Bromine – The Red Cloud Approaching

Igor Makarovsky MSc[1], Gal Markel MD PhD[1,2], Azik Hoffman MD[1], Ophir Schein MD[1], Tal M. Brosh-Nissimov MD[1], Arseny Finkelstien BSc[1], Zeev Tashma PhD[1,3], Tsvika Dushnitsky MD[1] and Arik Eisenkraft MD[1]

[1]CBRN Medicine Branch, Medical Corps, Israel Defense Forces
[2]Sheba Cancer Research Center, Sheba Medical Center, Tel Hashomer, Israel
[3]Department of Medicinal Chemistry and Natural Products, School of Pharmacy, Hebrew University-Hadassah Medical School, Jerusalem, Israel

Key words: bromine, dermal exposure, terror, health effects

IMAJ 2007;9:677–679

Bromine (Br_2) is a member of the halogen group and, like other halogens, is a reactive element. It is principally found in the form of soluble inorganic bromides, and to a lesser extent in minerals. Bromine evaporates readily at room temperature from liquid to a red vapor with a strong pungent odor resembling chlorine. One can compare the irritant bromine to chlorine and ammonia gases. Several of their properties are summarized in Table 1. Vapor pressure and IDLH values (immediately dangerous to life and health)* show that irritant substances in general, and these in particular, pose an inhalational threat. Its odor threshold is 0.05–3.5 parts/million [1]. Bromine is partially soluble in water and freely soluble in organic solvents. The chemical is a powerful oxidizing agent especially in the presence of water [2]. It is not combustible, but may cause fire on contact with combustibles [3]. Since bromine gas is heavier than air, it tends to settle at ground level. Bromine is used in the production of fumigants, flame proofing agents, water purification compounds, dyes, sanitizers, synthetic organic chemicals including medicines, etc. It is also used for disinfection of swimming pools, especially in southern Israel. Due to its unmistakable dark red color, bromine leaks are noticeable even at low concentrations (< 0.1 ppm).

Since bromine is an industrial compound, the people most exposed to it are workers in industry or researchers [1]. Children might be considered more susceptible, as is generally the case with other chemicals.

A considerable amount of bromine was found in 2002 in the *Muqat'a*, headquarters of the former Palestinian leader Arafat in Ramallah, and it was speculated that this might have been connected with terrorist intentions.

Terrorists have begun to realize the potential in utilizing toxic industrial compounds as weapons of mass terror. Bromine, considered a toxic industrial compound, is transported throughout the country, and as such may be involved in either an accidental or an intentional event. The objective of this short review is to discuss the properties of bromine and its health effects in order to enhance the knowledge of medical teams in the event of an emergency [4,5].

Table 1. Comparison between irritant chemicals

	Water solubility (%)	Vapor pressure (mmHg)	IDLH (ppm)
Bromine	4.0	172 (at 20.6°C)	3
Chlorine	0.7	7600 (at 30°C)	10
Ammonia	31.0	400 (at -45.4°C)	300

IDLH = immediately dangerous to life and health

Table 2. Dose-dependency of respiratory symptoms following acute exposure to bromine

Concentration (ppm)	Health effect
1	Irritation
10	Severe irritation
40–60	Dangerous
1000	Fatal

Data source: Ref. 1

Health effects

Bromine chemically reacts with tissue components, such as the respiratory epithelium and dermal keratinocytes, liberating radical oxygen species from the mucous membranes and thus causing tissue damage. In addition, the hydrobromic and hypobromic acids that are formed due to the reaction of bromine with moisture in tissues further contribute to the secondary irritation. Dose-dependant acute respiratory symptoms are summarized in Table 2.

