General toxicologic hazards and risks for search-and-rescue dogs responding to urban disasters

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The recent terrorist events in New York, Washington, DC, and Pennsylvania highlighted the indispensable role that **search-and-rescue (SAR)** dogs play in the response to urban disasters. Search-and-rescue dogs were also used after the 1995 bombing of the Alfred P. Murrah building in Oklahoma City.[1] Teams of SAR dogs may be mobilized as a part of the SAR effort following fires, explosions, and natural disasters such as hurricanes, earthquakes, and floods that cause large-scale damage to urban areas. These dogs often work in areas that are deemed unsafe for or inaccessible to human rescuers and enter disaster sites without the personal protection equipment typically worn by their human counterparts. A study[2] evaluating hazardous materials exposures among firefighters found that many of the worst exposures occurred when respiratory protective equipment was not used because of a visual impression of low smoke intensity. Thus, dogs entering areas initially judged as safe could still be at risk of substantial exposures to potentially dangerous substances.

Urban disaster sites should be considered potentially contaminated with many dangerous chemicals and substances.[3] A large-scale disaster could potentially involve the release of dozens or even hundreds of toxic agents. The purpose of this article is to raise awareness among veterinarians who are called on to provide care for SAR dogs of the hazards, risks, and potential problems these dogs face both during the time of exposure to urban disaster sites and during the weeks and months that follow.

General Classifications of Toxicants

Potentially toxic agents at disaster sites may be present in various physical forms, including solids, liquids, particulates, and gases. While the presence of some compounds, such as solids and liquids, may be immediately apparent to rescue personnel, agents in gaseous or particulate form may be less readily detected without specialized equipment. The various physical forms in which a compound may exist are important determinants of its toxicity. For example, elemental mercury (quicksilver) is of low toxicity when in a solid form but can cause substantial toxic effects if fumes containing gaseous elemental mercury are inhaled.[4]

Solids and liquids—A large number of solid and liquid toxicants may pose potential hazards to SAR dogs at urban disaster sites and may include hydrocarbons, polychlorinated biphenyls, various toxic metals, soaps, detergents, acids, alkalis, glycols, phenols, alcohols, and solvents.[5] These agents may pose hazards when ingested or inhaled, as well as through dermal or ocular exposure. While many of these agents are recognized as having the potential to cause acute toxicoses (eg, ethylene glycol), others pose more of a concern because of the risk of chronic injury or carcinogenesis (eg, polychlorinated biphenyls). The latter types of agents are of special concern, because the lack of immediate signs of toxicosis may result in prolonged exposure, which can have substantial repercussions months or years later.[6] Additionally, the long-term risks associated with many of these agents have not been well studied in dogs, often making risk assessment difficult.

Particulates—The explosive and compressive forces that accompany many urban disasters can result in the formation and release of a variety of toxic agents in particulate form, and the inhalation of and ocular exposure to particulate matter is a well-recognized hazard to rescue workers at disaster sites.[5] Fiberglass and asbestos fibers may be released from insulation and concrete matrices, resulting in hazardous concentrations being released into the environment.[3] Aerosolization of mold spores, hydrocarbons, glycols, and other substances increases the potential for clinically important inhalation of or ocular exposure to these agents. The effects of some of these agents may not be immediately apparent, but exposure to them may contribute to the development of chronic illness or cancer months or years after exposure.[5]

Even nontoxic dust and particulates have the potential to cause respiratory and ocular irritation. Because SAR dogs rely on their sense of smell to per-

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form their duties, the use of respiratory protection such as that worn by their human counterparts is not possible, leaving SAR dogs at a high risk of being exposed to irritating and potentially toxic particulates.[1]

Gases—Many substances exist in a gaseous state under normal physiologic conditions and environmental temperatures. Other substances may become gases or produce gaseous by-products when burned or exposed to the high temperatures associated with fires (eg, release of toxic fumes from burning plastics). Additionally, chemical reactions between products that are spilled or released during an urban disaster may result in the formation of toxic gases (eg, arsenic reacts with acids to form highly toxic arsine gas; ammonia reacts with hypochlorite to form chlorine gas).[7] Individuals and dogs at disaster sites may also be exposed to gases because of breakage of pipes or lines, exhaust from gasoline- or diesel-powered equipment, and fumes from welding and cutting torches.[3]

