of concern that should be addressed in developing education, interventions, and a standard federal code for tank cleaning.

Introduction

Occupational chemical safety and health is a broad field, encompassing a range of work-related activities and exposures. One of those activities is the cleaning of sodium hypochlorite chemical tanks. This kind of work is performed on tanks storing sodium hypochlorite that are utilized in disinfecting wastewater and food processing, and in the manufacturing processes for textile plants and paper mills [1]. Research on occupational workers' beliefs and knowledge of the risks associated with sodium hypochlorite and tank cleaning is lacking, but tank cleaners have been the focus of at least one investigation by the popular media [2]. An instrument to measure workers' understanding of the risks associated with tank cleaning will fill a gap in the literature and inform those in the field of occupational chemical safety and health training. The instrument could be used by educators, safety engineers, policymakers, and workers to quantify knowledge and beliefs and to target education, interventions, and regulations to improve worker health and safety.

The number of tank cleaning sites in the United States is unknown because the Occupational Safety and Health Administration does not record information on the number or location of sites. Without a standard industry code, collecting data on tank cleaners is problematic; currently, there is no way to quantify the number of occupational deaths and illnesses associated with this work activity. In a 2014 *Houston Chronicle* investigative piece, 373 sites were identified where tank cleaning of various chemicals was taking place. The author reported 51 on-site deaths over the last 15 years, not counting workers who died or had health complications at a later time or off-site. This investigative study was limited, and the number of tank cleaning sites and work-related deaths could be significantly higher [2].

The *Houston Chronicle* investigation found that the tank cleaners who were interviewed were unfamiliar with the chemicals they were handling and were unable to characterize basic chemical traits. Further, workers described inadequate respiratory protection, including not having supplied air for oxygen deficient atmospheres and a lack of air monitoring for the hazardous environment. The investigation revealed that personal protective equipment (PPE), including protective footwear and suits, worn by tank cleaners was often incorrect for the chemical being handled. Worker training was identified as a need for the tank cleaning industry.

In light of the lack of federal oversight of tank cleaning, the potential for chemical exposures, and limited training and PPE use, tank cleaners represent an at-risk occupational group. To reduce deaths and illnesses related to tank cleaning, further research is needed to understand workers' risk beliefs and to therefore create appropriate education, interventions, and regulations. A quantitative instrument would improve understanding of tank cleaners' risk beliefs.

In this pilot study, the *Pesticide Risk Beliefs Inventory*, which was originally designed to assess risk beliefs in pesticide educators, is modified, under the advisement of the first author, to evaluate the beliefs of sodium hypochlorite tank cleaners [3]. The theoretical framework for the *Pesticide Risk Beliefs Inventory* is the mental models approach, a method of formalizing risk communication that centers on

understanding the target audience's range of current understanding of risk and the gaps between the audience's and experts' beliefs [4]. This pilot study details the adaptation of the quantitative instrument in order to assess the beliefs of chemical tank cleaners, focusing specifically on tank cleaners who work with sodium hypochlorite. The items and analysis for this adapted instrument for sodium hypochlorite tank cleaners are modeled after the original instrument.

Literature Review

A review of the literature yields an expert conceptual model for the risks associated with sodium hypochlorite tank cleaning and a point of comparison for workers' beliefs [4]. Disparities in expert and worker beliefs suggest focal areas for education and interventions. The literature review also encompasses general chemical worker health and safety beliefs with possible relevance for sodium hypochlorite tank cleaning.

Sodium hypochlorite is primarily a contact irritant, damaging the skin and eyes, respiratory tract, and gastrointestinal tract [5]. There is no data to suggest that sodium hypochlorite is carcinogenic, and no definitive studies indicate that fiberglass, of which sodium hypochlorite tanks are commonly made, causes cancer [6]. Likewise, there is no data to support that sodium hypochlorite or fiberglass has reproductive or developmental toxicity [7, 8]. However, there is data that suggests chemical workers as a whole are susceptible to paternal birth defects in their children [9].

