ABC of conflict and disaster

Weapons of mass destruction—threats and responses

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This is the last in a series of 12 articles

Weapons of mass destruction (WMD) include chemical, biological, and radiological agents with the potential to cause death at low doses and with serious long term health effects in survivors. This article provides general information relevant to all situations, from terrorist attacks in developed countries to conflict zones in Third World countries. WMD agents can be used to terrorise or subjugate populations and wreak economic damage. Many agents are cheap to produce and can be deployed in different ways. As well as overt use, such as in bombs or by aerial spraying, they can be used covertly such as in packages sent in the post, via animal vectors, or by poisoning of water and food supplies.

Threats from WMD

The classic scenario of WMD use against civilians (the basis of many current exercises) is the release of the nerve agent sarin in the Tokyo subway. In this attack the actions of first responders and medical staff helped keep the final fatalities down to 12. Because they lacked protective clothing, however, many of these people absorbed sarin from victims' clothing and developed serious long term neurological complications. Other agents—such as mustard agent, VX, anthrax, and radiation—are more persistent and thus pose greater risks: doses to victims would be higher, attending staff would face protracted periods in protective clothing, and the threat would remain until full decontamination was achieved.

The diversity and gravity of threats are exemplified by the recent anthrax attack on the US Congress through the postal system. It claimed few victims, thanks to rapid intervention by bioweapons specialists, but it paralysed the postal system and cost over $6bn to clean up.

For the past seven years we have collaborated in a programme to treat and study the immediate and long term effects of WMD on the people of Halabja in northern Iraq. Our experiences have led us to draw up information about the risks from WMD agents, decontamination, immediate and long term effects, and responses to help victims and protect responders.

Diversity of WMD agents

The range of potential WMD agents and delivery mechanisms is extensive. For chemical weapons, as well as highly toxic and persistent new agents such as VX, older agents, such as mustard gas, remain highly dangerous and relatively easy to obtain. For biological agents, the key element is rapid identification so that countermeasures can be deployed before the agent is widely disseminated. Biological toxins resemble chemical agents rather than infectious organisms: they can pose major threats, but usually only over localised areas or to poison food or water. Radiological weapons include weaponised radioactive waste and dirty bombs as well as nuclear weapons.

Chemical weapons: agents and effects

Chemical agents include vesicants (blister or mustard agents), nerve agents (sarin, soman, tabun, and VX), and blood agents (cyanide).

Casualties from the attack on Halabja in northern Iraq by the former Iraqi government with multiple WMD agents, including nerve and mustard agents

Threats from weapons of mass destruction

- Threats overt or covert
- Delivery systems include bombs, shells, spraying, mines, hand grenades, animal vectors (such as fleas)
- Strategic and economic targets—Administrative and key centres, animals, crops, food
- More than one agent may be used in an attack

Subway passengers affected by sarin gas planted in central Tokyo attended by unprotected first responders and medical staff

In the attack on Halabja 5000 civilians died immediately. The entire town of 80 000 was overcome, and there was no one to respond or provide medical support. The agents used included powerful and persistent carcinogens, resulting in many survivors with major long term illness

The former government of Iraq often used mustard and nerve agents in the same attack and weaponised chemical agents mixed with biological agents such as anthrax and aflatoxin. Use of more than one agent can lead to difficulties in detecting all the agents involved, increase mortality, complicate symptoms, and make decontamination more difficult

Mustard agent causes immediate severe damage to the respiratory tract, skin, and eyes, but skin blisters and corneal effects are not usually apparent for minutes to hours, though the characteristic garlic odour and burning sensation in throat and eyes may provide earlier warning. The carcinogenic effects of mustard agent begin within 2-4 minutes, and there are no antidotes. Long term effects include cancers; damage to respiratory, immune, and reproductive systems; and blindness. Victims need rapid decontamination to minimise effects.

Nerve agents may be colourless and odourless and give little warning of their presence, but minute amounts can kill rapidly. Their immediate effects can be recognised with the acronym DUMBELS (diarrhoea; urination; miosis; bradycardia, bronchorrhoea, and bronchospasm; emesis; lacrimation; and salivation and sweating). Victims—especially those without protective clothing, gas masks, or antidotes—rapidly become unconscious, have breathing difficulties, and may die. Sarin, tabun, and soman are relatively non-persistent but tend to "off gas" as they evaporate, which can present a vapour hazard for first responders. VX persists for several days and is over 150 times more toxic than sarin and tabun and is therefore very dangerous. Warning signs may include symptoms or death in animals, birds, and insects. Nerve agents can have various long term effects from cardiac arrhythmias to major neuropathies.

Cyanide is extremely light and disperses rapidly in the open air but is dangerous at high concentrations in enclosed spaces.