As an active halogen, bromine is highly toxic, but the particular health effects depend on the concentration, route and length of exposure, as well as the age and preexisting medical condition of the victim [6]. Exposure in a confined space is more dangerous than in an open space for two main reasons. Bromine is an intrinsic pulmonary irritant and it replaces oxygen in the air. Most of the documented bromine incidents have been caused by inhalational exposure, due to the volatility of bromine. The main toxidrome of bromine exposure consists of irritation symptoms, including conjunctivitis, lacrimation, severe eye irritation, nose and throat irritation,

* IDLH = Immediately Dangerous to Life and Health. This is a regulatory value defined as the maximum exposure concentration in the workplace from which one could escape within 30 minutes without any escape-impairing symptoms or any irreversible health effects

ppm = parts per million

Table 3. Major human health effects following acute bromine exposure

System	Acute effect	Chronic effect
Eyes	Irritation, lacrimation, conjunctivitis, pain, blurred vision, erosion of the sclera, photophobia and blepharospasm	Conjunctivitis or effects as in acute exposure
Skin	Redness, pain with brown discoloration, measles-like rash, formation of vesicles, blisters, discharging pustules, furuncles, third-degree burns, deep-seated ulcers and scars	Dermatitis, slow healing ulcers, bromoderma tuberosum*, acneiform papular eruption of the face and hands, alopecia
Respiratory tract	Dyspnea, cough, choking, wheezing, immediate or delayed bronchoconstriction, rhinorrhoea, epistaxis, acute lung injury, laryngeal and pulmonary edema, asthma, trancheobronchitis, chemical pneumonitis (hours later), bronchiolitis	Damage to the lower respiratory tract, esophageal and pyloric stenoses, diffuse interstitial pulmonary fibrosis, emphysema, airway hyper-reactivity, chest pains
Gastrointestinal tract	Burns in the mouth, throat and stomach, brown discoloration and corrosion of the tongue and mucous membranes, sore throat, vomiting, abdominal spasm, severe gastroenteritis with possible ulceration or perforation, prostration	Not relevant in mass intoxication scene
Central nervous system	Ataxia, slurred speech, tremor, nausea, vomiting, lethargy, vertigo, visual disturbances, unsteadiness, headaches, impaired memory and concentration, disorientation, hallucinations, delusions, psychotic behavior, stupor and coma	Headache, anorexia, irritability
Cardiovascular	Hypoxemia, hypercapnia, sinus tachycardia and cardiac arrhythmias; may progress to cardiac arrest, circulatory collapse	Myocardial degeneration and hypotension
Laboratory findings	Hypoxemia, metabolic acidosis, leukocytosis, moderate hypoglycemia or altered blood sugar curves, hypercholesterolemia, reduction of total bilirubin, decreased hemoglobin concentration, increased erythrocyte sedimentation rates	No data available
Carcinogenicity, teratogenicity and mutagenicity	No data available	No data available

* Bromoderma tuberosum is an acneform or granulomatous eruption due to hypersensitivity to bromide

Data source: refs 1,11,15-20

cough and dyspnea. Ingestion of liquid bromine can cause abdominal pain and hemorrhagic gastroenteritis with secondary shock. Contact with the skin may cause chemical burns [7,8]. There are some chronic dermal effects that are characteristic of halogens, namely halodermas. Bromoderma tuberosum is a dermal manifestation specific to bromine exposure [9,10]. The major health effects on humans following acute bromine exposure are summarized in Table 3.

Immediate and general medical care

The contaminated area must be evacuated to prevent further exposure. In case of a fire, any extinguishing agent can be used. The attending personnel must be equipped with appropriate protective measures, including air-purifying or supplied-air respiratory equipment (level A to C protection). Emergency services should be prepared for such an event by having protective suits and respirators available at hand. Bromine has no specific antidote, and most of the treatment is supportive. Victims' clothes must be removed as soon as possible and placed in a double plastic bag to prevent further contamination.

After receiving information about such an incident, a team of physicians, nurses and non-medical personnel, all wearing protective gear, should decontaminate and treat the victims outside the emergency department, letting them inside only after they are fully decontaminated.