Inhalation is an important route of exposure for occupational workers handling sodium hypochlorite [1]. The high reactivity of the chemical to water, vibrations, light, acids, and metals raises the concern for the release of toxic gases [1]. Chlorine gas is released from sodium hypochlorite when combined with water. At 1-3 parts per million (ppm), exposure to chlorine gas causes irritation to the mucus membrane, and exposure to levels of 30 ppm and greater can result in chest pains and coughing [10]. Over a 15-minute period, exposure to chlorine gas is recommended not to exceed 1 ppm [10]. Greater exposure necessitates the use of respirators when working within the confined space of a tank or

in close proximity the chemical. Interestingly, the Occupational Safety and Health Administration (OSHA) does not require respirator fit testing (to ensure adequate respiratory protection) for Hazardous Waste Operations and Emergency Response (HAZWOPER) workers, which might represent the most highly trained of tank cleaners. Research of healthcare workers suggests that even when fit tests are required and performed, only two-thirds of individuals use respirators when necessary [11].

Humans can detect the odor of chlorine gas at 0.1-0.3 ppm. For many chemicals, including sodium hypochlorite, odor detection occurs at a lower level of exposure than that at which irritation occurs [12]. However, presence of detectable odor during tank cleaning is not a reliable method in determining level of risk. Within the confined space of the tank, concentrations of toxic gases can vary based on the location within the tank. Therefore, an odor may not be present outside the tank or at certain sections, but may exist at higher concentrations in other locations. In addition, oxygen deficiency monitoring would be necessary, because if the oxygen is too low the use of filter air-purifying respirators would need to be replaced with an air-supplied system. The worker would need to rely on air monitoring devices for accurate values, rather than measuring risk by odor.

In other industries, odor has also been linked to workers' perception of risk, if a smell reminds them of a dangerous past experience. Thus, workers rely on their senses and experiences in assessing chemical risk, using trial and error from previous situations to evaluate present risks. Therefore, even if an odor does not signify actual risk in the present, the mere presence of the odor may increase the perception of risk and motivate more cautious behaviors [13]. Relatedly, personal experience tends to be more impactful than others' experiences in risk perception and practice, and individuals may disregard another's warning until they have firsthand experience [14]. Beliefs among workers about odor and respiratory protection for tank cleaning are unknown.

Based on field observations, sodium hypochlorite by-products can leave dry residue salts on surfaces, posing a threat of inhalation exposure to the toxic and reactive residues during tank cleaning.

When a worker enters the tank, the worker typically blasts the walls with a liquid solution to clean off residues, creating a mist in which residue salts can become airborne. Workers' use of PPE has been associated with threats that are visible, as would be the case for a mist or residue [15].

Sodium hypochlorite is highly corrosive, and the potential for the chemical to induce burns on dermal contact is a documented safety concern [1]. Upon contact with the eyes, it can cause immediate and permanent damage if not treated. Prior research has shown that occupational workers do not necessarily seek emergency help upon having an eye injury. One study of the general population in Tanzania found nearly 40% of eye injured workers waited more than 24 hours to get aid, but those numbers improved if the worker received proper communication on the severity of the injury and the consequences for delay [16].

Given the nature of their work, chemical occupational workers must rely on PPE to a greater extent than engineering controls to protect themselves from dermal exposure [17]. The National Institute for Occupational Safety and Health (NIOSH) estimates nearly 13 million workers annually are exposed to chemicals that can cause adverse effects via dermal contact [18]. While PPE might prevent injury through dermal contact, workers tend to avoid PPE if it makes them feel uncomfortable or delays work progress [19]. For example, workers avoided gloves if they were loose or made it difficult to handle fine things. Similarly, goggles are avoided if they fogged up, were scratched, or made communication through observation difficult (e.g., using hand signals). Workers avoided PPE altogether if the exposure was brief, as the perceived risk was low [19, 20].

Workers who enter a confined space are required to have training to mitigate substantial risks to safety associated with this particular work area. However, even with knowledge of confined space risks, workers have been shown to take shortcuts with safety procedures [21]. Based on the belief that a shorter duration of a task equates to less risk [19, 20], workers may use shortcuts to reduce their time in the confined space and therefore their perceived risk.

Chemical workers in previous studies have stated that they receive inadequate toxicological information and are unable to make informed judgments as to whether a chemical possesses an actual risk for exposure and health effects [13, 33]. Research has found that Material Safety Data Sheets (MSDSs) are difficult to follow or lack necessarily detailed instructions for workers [13, 22, 23]. Further, it has been found that occupational workers describe effects of chemicals through experiences and observations, not in a textbook manner [24].