A wide range of factors can influence whether a toxicant in a gaseous state may be an important health issue for SAR dogs. In outdoor SAR environments, natural diffusion and wind action may help remove or dilute gases that may be present, preventing these gases from accumulating at toxic concentrations. Natural diffusion is also assisted if the gas is less dense than air.[8] For example, hydrogen cyanide is lighter than air and may readily dissipate in an open environment. In contrast, hydrogen sulfide is heavier than air and may pool in pockets in the ground, increasing the risk of exposure for SAR dogs entering those pockets.[8,9] Search sites that involve indoor or confined areas may be associated with a higher likelihood that SAR dogs will be exposed to hazardous concentrations of gaseous toxicants because of the inability of the gases to dissipate. Because SAR dogs are often sent into confined areas inaccessible to humans, it is imperative that a careful assessment of disaster sites be made to determine the potential for accumulation of toxic gases prior to sending dogs into the area.

Search-and-rescue dogs may be exposed to a variety of gases such as **hydrogen cyanide (HCN)**, **nitrogen dioxide (NO_2)**, **hydrogen chloride (HCl)**, and other **halogen acid gases (HF** and **HBr)** if fires are still burning during an SAR operation.[2,5] Many of these gases are respiratory irritants or sensitizers, whereas others may have systemic effects. Because smoke and other by-products of combustion can be very dangerous, ongoing fires will have a profound effect on how safely an SAR operation can be conducted.[10]

Routes of Exposure

Just as important as understanding the types of toxic agents to which SAR dogs may be exposed when working urban disaster sites is understanding the potential routes by which those toxicants may gain access to the body. Common routes of exposure for humans may not always be the same for SAR dogs. Eating and drinking may be the most obvious methods of oral exposure, but inhalation of toxicants may also result in substantial exposure via the gastrointestinal tract, as inhaled agents are moved from the respiratory tract to the pharyngeal area, where they are then swallowed. Knowing the potential routes of exposure is essential to determining the appropriate decontamination and treatment measures that need to be taken.

Respiratory exposure—In urban disaster sites, respiratory exposure to toxicants is an important concern for both SAR dogs and humans.[1] Elaboration of dust, ash, gases, and toxic fumes as a result of fires, explosions, and chemical reactions can result in situations where asphyxiation is possible. Some gases or fumes may not cause acute asphyxiation but may result in development of pulmonary edema within 24 to 48 hours after exposure (eg, halogenated gases).[11,12] Less severe exposure to inhaled agents may result in mild to severe respiratory tract irritation, leading to tracheobronchitis, bronchiolitis, pneumonitis, or aspiration pneumonia, depending on the inhaled substance. Importantly, some agents with relatively low systemic toxicity (eg, silica, fiberglass) may cause substantial respiratory tract irritation.[11] Inhalational exposure to a toxic agent may lead to systemic effects if the agent is absorbed across the lungs or the agent is swallowed and absorbed via the gastrointestinal tract. Finally, certain inhaled agents, such as asbestos and beryllium, may trigger chronic inflammatory responses in the respiratory tract, resulting in long-term pulmonary disease, or may result in the development of cancer at a later time.[13-15]

In most cases, inhaled gases readily reach the alveoli, where some, such as lead fumes and arsine gas, are readily absorbed into the bloodstream, but others, such as chlorine and fluorine, tend to cause local alveolar damage.[12] Inhaled particles tend to follow similar patterns of deposition and absorption depending on particle size. In general, particles that are 5 µm or larger are deposited in the nasopharyngeal area and are either swallowed or removed via sneezing. Particles that are 2 to 5 µm are deposited in the tracheobronchial tree and moved to the nasopharyngeal area by the retrograde action of the mucociliary escalator; once in the nasopharynx, these particles are then swallowed. Thus, larger particles are likely to pose a risk of systemic toxicosis only if the agents are well absorbed via the gastrointestinal tract. Viral infections and inhalation of toxic or corrosive agents may damage the mucociliary apparatus, resulting in delayed clearance of particulate matter and an increased risk of pulmonary injury from inhaled particles.[11] Similarly, some agents are sufficiently injurious as to cause ciliary paralysis, resulting in loss of the mucociliary escalator. Particles that are smaller than 2 µm may reach the alveoli of the lungs, where they may be absorbed into the blood or lymph or cleared by intra-alveolar pulmonary macrophages.[12] In a manner similar to small particles, volatilized droplets of liquid agents such as hydrocarbons may reach the alveoli, where they may be absorbed, cause local pulmonary damage, or contribute to aspiration pneumonia.