Inhalational exposure

At the scene, the victim should be brought out into fresh air, and if needed, should receive supplemental humidified oxygen. In the hospital, bronchodilation therapy with β_2-agonists and corticosteroid aerosols is advised in case of bronchospasm [11]. Since pulmonary edema might evolve during the first 72 hours following exposure [11], fluid resuscitation must be carefully monitored. While the question of corticosteroids in irritant gas inhalation such as bromine is debatable, early anti-inflammatory therapy with corticosteroids is advised for all symptomatic patients [11]. Antibiotics should be administered only if there is evidence of infection [1,11]. Despite the lack of data concerning the role of corticosteroids and nitric oxide in the treatment of acute lung injury following bromine exposure, we presume that it might have beneficial effects, as in other cases of irritant volatile compounds [12]. There are insufficient data regarding other experimental therapies, such as N-acetylcysteine and heparin for treating irritant gas inhalation [12].

Ocular exposure

Eyes must be rinsed with copious amounts of water for at least 15 minutes. Fluorescein staining should be applied to detect erosion of the sclera. If confirmed, the victim must be further evaluated by an ophthalmologist [11,13,14].

Dermal exposure

Contaminated clothes must be removed by cutting them with a scissors and not by passing them over the head, and discarded carefully. The exposed skin must be washed thoroughly with water for at least 6 minutes. Because of delayed effects [Table 3], close observation during the next 24 hours is crucial. Tetanus toxoid is advised in burn cases. In victims with first-degree burns only, topical corticosteroids or antihistamines may be applied [1,7,11,13,14].

Gastrointestinal exposure

Although gastrointestinal exposure is unlikely in mass intoxication events, it is essential that health personnel adhere to the following: Vomiting should not be induced and gastric lavage should not be performed [15]. Activated charcoal is of no value [13]. Dilution of the ingested compound with milk or water should be done only if there is no respiratory compromise, and only in alert patients. No recommendations were found in the literature for gastrointestinal endoscopy and surgery in case of bromine poisoning. The victim should be transported to a medical facility promptly for further evaluation [11,14].

Laboratory tests

Arterial blood gases, chest X-ray, and pulmonary function tests should be monitored in patients with significant bromine exposure [11].

Case studies

Below is a list of several incidents in the last 20 years involving accidental spills or intentional attempts to spread bromine.

Geneva, Switzerland, 1984: Following a bromine spill in a chemical plant near Geneva, a large section of the city was exposed to a concentration above the accepted STEL (**s**hort-**t**erm **e**xposure **l**imits for workers, 0.2 ppm) [11]. More than 90 people were hospitalized, most of them suffering from moderate ocular and upper airways irritation. Most of the victims were discharged home shortly after admission and did not need further medical care [7].

Cardiff, Wales, UK, 2003: Contractors working on the air-conditioning system in the British Gas building were treating water with what was thought to be hydrobromic acid. When it came into contact with another chemical, the pipes melted, forming toxic fumes. As a result, 1700 workers were evacuated from the building, 17 were treated at the scene, and 18 others were hospitalized but eventually did not suffer serious injuries.

Ramallah, West Bank, 2002: Six containers were found at Arafat's headquarters, the *Muqat'a* in Ramallah, each containing two liters of bromine. As mentioned earlier, the exact **i**ntended use is still unknown.

Ashdod, Israel, 2004: Two suicide bombers detonated an explosive belt and an explosive bag at the Ashdod port. Ten Israelis were killed and 12 others were injured. It was later found that the two terrorists planned to launch a mega-terrorist attack by blowing themselves up near the port's bromine tanks, and other hazardous materials stored nearby. The effects could have been devastating, killing many residents within minutes.

Summary

Bromine is a strong and prevalent irritating agent that can spread both as liquid and as fumes. It has a characteristic reddish-brown color. The mainstay of the medical management is supportive and symptomatic therapy that should be given as soon as possible to prevent further damage. Medical personnel, especially the emergency department staff, should be familiar with its health effects, including the safety precautions needed when caring for casualties following such an exposure.