A number of demographic variables have been associated with worker risk perception and workplace injuries. Previous findings also suggest that those workers with more experience take greater risks [23] and that young workers view injury as part of the job [25].

Methods

To measure the risk beliefs of chemical tank cleaners, the *Pesticide Risk Beliefs Inventory* (see Appendix A) was modified to reflect the occupational risks associated with sodium hypochlorite tank cleaning [3]. In alignment with the original instrument, the *Sodium Hypochlorite Tank Cleaning Inventory* was devised with the intention of measuring workers' beliefs in four facets: (1) assessment of sodium hypochlorite tank cleaning risk using physical properties, (2) assessment of sodium hypochlorite tank cleaning risk using chemical properties, (3) assessment of routes of entry of sodium hypochlorite into the body during tank cleaning, and (4) adverse health outcomes from sodium hypochlorite tank cleaning.

The modified instrument contained 18 Likert-type items with six point scales to avoid neutral responses and provide an appropriate response range for the participants (see Table 1) [26]. Four items pertained to risk assessment related to physical properties, and two items related to chemical properties. Six items measured risk beliefs based on routes of entry. Lastly, six items measured adverse health outcome beliefs. Two professionals in environmental and chemical health and safety were asked to review the modified inventory.

The items were placed in an order similar to the original instrument and not by facet. For the data to be analyzed, the responses were assigned a numerical value where “strongly disagree” was valued at 1, “disagree” was valued at 2, “slightly disagree” was valued at 3, “slightly agree” was valued at 4, “agree” was valued at 5, and “strongly agree” was valued at 6. Reverse coded items were assigned 1 for “strongly agree” and so forth. For all items, a score of 4 or higher indicated expert beliefs on the risks associated with sodium hypochlorite and tank cleaning.

Item No.	Facet	Inventory Item
1	Physical Properties	I can determine if the tank is dangerous by its smell.
2	Routes of Entry	When I am working with sodium hypochlorite, I am worried about having the sodium hypochlorite enter my body when I breathe.
3	Chemical Properties	I can determine if sodium hypochlorite is dangerous by reading its Material Safety Data Sheet.
4	Adverse Health Outcomes	When I am working with sodium hypochlorite, I am not worried about getting cancer in the future.
5	Physical Properties	I can determine if the tank is dangerous by seeing if the sodium hypochlorite is a liquid or residue.
6	Adverse Health Outcomes	When I am working with sodium hypochlorite, I am worried about having a recurrent problem with my skin.
7	Routes of Entry	When I am working with sodium hypochlorite, I am not concerned about covering my nose.
8	Routes of Entry	When I am working with sodium hypochlorite, I am not worried about having the chemical enter my body through my skin.
9	Adverse Health Outcomes	When I am working with sodium hypochlorite, I am worried about having to go to the emergency room.
10	Physical Properties	I can determine if the sodium hypochlorite is dangerous in the tank by its color.
11	Routes of Entry	When working with sodium hypochlorite, I am concerned about covering my skin.
12	Physical Properties	I don't need to follow confined space procedures if the sodium hypochlorite in the tank is shallow.
13	Chemical Properties	When I am working in a sodium hypochlorite tank, I am concerned about high temperatures inside the tank.
14	Routes of Entry	When I am working with sodium hypochlorite, I am not worried about having the chemical enter my body through my eyes.
15	Adverse Health Outcomes	When I am working with sodium hypochlorite, I am worried about losing my ability to have children.

16	Routes of Entry	When I am working with sodium hypochlorite, I am worried about having the chemical enter my body when I eat or drink.
17	Adverse Health Outcomes	When working with sodium hypochlorite, I am not worried about having difficulty breathing.
18	Adverse Health Outcomes	When I am working with sodium hypochlorite, I am not worried about being poisoned.

Figure 1. Risk Facets and Items used in the *Sodium Hypochlorite Tank Cleaning Inventory*

While most of the items in the original survey were readily adapted for sodium hypochlorite tank cleaning, items pertaining to the chemical family and ingredients were not applicable. New items were added (Items 12, 13) related to confined space and chemical reaction beliefs, respectively.

