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ORIGINAL RESEARCH

The use of a photoionization detector to detect harmful volatile chemicals by emergency personnel

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Objective: The objective of this investigation was to determine if a photoionization detector (PID) could be used to detect the presence of a simulated harmful chemical on simulated casualties of a chemical release.

Methods: A screening protocol, based on existing radiation screening protocols, was developed for the purposes of the investigation. Three simulated casualties were contaminated with a simulated chemical agent and two groups of emergency responders were involved in the trials. The success–failure ratio of the participants was used to judge the performance of the PID in this application.

Results: A high success rate was observed when the screening protocol was properly adhered to (97.67%). Conversely, the success rate suffered when participants deviated from the protocol (86.31%). With one exception, all failures were noted to have been the result of a failure to correctly observe the established screening protocol.

Conclusions: The results of this investigation indicate that the PID may be an effective screening tool for emergency responders. However, additional study is necessary to both confirm the effectiveness of the PID and refine the screening protocol if necessary.

Keywords: prehospital, device, protocol, photoionization detectors

Introduction

Intentional or accidental releases of harmful chemical agents (eg, chemical warfare agents [CWAs] or toxic industrial chemicals [TICs]) remain a continued threat to our communities and nation. Traditionally, the threat of exposure to chemical warfare agents has remained an issue primarily for military personnel.[1] However, the chemical terrorist attacks of Matsumoto[2] and Tokyo[3,4] increased public awareness that terrorists may utilize harmful chemical agents in future attacks.[5]

Brennan and colleagues[1] have outlined several possible sources of chemical threats to civilian populations. Terrorist organizations which are able to obtain harmful chemicals, either CWAs or TICs, could potentially deploy them against a civilian population. The incidents in Matsumoto and Tokyo are prime examples of how significantly chemical agents can impact a civilian population. Furthermore, military stockpiles of CWAs pose a potential threat to civilian populations despite strict containment and storage protocols. Another, highly unlikely, but possible scenario, involves the use of CWAs against a civilian population by another government during a time of war. Toxic industrial chemicals (eg, chlorine, phosgene, chlorine) present in most aspects of heavy industry are another potential threat.

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Regardless of the source, CWAs and TICs have the potential to create mass casualty disasters. For example, the release of sarin gas in the Tokyo subway by an extremist religious group resulted in 11 deaths and over 5,000 civilians who required medical evaluation.[3] Although it is clear that harmful chemical agents have the potential to create mass casualty disasters, it is important to note that the victims of these attacks may be contaminated to varying degrees. In fact, the ratio of psychogenic casualties to actual casualties may be on the order of five to one.

Despite the potential ratio of psychogenic to actual casualties, current decontamination protocol calls for the full decontamination of all victims of a chemical release. Full decontamination involves preliminary gross decontamination; victims are doused en masse with water from a fire hose or similar implement. Then victims are sent to further stages of technical decontamination where they replace their clothing and are able to clean using soap and other cleansing agents. Technical decontamination following gross decontamination is a resource-intense process. The processing capacity of these decontamination systems is limited by both the availability of these systems and the length of time required to fully decontamination a single victim.

It is clear from this discussion that an objective method of determining whether a victim has been contaminated or not would be very useful for first-responders. The ability to separate psychogenic from actual casualties would greatly enhance the efficiency of first-responders by allowing them to triage casualties. Prioritization would enable first-responders to defer the decontamination of certain victims while ensuring that victims who have received the highest levels of contamination are able to be decontaminated rapidly.

Photoionization detectors (PIDs) have previously been used in industrial settings to monitor the release of volatile organic chemicals (VOCs) often found in industrial applications. PIDs are able to qualitatively detect over 100 chemicals including CWAs.[6] Furthermore, recent research has demonstrated the qualitative and quantitative ability of PIDs to detect sarin gas in a laboratory setting.[7] PIDs utilize a high-power lamp to ionize vaporized particles whose concentration can then be measured and reported. Thus PIDs are able to report the concentration of VOCs in the air but are not able to identify specific chemical agents. The use of PIDs in industrial settings suggests there is a potential application of PIDs as a tool for first-responders to identify contaminated casualties. This application of PIDs has not been reported on yet; this study aims to evaluate the feasibility of the use of PIDs by emergency responders to detect the presence of chemical contamination among simulated casualties.