Because the nature of their duties relies on the sense of smell, SAR dogs are at particular risk of exposure to respiratory toxicants. These dogs are constantly inhaling possibly irritating and potentially toxic substances while at a disaster site. Inhalation of cement

lime and fiberglass was associated with respiratory irritation in SAR dogs during the 1995 rescue operation following the Oklahoma City bombing.[1] Unlike their human counterparts, who may wear personal protection equipment in areas that might contain hazardous inhalants, SAR dogs are unable to be outfitted with equipment that might inhibit their sense of smell. Therefore, they are at risk for respiratory exposure to toxicants during the entire time they are working a disaster site. In addition, because of their proximity to the ground, SAR dogs may be continually exposed to dust and particulates that are disturbed as they and rescue personnel work through the site, as well as to heavier-than-air gases that tend to settle in low-lying areas. Search-and-rescue dogs are often sent into confined areas that are inaccessible to their handlers, and these confined areas may contain pockets of toxic gases or fumes to which the dogs may be exposed. Dogs recovering from recent respiratory tract infections (eg, kennel cough) may have delayed respiratory tract clearance because of damage to the mucociliary escalator and may, therefore, be at increased risk of respiratory exposure to toxicants.[1,11]

Dermal exposure—Because of its location and size, the integument serves as the body's primary protective barrier against the introduction of toxicants and infectious agents.[16] The skin can serve both as a target organ and as an agent for absorption of toxicants into the body. Direct corrosive injury to the skin may result from exposure to agents such as cationic detergents, concentrated phenols, oxidizing agents, acids, and alkalis. These agents cause denaturation of dermal proteins and induce coagulative or liquefactive necrosis of the epidermis and, possibly, dermis.[17] While dermal injury from acids and oxidizing agents usually results in signs of acute discomfort (and subsequent removal of the dog from the area by the handler), injury from alkalis and cationic detergents may cause little initial discomfort. Without acute evidence of pain, exposure to alkalis and cationics may be prolonged, resulting in the potential for more severe corrosive injury of the skin to occur.

In addition to agents that are directly corrosive to the skin, some agents, such as hydrocarbons and solvents, may cause less severe epidermal injury following topical exposure. Dermal application of solvents may cause acute defatting of the epidermis,[18] usually causing immediate discomfort; for this reason, solvents such as paint thinner should never be used in an attempt to remove products such as tar from the skin or hair of SAR dogs. Finally, a variety of agents may cause mild dermal irritation as a result of desiccation of the skin or activation of dermal mast cells, resulting in a contact dermatitis. Mild aural irritation due to dust reportedly developed in 1 SAR dog during the search operation in Oklahoma City in 1995.[1]

Although less common than direct dermal injury, systemic toxicosis may develop following dermal exposures to toxic agents that are able to penetrate the skin layers. The rate-limiting step in dermal absorption is the thickness of the stratum corneum of the epidermis.[16] In general, toxicants that are lipophilic (eg, solvents and hydrocarbons) pass more readily through the epidermis than do hydrophilic agents. Compromise to the integrity of the epidermis through abrasion or laceration may increase the systemic absorption of toxicants that normally would not penetrate the skin. Fortunately, the number of agents that are well absorbed through intact skin is relatively small. However, substantial dermal absorption may occur when SAR dogs are exposed to agents such as polychlorinated biphenyls, phenols, heavy metals such as thallium and organic lead compounds, and organophosphorous pesticides such as malathion and parathion.[17]

Search-and-rescue dogs may be at increased risk for dermal exposure to toxicants, as they may not necessarily avoid walking through spilled liquids and solids, and they lack the protective clothing worn by their human counterparts. Dogs also have a larger surface area to body mass ratio than humans, resulting in increased area for potential dermal absorption. Additionally, some agents may not trigger immediate reactions on the part of the dog; thus, the dog's handler may not notice an exposure has occurred, resulting in delay in decontamination. Features that enhance the protective mechanism of the dog's integument include the dense hair coat and the increased thickness of the stratum corneum of the foot pads.