Administration of the Instrument and Analysis of Responses

The study was conducted with the intention of being a pilot study. Therefore, the survey was administered to a small sample of tank cleaners to gather information that could be used in later studies with larger numbers of participants. This study sampled 54 participants throughout the United States. Thirty of the participants had performed sodium hypochlorite tank cleaning during their careers. Two of those 30 participants had incomplete surveys. One of those two incomplete surveys was eliminated from analysis due to the lack of information provided. The other was retained, as it contained responses to 17 of the 18 inventory items. Therefore, 29 surveys were included in the analysis.

The survey was either completed by a printed copy or online via Qualtrics. Printed surveys were completed by participants and returned directly to the principal investigator after completion; no third party was involved in the exchange of any printed survey either to or from the participant. The online survey link was sent to companies, industry experts, or people listed on forums as providing sodium hypochlorite tank cleaning services. Responses to both printed and online surveys were scored, averaged, and analyzed for Cronbach's alpha values. Responses were checked for quality assurance using a random number generator to compare raw data (i.e., completed surveys) with data that has been entered and analyzed.

Interviews

Interviews were conducted voluntarily and were not paired with survey responses. Interviews were used in the preparation of case studies and to support conclusions drawn from the results. A total of 9 interviews were conducted. Interviews ranged in duration from approximately 15 to 30 minutes.

Participants

The participants consisted of 29 males and 1 female. The self-reported race/ethnicity for the participants was 18 White (non-Latino), 5 Latino, 3 Asian, 1 Native American, and 2 “other”. Twelve listed their highest education attained as some college, 8 as bachelor’s degree, 5 as a high school diploma, and 4 as graduate/professional degree. The average number of years of experience was 16.7; eleven participants had 0-5 years of experience, 4 had 6-10 years, 2 had 11-20 years, 8 had 21-30 years, 2 had 31-40 years, and 2 had 41-50 years. The average age of the sample was 40.8 years. It is important to note that these demographic characteristics reflected the participants’ present status, not their status when they last performed a sodium hypochlorite tank cleaning. Not all 29 participants were actively engaged in tank cleaning at the time of the survey. Three participants did not have either OSHA HAZWOPER training or confined space training; however, those three did undergo respirator fit testing. A total of two participants had never undergone fit testing.

Results:

Cronbach’s alpha estimates were used to measure consistency and reliability within the instrument [27]. Overall, the Cronbach’s alpha for the 18-item instrument was found to be 0.772, indicating that it met the standard recognized for internal consistency. The individual participants’ summed scores ranged from 42 to 88. The mean score was 67. Facet Cronbach’s alpha and means are reported in Table 2. Mean scores by question are displayed in Table 3. The highest mean score was for found the item related to covering skin, and the lowest mean score was for the item related to ingestion as a route of entry.

Table 2. Sodium Hypochlorite Tank Cleaning Inventory Facets with Cronbach's Alpha and Mean Values*

Facet	Facet Cronbach's Alpha	Facet Mean
Determination of Risk Using Physical Properties	0.811	4.175
Determination of Risk Using Chemical Properties	0.152	4.434
Risk Associated with Adverse Health Effects	0.812	4.237
Risk Associated with Routes of Entry into Body	0.503	4.718
Entire Inventory Questions 1 to 18	0.772	4.482

* Inventory item 12, concerning confined space, was removed from these calculations. The wording of the confined space inventory item was deemed too different from the other items. However, the mean score associated with the confined space inventory item (12) can be found in Table 3.

Table 3. Mean Response Scores by Item

Item	Score Average
1	3.96*
2	5.17
3	5
4	3.93
5	4.17*
6	4
7	5.04*
8	4.44*
9	3.52
10	4.71*
11	5.25
12	5.25*
13	3.86
14	5.07*
15	4.57*
16	3.32
17	4.68*
18	4.79*

* Reverse coded inventory item

Case Studies

The following cases are paraphrased from interviews with study participants and represent first-hand experiences of tank cleaners or their observation of other tank cleaners while working.

Case Study #1 - What is Chlorine Gas?

Following the cleaning of a sodium hypochlorite tank, a crew prepared to enter the tank to perform repairs, additional cleaning, and initial inspections. The tank had been cleaned by a separate crew from a separate company only an hour before. After the cleaning of the tank interior, the confined space still contained concentrations of chlorine gas that could be damaging to health without a respirator. The second crew entered the tank with only dust masks and no escape or rescue setup.