Characteristic blistering of skin from exposure to mustard agent. The blisters resolve, but 30% of mustard agent victims have severe, irreversible damage to the skin, eyes, and lungs. Even those lacking these symptoms are at risk of serious future problems. Medical authorities should be concerned about all victims' future health and wellbeing

Chemical WMD agents and their properties

Agent	Physical characteristics	Lethal dose (LD_{50})	Time to onset of symptoms	Principal effects
Vesicants				
Mustard agents	Colourless to brown oily liquid; garlic or mustard odour	7 g/person	15 minutes to 4 hours	Blisters, eye irritation, tearing, cough, dyspnoea, pulmonary oedema, nausea, vomiting, diarrhoea, anxiety
Nerve agents				
Tabun	Colourless liquid; slight fruity odour	1 g/person	Seconds to minutes	Increased salivation and bronchial secretions, cough, dyspnoea Miosis, tearing, nausea, vomiting, abdominal cramp, diarrhoea, involuntary defecation and micturition Apprehension, headache, confusion, ataxia, weakness, coma, convulsions, paralysis
Sarin	Colourless liquid; faintly sweet odour	1.7 g/person		
Soman	Colourless liquid; camphor odour	0.35 g/person		
VX	Colourless or amber oily liquid; odourless	0.01 g/person		
Blood agent				
Hydrogen cyanide	Colourless or grey crystalline solid; sharp, irritating floral odour	7 g/person	Immediate	Dyspnoea, eye irritation, nausea, vomiting, depression, headache, ataxia, convulsions, coma

Responses to chemical WMD

An effective response to chemical WMD requires chemical detection or monitoring systems, antidotes where appropriate, rapid decontamination, and ensuring that exposed populations do not consume contaminated food and water or remain in contaminated environments. The sarin attack in Tokyo showed the vulnerability of civilian populations, first responders, and medical teams. Victims were overcome by a colourless, odourless, volatile agent; delays in identifying the responsible agent allowed contamination to extend to receiving hospitals, where staff failed to put on protective clothing and gas masks.

Antidotes for nerve agents include atropine, which works by blocking acetylcholine at the postsynaptic receptor sites, thus counteracting muscarinic effects. Because atropine does not affect nicotinic synapses, oximes such as pralidoxime are also given. Oximes bind with acetylcholinesterase and hydrolyse the nerve agent, but are effective only if given soon after exposure, otherwise nerve agent binding becomes irreversible. Because nerve agents act rapidly, responders must put on gas masks and protective clothing immediately to avoid becoming casualties themselves.

Responses to food contaminated with chemical agents (mustard or nerve agents)

High fat foods (butter, fats, eggs, cheese, meat)
- Condemn if exposed to agents in liquid or vapour form

Low fat foods

High moisture (fruit, vegetables, sugar, salt)
Low moisture (cereal, tea, coffee, flour, bread, rice)
- Condemn if exposed to agents in liquid form
- If exposed to agents in vapour form:
  Expose dry food to air for 48 hours
  Wash other foods in 2% sodium bicarbonate
  Peel where applicable
  Cook by boiling

It is important not to delay decontamination. In the absence of specialised decontamination, household bleach (sodium hypochlorite) should be used. This is effective against nerve and mustard agents and many bioweapons, but it requires clear instructions about the correct dilution (1 in 10, such as 1 litre of bleach in 9 litres water) and of special precautions such as avoiding the eyes. Although direct contact with such a bleach solution would normally be considered unwise, rapid decontamination may save lives, especially for fast acting, highly toxic agents such as VX. In Halabja, Iraq, thousands died immediately and many survivors have severe long term problems because no decontamination was carried out on victims, the environment, or the unexploded bombs that harboured large amounts of native nerve and mustard agents.

Bioweapons: bacteria, viruses, and toxins

Many potential biological agents exist, but we will consider only high risk (category A) agents. These pose the greatest threat to public health, may spread across large areas, carry a high risk of death, and are readily transmissible from person to person or are easily disseminated. The dangers are greatest when no vaccines or effective treatments are available.

Protection, prophylaxis, and treatment

Bioweapons can be countered by recognition of risks, accurate diagnosis, and rapid treatment. For most agents, specialised testing is necessary by public health specialists or laboratories. For bacterial agents, vaccination and treatment with antibiotics or antitoxins must be started early to prevent disease progression and death. For viral diseases, vaccination is the principal form of prophylaxis: the use of antiviral drugs might be useful, but effectiveness and safety have yet to be established.

Smallpox is very contagious, and lack of natural resistance or vaccine means it would be highly lethal

Biological agents of mass destruction

Agents with direct person to person transmission

- Include bacterial and viral diseases
- Obviate the need for specialised weapons delivery systems
- Many contacts may be infected and the disease widely disseminated before the outbreak is recognised

Agents with no or rare person to person transmission

- Include bacterial agents and biological toxins
- Easily disseminated and can pose major threats, such as the risks to staff and the cost of decontaminating US government buildings after anthrax was released via the postal system
- Toxins can be derived from diverse organisms and have a wide spectrum of effects varying from immediate lethality (botulinum toxin, ricin) to long term carcinogenicity (aflatoxin and other mycotoxins)