Oral exposure—Oral exposure to toxicants may result in local injury to the gastrointestinal tract mucosa and systemic effects if the agent is absorbed via the gastrointestinal tract. Agents likely to cause local injury are corrosives such as alkalis, acids, cationic detergents, and phenols.[17] Local injury may be limited to the oral mucosa or may include the esophageal and gastric mucosa, depending on the type and concentration of the toxic agent, and the degree of injury may range from mild irritation to severe ulceration. Some agents, such as anionic detergents, may cause mild to moderate vomiting without causing more serious local or systemic effects. In addition to corrosive injury, some of these agents, such as cationic detergents and phenols, may also have systemic effects following absorption.

Whether a toxicant will be absorbed from the oral cavity or gastrointestinal tract is dependent on a variety of factors such as the degree of ionization, pH, particle size, and solubility of the agent.[16] In general, lipophilic agents such as alcohols and organic lead compounds are rapidly absorbed by the gastrointestinal tract. Weak acids tend to be absorbed more readily in the stomach, whereas weak bases are better absorbed in the intestine. Liquids and small particulates tend to be absorbed more readily than larger solids. Agents that dissolve well in the gastric environment generally are more readily absorbed than are those that are less soluble. Systemic absorption of ingested toxicants may result in immediate acute intoxication (eg, glycols and alcohols) or may have delayed or cumulative effects (eg, some heavy metals). It is important to remember that absorption can conceivably take place at any level of the alimentary tract, from mouth to rectum.

Ingestion of toxicants at disaster sites may occur when dogs drink from puddles contaminated with toxicants or ingest solid materials and debris on the ground. Just as importantly, but perhaps less obviously, dogs that are actively searching tend to constantly lick their noses and may ingest debris, liquids, or particulates that collect on the nasal planum. Also, inhaled toxicants that are cleared from the respiratory tract by the mucociliary escalator are swallowed as they reach the pharynx; in areas heavily laden with dust and particulate matter, this mechanism may be a major source of gastrointestinal exposure to toxicants.[11] Finally, dogs may lick contaminants off their hair or feet or may be exposed through contamination of their food or water while at the search area.

Ocular exposure—Because the eye offers only a small surface area for systemic absorption of toxicants,[19] the primary concern for SAR dogs following ocular exposures to toxicants is the potential for local discomfort and mild to severe corneal injury. Exposure to fumes, dust, particulates, splashing liquids, or corrosive agents may result in acute conjunctival or corneal irritation or injury[20] that can interfere with the ability of SAR dogs to effectively perform their duties. Organically reactive hydrocarbons such as formaldehyde, organically active metals such as titanium, and caustic agents such as alkalis and acids may cause severe corneal injury that may result in permanent visual impairment,[20] potentially ending the career of an SAR dog. Other agents may act as sensitizers, resulting in immune-mediated conjunctivitis or keratitis that may intermittently flare up throughout the dog's life.

Summary

In large-scale disasters, it is not always possible to identify every potential toxic agent to which SAR dogs may be exposed. However, an understanding of the basic means by which dogs may be exposed to toxic agents can aid veterinarians in determining basic risks for particular SAR sites and allow veterinarians to institute general preventive measures (eg, frequent eye washes) to minimize exposure. Discussions with public health and other authorities on-site may aid in identifying site-specific risks for SAR dogs. Finally, ensuring that SAR dog handlers are aware of basic risks, precautions, and decontamination measures is essential, as handlers are the first line of defense in preventing illness or injury to SAR dogs as they work a disaster area.

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