When confronted about the chlorine gas, the second crew responded that they were unaware what chlorine gas was or how to monitor it and expressed confusion regarding why a dust mask would be a potential health issue. Upon the conclusion of the interview, the principal investigator/interviewer explained that the dust mask would offer little to no protection from the chlorine gas fumes. The participant responded that a dust mask was all the equipment they had and that they would only be in the tank for a short duration. The crew he was working with proceeded to work in the tank.

Case Study #2 - Down the Drain

Many aboveground tanks have containment areas or dykes to hold spills. During a cleaning, some of the sodium hypochlorite within the tank spilled inside the containment area and down below a grating. To get rid of the sodium hypochlorite but without going down below the grate, the worker used a water

hose to flush the sodium hypochlorite into an approved drain. The drain had been approved by the company health and safety officer. However, unexpectedly to the worker and the health and safety personal watching, the water reacted with the sodium hypochlorite to form chlorine gas. The worker never realized that the gas could be produced until days later when the scenario was mentioned to the principal investigator/interviewer. The worker was then told that water and sodium hypochlorite react to form toxic gases. The worker then stated this made sense, as he had felt weak and fatigued the days after doing that work and had to stay home in bed.

Case Study #3 - Lunch with a Side of Poison

A tank cleaner had stated his concern about being poisoned doing sodium hypochlorite tank cleanings. Yet, when met in the field to conduct the interview, the principal investigator/interviewer observed that he was eating his lunch ten feet downwind from an open tank containing sodium hypochlorite, with an odor of bleach present.

Case Study #4 - Dangling Feet

A crew was ready to lower a tank cleaner into a tank used to hold a highly corrosive chemical. The crew had been informed that the tank was emptied and contained only water by the chemical plant engineering staff. The worker's feet were dangling only inches above the liquid in the tank. At that moment, the vacuum truck operating engineer asked for the pH as a standard practice. This was needed to ensure his vacuum truck could properly hold the liquid he would vacuum out. The worker was frustrated by the request, but after a heated exchange, the sample was taken. It was found that the sample held a pH of 11 and turned out to be purely of the highly corrosive chemical. The nearly-exposed worker was not wearing a chemical resistant suit or using chlorine gas resistant respirator cartridges, as he did not anticipate being exposed to anything other than water. When asked why he didn't assume any risk, the worker stated that it was a clear liquid and looked like water, so he had no belief that he was in any real danger.

Case Study #5 - Muffled and Muzzled

One of the most prevalent complaints among chemical workers (in this study and based on personal experience of the principal investigator) is the inability to communicate while using a respirator. One participant noted that voices become muffled and frustration sets in because of the difficulty in communicating with the outside attendants. When asked how he got around this issue during the interview, the tank cleaner stated that sometimes he lifts the bottom portion of his respirator slightly away from his face so that he can speak more clearly. Then when done communicating, he lets go of the respirator and lets it fall back down to his chin. When the interviewer mentioned that this practice breaks the tight seal of the respirator at the end of the interview, the tank cleaner responded that he really has no other choice.

Case Study #6 - Being a Troublemaker

A worker cleaning a tank had his protective suit rip along the arms. He did not say anything, finished the work, and wiped the areas exposed with a rag. He did not want to stop working because the crew was on a tight schedule and did not have any backup suits. The worker also did not use the nearby emergency wash because it would trigger an alarm and would mean that the on-site safety person would be notified of the accident.

Case Study #7 - I don't know, I don't know, I don't know

A chemical technician for a laboratory was responsible for cleaning sodium hypochlorite tanks and pouring in the new batch. During the process, the tank was never entered, as a wash system was used to clean the interior. However, the tank was open during these activities, and the technician would sense a strong odor during work. To manage the intense odors, he was supplied a full-face mask respirator, which

he was fit tested for. However, when he was asked during the interview how he measures gases, he was unaware, reporting that the company never monitored for gases, including chlorine gas. Further, the technician had never seen or had access to any MSDSs. He believed he had no one to go to for information, and he described that he was only supplied respirator cartridges by an engineer. The technician was unaware how to determine if that respirator cartridge worked or if it was applicable to the toxic substances he was exposed to during tank cleaning. His only source of training was a video shown to workers that detailed the tasks he needed to perform and instructions on how to perform them.