References

1. Kasilo OMJ, Edelman PA. Bromine, Poisons Information Monographs 080, IPCS INCHEM, 1999. http://www inchem org/documents/pims/chemical/pim080 htm
2. Gosselin RE, Smith RP, Hodge HC. Clinical Toxicology of Commercial Products. 5th edn. Philadelphia: Williams & Wilkins; 1984.
3. MCA. Chemical safety data sheet SD-49: Properties and Essential Information for Safe Handling and Use of Bromine. Washington, DC: Manufacturing Chemists Association, 1968.
4. Hughart JL, Bashor MM. Agency for Toxic Substances and Disease Registry, U.S. Public Health Service. Industrial chemicals and terrorism: human health threat analysis, mitigation and prevention. 2007. http://www mapcruzin com/scruztri/docs/cep1118992 htm
5. Rogers GO, Sorensen JH, Watson AP. Protecting civilian populations during chemical agent emergencies. In: Somani SM, ed. Chemical Warfare Agents .New York: Academic Press, 1992:357–86.
6. Fact Sheet. Facts About Bromine – Emergency Preparedness and Response Web site, 2007. http://www bt cdc gov/agent/bromine/basics/pdf/factsheet pdf
7. Morabia A, Selleger C, Landry JC, Conne P, Urban P, Fabre J. Accidental bromine exposure in an urban population: an acute epidemiological assessment. *Int J Epidemiol* 1988;17:148–52.
8. Shannon MW. Bromine and iodine compounds. In: Haddad LM, Shannon MW, Winchester JF, eds. Clinical Management of Poisoning and Drug Overdose. 3rd edn. Philadelphia: WB Saunders, 1998:803–12.
9. Pfeifle J, Grieben U, Bork K. Bromoderma tuberosum caused by anticonvulsive treatment with potassium bromide. *Hautarzt* 1992;43:792–4.
10. Anzai S, Fujiwara S, Inuzuka M. Bromoderma. *Int J Dermatol* 2003;42:370–1.
11. Bentur Y. Therapy Guidelines for Hospitals during a Mass Toxicological Event. Haifa: Emergency & Disaster Management Division, Ministry of Health, 2001.
12. Cepkova M, Matthay MA. Pharmacotherapy of acute lung injury and the acute respiratory distress syndrome. J *Intensive Care Med* 2006;21:119–43.
13. Bromine. Emergency First Aid Treatment Guide, Chemical Emergency Preparedness and Prevention. EPA, 2007. http://yosemite epa gov/oswer/CeppoEHS nsf/firstaid/7726-95-6?OpenDocument
14. Chlorine Material Safety Data Sheets. 2004. http://www praxair com/praxair nsf/d63afe71c771b0d785256519006c5ea1/799ae9bb7fb9197d85256e5b0068bb65/$FILE/Chlorine-Canada pdf
15. Bromine Material Safety Data Sheet, 1994. http://www denison edu/sec-safe/safety/msds/br2 html
16. Safety page Bromine. 1 Reagent Lanefair Lawn, NJ: Fischer Scientific, 2007. 07410. http://www doctoryourself com/diaz html
17. Facts about bromine dangers. U.S. Department of Transportation. Hazard class or division, 2007. 49 CFR. http://www doctoryourself com/diaz html
18. Dart RC. Medical Toxicology. 3rd edn. Philadelphia: Lippincott Williams & Wilkins, 2003.
19. Goldfrank LR, Flomenbaum M, Hoffman RJ, Howland M-A, Lewin NA, Nelson LS. Goldfrank's Toxocological Emergencies. 8th edn. New York: McGraw-Hill, 2002.
20. Sticht G, Kaferstein H. Bromine. In: Seiler H, Sigel H, Sigel A, eds. Handbook on Toxicity of Inorganic Compounds. New York: Marcel Dekker, 1988:143–54.

Correspondence: Dr. A. Eisenkraft, 2 Hatavor Street, Ganei Tikva 55900, Israel.
Phone: (972-3) 6353835
Fax: (972-3) 737-6111
email: aizenkra@gmail.com