Methods

Study design

The study was observational in nature. The participants were evaluated on their ability to detect the presence of a simulated chemical contaminant on simulated potential casualties.

Participants

Two groups of volunteer emergency responders (firefighters and paramedics) were evaluated during the experiment. These groups were selected based upon their status as first-responders and their prior training in the use of self-contained breathing apparatuses (SCBAs) and powered air-purifying respirators (PAPRs). The involvement of human participants in the study was approved by the local Institutional Review Board (IRB). Written consent was waived.

Chemical simulant

Witch hazel was chosen as the chemical simulant. The nontoxic properties of witch hazel in combination with its constant volatility (off-gassing behavior) made it ideal for this application.

PID device

The photoionization detector used during testing was a MiniRAE 2000 (Rae Systems Corp., San Jose, CA, USA).

PID survey protocol

A systematic head-to-toe survey protocol was developed and pilot-tested for use by the study participants. The protocol was modified from a well established radiation survey protocol.[8] The protocol which was developed calls for the body of the victim to be divided into several segments (see Figure 1). In order to increase recall of the protocol each section was allotted five seconds for scanning. This consistent specification in combination with the division of the body into naturally occurring sections should aid potential first-responders in remembering the protocol following "just-in-time" training. For each section except the arms and legs, users are expected to sweep back-and-forth across the victim's body. A lengthwise survey procedure was specified for the arms and legs. In all cases the protocol calls for the user to maintain the tip of the PID probe within 2–3 cm of the victim's body. In order to ensure that users were able to maintain this distance without contaminating the PID probe a simple probe guard was improvised using a simple coffee

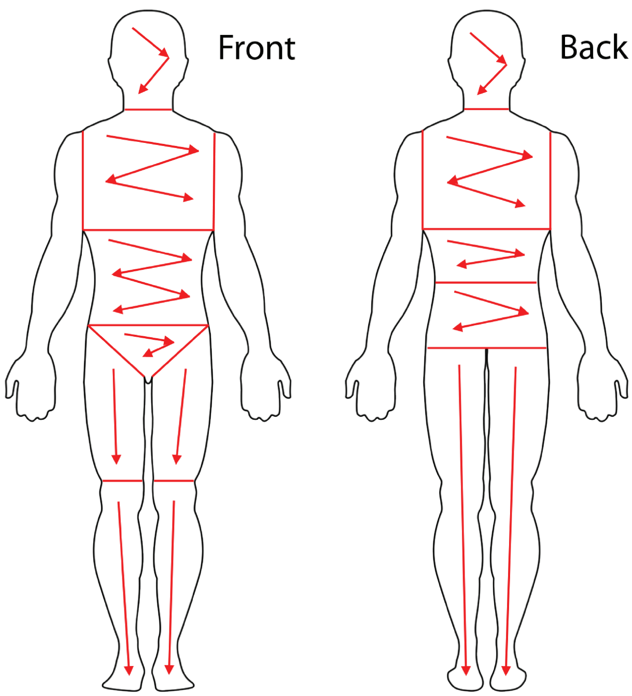

Figure 1 Photoionization detectors survey protocol demonstrating the division of the body into multiple sections.

Figure 3 Example of manikins laid out during firefighter trial to represent potential casualties.

stirrer affixed to the end of the PID probe (see Figure 2). A five-part-per-million (PPM) alarm limit was chosen and the PID was programmed to emit visual and audio cues at concentrations of gas at or above this limit.

Methods

One trial was conducted with each of the two groups who participated in the trial (firefighters and paramedics). In each case three manikins in thermal underwear were setup to simulate potential victims of a chemical release (see Figure 3). Each of the three manikins was doused with water to simulate gross decontamination with fire hoses. This gross decontamination both simulated actual disaster protocol and served to obscure the location of the chemical stimulant. Individual trials involved the contamination of one or more of the manikins; at most, one area per manikin was contaminated. A contaminated manikin could have been contaminated at one of these three locations:

- 100-cm^2 area of abdomen
- 200-cm^2 area of upper thigh/groin
- 200-cm^2 area of mid-back.

A sufficient amount of simulant to provide constant volatility (between 5–25 PPM) was placed at each location. The concentration of simulant was rechecked before each individual trial and adjusted as necessary. In addition, the PIDs utilized were recalibrated to manufacturer specifications prior to each testing session.