Discussion

The *Sodium Hypochlorite Tank Cleaning Inventory* was designed by modifying the *Pesticide Risk Beliefs Inventory* in order to capture the occupational risk beliefs of sodium hypochlorite tank cleaners. Until now, scholarly literature on tank cleaner beliefs was non-existent, and a tool to assess beliefs was needed. Given the at-risk status of tank cleaners and the lack of federal oversight of tank cleaning, an understanding of workers' risk beliefs will serve to inform education, interventions, and regulations.

The pilot study found that the facet for use of physical properties in risk assessment and the facet for beliefs about adverse health outcomes were internally consistent. The facet for routes of entry showed low internal consistency, with a Cronbach's alpha well below the 0.7 value known to be within acceptable limits. These items should be considered for exclusion in future studies should the internal consistency not improve. Future studies should also consider the inclusion of additional questions, particularly related to the use of chemical properties to assess risk, for which there were only two items and diminished internal consistency. Additionally, the confined space item should be assessed in a separate tool that focuses on confined space beliefs, another area in which the literature on occupational worker beliefs is lacking.

A possible explanation for the reduced internal consistency observed within some facets individually is the small sample size, typical of a pilot study. Evaluating the instrument with a larger

sample and extending the survey to all chemical tank cleaners would allow for an improved assessment of the inventory. Additionally, the inconsistent responses may be due to actual inconsistency of the participants' beliefs [28] or the failure of the selected facets to reflect beliefs. For example, the participants themselves may generally hold beliefs regarding routes of entry that are inconsistent across the spectrum of inventory items.

Based on the average score per item, tank cleaners had general agreement with expert beliefs (i.e., score > 4). The tank cleaners most strongly agreed with expert beliefs about covering skin (5.25) and breathing as a route of entry (5.17). Borderline expert agreement was found for items related to detecting risk based on smell (3.96), concern about getting cancer in the future (3.93), and concern about high temperatures when cleaning a tank (3.86). Also, there were overall ambivalent responses to items pertaining to concern about having to go to the emergency room (3.52) and concern about ingestion as a route of entry (3.32).

The fact that a portion of tank cleaners (n = 12) disagree with the statement that they are concerned about high temperatures within the tank is potentially concerning and an area for education. High temperatures make sodium hypochlorite more reactive, and can occur when sodium hypochlorite reactions take place [1]. Some workers may just have a lack of knowledge of the chemical with regard to reactivity. Another possibility is that workers are relying on experiences from past tank cleaning work with chemicals other than sodium hypochlorite, where heat and reactivity were not an issue.

A number (n= 15) of participants were not concerned about possible exposure to sodium hypochlorite through ingestion. Because workers do not eat in the tank but near it, they may not perceive risk for the chemical entering their bodies while eating or drinking. The highly corrosive nature of sodium hypochlorite underscores the importance of protecting the gastrointestinal tract from exposure.

One way to address some of the concerning beliefs identified through this study is through an extension to worker-required education that would make it mandatory that a worker exposed to any

chemical identified as toxic and hazardous by NIOSH [29] read and sign a short but informative pictogram addressing the chemical's physical and chemical properties, adverse health outcomes, and routes of entry risks. This pictogram may be modeled on an example from LePrevost et al. [30] and modified to target a specific toxic chemical. The addition of visual cues can help illustrate health and safety to those that learn better visually, improve memorization, and aid in the learning of non-English speaking workers [31].

A limitation of this study is the selected terminology and associated readability of the inventory. Using the Flesch-Kincaid formula for assessing readability, the average grade level for each question in the inventory was 10.9. If the term "sodium hypochlorite" was replaced with its common name, "bleach," the average grade level for the inventory questions drops to 7.53. This corresponds to a significant increase in readability. Further, using the term "sodium hypochlorite" may influence responses of the chemical workers taking the survey, as chemical names have been found to illicit responses of more caution than common names [32]. Future research should explore how replacing chemical names with common names can improve chemical occupational worker health and safety training and shape risk beliefs.

Conclusions

The *Sodium Hypochlorite Tank Cleaning Inventory* was found to be psychometrically sound overall among the pilot study sample. The instrument was able to gauge sodium hypochlorite tank cleaner beliefs, which largely reflected expert beliefs. The instrument suggests several areas to target for worker training to reduce risk and improve safety. Using this instrument, further modifications can be made to assess the risk beliefs of tank cleaners more broadly with a larger sample and for any chemical. Educators, safety engineers, and policymakers can use this instrument in furthering understanding of worker knowledge and beliefs and developing education, interventions, and regulations to improve worker health and safety.

References

1. Luttrell, W. (2001). Toxic tips: sodium hypochlorite. *Chemical Health And Safety*, Vol. 8, Issue 6, pp. 24 - 26.
2. Lobet, I. (2014). Largely invisible tank cleaning industry awash in risk. *Houston Chronicle*. URL: <http://www.houstonchronicle.com/news/investigations/article/Largely-invisible-tank-cleaning-industry-awash-in-5468819.php> accessed:3/24/2016 at 10:20 PM EST.
3. LePrevost, C. E., Blanchard, M. R., & Cope, W. G. (2011). The Pesticide Risk Beliefs Inventory: A quantitative instrument for the assessment of beliefs about pesticide risks. *International Journal of Environmental Research and Public Health*,8(6), 1923-1935.
4. Morgan, G.M., Fischhoff, B., Bostrom, A., Atman, C. (2002). *Risk Communication: A Mental Models Approach*. Cambridge University Press.
5. Agency for Toxic Substances and Disease Registration. <http://www.atsdr.cdc.gov/toxfaqs/tf.asp?id=928&tid=192> Accessed: 4/20/2016 at 6:27 PM EST.
6. Fultz, O. (1992, 02). Home newsfront--fiberglass: Cancer threat? *Popular Science*, 240, 48-49
7. Risk Assessment Report on Sodium Hypochlorite (2008). Scientific Committee on Health and Environmental Risks.
8. Toxicology Profile for Synthetic Vitreous Fibers (2004). US Department of Health and Human Services, Agency for Toxic Substances and Disease Registry.
9. Desrosiers, T.A., etc. al (2012). Paternal occupation and birth defects: findings from the National Birth Defects Prevention Study. *Occupational Environmental Medicine*, 69(8):534-542.
10. White, C.W. and Martin, J.G. (2010). Chlorine Gas Inhalation Human Clinical Evidence of Toxicity and Experience in Animal Models. *Proceedings of the American Thoracic Society*, Vol. 7.
11. Bryce, E., Forrester, L., and Eshghpour, M. (2008). What do healthcare workers think? A survey of facial protection equipment user preferences. *Journal of Hospital Infection*, 68, 241-247.
12. Paustenbach, D., and Gaffney, Shannon (2006). The role of odor and irritation, as well as risk perception, in the setting of occupational exposure limits. *Int Arch Occup Environm health*. 79:339-342.
13. Hambach, R. etc. al. (2011). Workers' Perception of Chemical Risks: A Focus Group Study. *Risk Analysis*, Vol. 31, No. 2.
14. Viscusi, W.K., and Zeckhauser, R.J. (2015). The Relative Weights of Direct and Indirect Experiences in the Formation of Environmental Risk Beliefs. *Risk Analysis*, Vol. 35, No. 2.
15. Meijman, T. etc. al. (1996) Behavioral Determinants of Occupational Exposure to Chemical Agents. *Journal of Occupational Health Psychology*. Vol. 1, No.1, 85-91.
16. Attas, A.H., etc. al. (2010). Understanding Delay in Accessing Specialist Emergency Eye Care in a Developing Country: Eye Trauma in Tanzania. *Ophthalmic Epidemiology*, 17(2), 103-112.
17. Rutz , R and Krieger , R.I. 1992. Exposure to pesticide mixer/loaders and applicators in California. *Rev. Environ. Contam. Toxicol.*, 129: 121-139.