Prior to each trial the participants received a brief (<5 minutes) orientation to the PID and survey protocol. Participants were instructed to move onto the next manikin as soon as a source of contamination was discovered. During the trial participants wore either a self-contained breathing apparatus or a powered air-purifying respirator (see Figures 4 and 5). The use of these devices simulated actual conditions during a chemical mass casualty incident and prevented participants from using any potential odors emitted by the stimulant to locate it. The performance of the participants was both timed and carefully monitored for protocol compliance.

The results of the trials were interpreted primarily utilizing the success-failure rate of the participants at utilizing the protocol to detect the presence of the simulant.

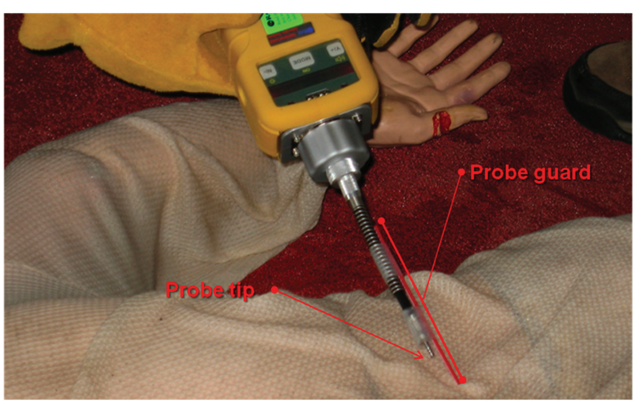

Figure 2 An example of correct photoionization detector placement.

Figure 4 Firefighter using photoionization detector-wearing self-contained breathing apparatus.

Results

The data collected were analyzed and tabulated for survey region, all surveys, all surveys adhering to protocol, and median time; the results are summarized in Table 1. All data were also categorized for firefighter, paramedic, and pooled groups. The results showed a high success rate (97.67%) for the PID to detect the presence of simulated chemical when the protocol was adhered to. Success rate dropped significantly (ranging from 11.36% to 86.31%) in instances where the participant deviated from the protocol.

Table 1 Summary of results from both the firefighter and paramedic trials

Survey region	All surveys	All surveys adhering to protocol	Median time (s)
Firefighters			
Abdomen	75.00% (n = 8)	86.00% (n = 7)	40
Back	100.00% (n = 10)	100.00% (n = 10)	116
Groin	71.43% (n = 7)	100.00% (n = 5)	42
All areas	82.14% (n = 25)	95.33% (n = 22)	
Paramedics			
Abdomen	92.86% (n = 14)	100.00% (n = 13)	30
Back	85.71% (n = 14)	100.00% (n = 11)	152
Groin	92.86% (n = 14)	100.00% (n = 13)	55
All areas	90.48% (n = 42)	100.00% (n = 37)	
Pooled groups			
Abdomen	83.93% (n = 22)	93.00% (n = 20)	35
Back	92.86% (n = 24)	100.00% (n = 21)	134
Groin	82.15% (n = 21)	100.00% (n = 18)	48.5
All areas	86.31% (n = 64)	97.67% (n = 59)	

Discussion

The use of a PID for the purpose of identifying potentially contaminated victims has several benefits; the device could be used as a tool which would improve current decontamination protocol and enhance the safety of emergency personnel. The practice of mass decontamination could be refined by the ability to pinpoint and prioritize victims who are actually contaminated. This has the practical effect of reducing the number of people requiring full decontamination and allowing for the prioritization of those most affected. Emergency personnel may benefit from the ability to better identify casualties that present a potential inhalational hazard through secondary "off-gassing." The identification of casualties that do not present a hazard would allow emergency personnel to "dress-down" to the point where they would not require respiratory protection. The benefit is a reduction in physiologic stress on emergency personnel which would improve both their overall safety and efficiency. Overall, the potential benefits of the PID could allow for emergency personnel to respond more efficiently and faster than current mass casualty disaster protocol limits them to.

Figure 5 Paramedic wearing powered air-purifying respirator.

Conclusions

The results of the study indicate that the PID effective in rapidly identifying simulated contaminated casualties. With one exception, all failures were due to violations of the survey protocol. This indicates that although the protocol was effective, strict adherence to it is required. Furthermore, this suggests that training and practice beyond the "just-in-time" training provided to participants would further improve the scanning time and success rate. In summary, the results of this study suggest that the PID has a place as a tool for first-responders in situations involving releases of harmful chemical agents.

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