18. Skin Exposures & Effects. Centers for Disease Control and Prevention: The National Institute for Occupational Safety and Health. <http://www.cdc.gov/niosh/topics/skin/> Accessed: 4/20/2016 at 7:04 PM EST.
19. Lombardi, D., etc. al. (2009). Factors influencing worker use of personal protective eyewear. *Accident Analysis and Prevention*, 41, 755-762.
20. Salazar, M.K., etc. al. (1999). A Description of Factors Affecting Hazardous Waste Workers' Use of Respiratory Protective Equipment. *Applied Occupational and Environmental Hygiene*, Vol. 14, 471-479.
21. Taylor, B. (2011). Confined Spaces Common Misconceptions and Errors in Complying with OSHA's Standard. *Professional Safety American Society of Safety Engineers*.
22. Cox, P., etc. al. (2003). The Use of Mental Models in Chemical Risk Protection: Developing a Generic Workplace Methodology. *Risk Analysis*, Vol. 23, No.2.
23. Niewohner, J., etc al. (2004). Evaluating the Efficacy of a Mental Models Approach for Improving Occupational Chemical Risk Protection. *Risk Analysis* Vol 24, No 2.
24. Sadhra, S., etc. al. (2002). Workers' Understanding of Chemical Risks: Electroplating Case Study. *Occupational Environmental Med*, 59, Pg. 689-695.
25. Breslin, C., etc.al (2007). Workplace injury or "part of the job"?: towards a gendered understanding of injuries and complaints among young workers. *Social Science Medicine*, 64(4):782-793.
26. Matell MS, Jacoby J (1972). Is there an optimal number of alternatives for Likert-scale items? Effects of testing time and scale properties. *J. Appl. Psychol.* 56:506-509
27. Reynolds CR, Livingston RB, Willson V. (2009). *Measurement and Assessment*. Pearson; Upper Saddle River, NJ, USA.
28. Fong, D., etc. al. (2012). Evaluation of internal reliability in the presence of inconsistent responses. *Health and Quality of Life Outcomes*. 8:27
29. National Institute for Occupational Safety and Health Pocket Guide to Chemical Hazards. 2005.
30. LePrevost, C. E., Storm, J. F., Asuaje, C. R., & Cope, W. G. (2014). Assessing the effectiveness of the Pesticides and Farmworker Health Toolkit: A curriculum for enhancing farmworkers' understanding of pesticide safety concepts. *Journal of Agromedicine*, 19(2), 96-102.
31. Verdi, M. P., Johnson, J. T., Stock, W. A., Kulhavy, R. W., Whitman-Ahern, P. (1997). Organized spatial displays and texts: Effects of presentation order and display type on learning outcomes. *Journal of Experimental Education*, 65, 303-317.
32. Dihydrogen monoxide: The invisible killer (2001). *Australasian Science* 22.1:43
33. Nelkin, D. and Brown M.S. (1984). *Workers at Risk Voices from the Workplace*.

Appendix A.
Pesticide Risk Beliefs Inventory

Item No.	Facet	Item
1	Physical Properties	I can determine if a pesticide is dangerous by its smell.
2	Routes of Entry	When I am working with a pesticide, I am worried about having the pesticide enter my body when I breathe.
3	Chemical Properties	I can determine if a pesticide is dangerous by reading its chemical label.
4	Adverse Health Outcomes	When I am working with a pesticide, I am not worried about getting cancer in the future.
5	Physical Properties	I can determine if a pesticide is dangerous by seeing whether it is a powder, liquid, or granule.
6	Adverse Health Outcomes	When I am working with a pesticide, I am worried about having a recurrent problem with my skin.
7	Routes of Entry	When I am working with a pesticide, I am not concerned about covering my nose.
8	Routes of Entry	When I am working with a pesticide, I am not worried about having the pesticide enter my body through my skin.
9	Adverse Health Outcomes	When I am working with a pesticide, I am worried about having to go to the emergency room.
10	Physical Properties	I can determine if a pesticide is dangerous by its color.
11	Routes of Entry	When I am working with a pesticide, I am concerned about covering my skin.
12	Chemical Properties	I can determine if a pesticide is dangerous by knowing the family of chemicals that the pesticide belongs to.
13	Chemical Properties	I can determine if a pesticide is dangerous by knowing its ingredients.
14	Routes of Entry	When I am working with a pesticide, I am not worried about having the pesticide enter my body through my eyes.
15	Adverse Health Outcomes	When I am working with a pesticide, I am worried about losing my ability to have children.
16	Routes of Entry	When I am working with a pesticide, I am worried about having the pesticide enter my body when I eat or drink.
17	Adverse Health Outcomes	When I am working with a pesticide, I am not worried about having difficulty breathing.
18	Adverse Health Outcomes	When I am working with a pesticide, I am not worried about being poisoned.
19	Physical Properties	I can determine if a pesticide is dangerous by its taste.