Biological WMD agents (class A) and their properties

Agent	Transmission mode	Incubation and lethality	Symptoms	Prophylaxis and treatment
Direct person to person transmission				
Bacterial				
Plague (pneumonic or bubonic)	Aerosol droplets or flea vectors	1-6 days. High lethality unless treated	Fever, weakness, cough, respiratory failure, pneumonia	Antibiotics (streptomycin, gentamicin, tetracyclines)
Cholera	Contaminated food or water	Hours. 20-25% lethality if untreated	Watery diarrhoea, vomiting, leg cramps. Death can be in hours	Vaccines (not in US). Prompt rehydration. Antibiotics
Typhoid	Contaminated food or water	3 days to 8 weeks. Moderate lethality	Fever, weakness, pain, headache	Vaccine. Antibiotics (but resistance emerging)
Viral				
Smallpox	Direct contact, body fluids	7-17 days. High lethality	High fever, rash, severe aches, headache, abdominal pain	Vaccine
Viral haemorrhagic fevers (Ebola, Lassa, Marburg)	Nosocomial (possible animal reservoir)	2-21 days. High lethality	High fever, severe prostration, haemorrhage, petechiae, oedema, myalgia, headache	Supportive treatment (need stringent infection control, VHF barrier precautions)
No or rare person to person transmission				
Bacterial				
Anthrax	Spores, aerosol, food	1-5 days. High lethality unless treated	Fever, malaise, cough, shock. Death can be within 36 hours	Vaccine. Antibiotics (ciprofloxacin, doxycycline)
Tularaemia	Aerosols, tick or insect bites, contaminated food or water	3-14 days. Moderate lethality if untreated	Sudden onset acute febrile illness, cough, weakness	Live attenuated vaccine. Antibiotics (gentamicin, streptomycin). Protect against biting arthropods
Biological toxins				
Aflatoxin	Aerosol, contaminated food or water	Variable time. Lethality depends on dose and route of exposure	Fever, wheezing, cough. Liver damage, stillbirths, birth defects, cancer	Testing, removal of contaminated food
Botulinum toxin	Aerosol, contaminated food or water	6 hours to 14 days. High lethality	Blurred vision, difficulty swallowing, muscle weakness, paralysis of respiratory muscles	Antitoxin effective if given early. Supportive care, ventilation
Staphylococcus enterotoxin B	Aerosol, contaminated food or water	1-6 hours. Lethality $<1\%$	Vomiting, nausea, diarrhoea, chest pain, headache, myalgia	No antidotes, vaccine, or antitoxins. Supportive care, ventilation
Ricin	Aerosol, contaminated food or water	Hours to days. High lethality	Fever, dyspnoea, nausea, pulmonary oedema	No vaccine or antitoxins. Supportive care, ventilation for severe cases

Radiological weapons

Nuclear devices are unmistakable because of the thermal blast, but radiological dispersal devices such as dirty bombs (conventional explosives laced with radioactive isotopes in the form of pellets or powder) may not be immediately recognised if monitoring with a Geiger counter is not done. Monitoring (including identifying contaminated food, water, and milk) is crucial in any radiological incident, as are decontamination and providing iodine tablets if radioiodine is released.

Management of mass casualties

Given the wide array of WMD and delivery mechanisms, preparedness for all possible events is extremely challenging. The basis of an effective response involves

- Stay upwind and uphill
- Monitor to identify agents (more than one may be used)
- Decontaminate or isolate people affected
- Give antidotes as appropriate for nerve agents
- Provide treatment for bioweapons (antibiotics, vaccination)
- Provide respiratory support if necessary (respiratory paralysis is a common primary event that is often temporary), but remember that victims may pose a risk to responders who lack adequate protection
- Good communication and coordination of information from pharmacies, laboratories, first responders, emergency medicine, and medical and public health staff
- Deal swiftly with any contaminated food, water, and environment to prevent casualties extending beyond those directly affected (the main cancers among survivors of the atomic bombs dropped on Japan were of the gut because of ingestion of contaminated food and water)
- Preparedness measures include supplies of bottled water and safe food stored in non-permeable containers.

Long term effects of WMD

The long term health effects of WMD depend on the agent used, dose, route of exposure, and victims' genetic susceptibility. The Japanese atomic bombs resulted in cancers, infertility, and adverse pregnancy outcomes. Mustard agent can cause cancers of the head, neck, and respiratory tract, haematological malignancies, immune system dysfunction, infertility, and birth defects in offspring. Long term effects of nerve agents include neurological and psychiatric problems and cardiac arrhythmias.

Fetuses are especially vulnerable because, unlike children and adults, they lack most of the protective mechanisms for metabolising or protecting against WMD agents (thus, rates of leukaemia among the survivors of the Hiroshima bomb were far greater for those exposed in utero than for other age groups).

There has been little study or acknowledgment of the long term risks of WMD, because people have concentrated almost exclusively on short term problems. Long term risks may be severe and life threatening, but the lack of recognition of the sequelae means survivors receive no help.

Reducing these effects depends on deploying effective detection systems to alert to WMD risks, establishing systems for rapid responses with facilities for decontamination and treatment of casualties, providing information to the affected population, and providing uncontaminated food, water, and environment after an attack.

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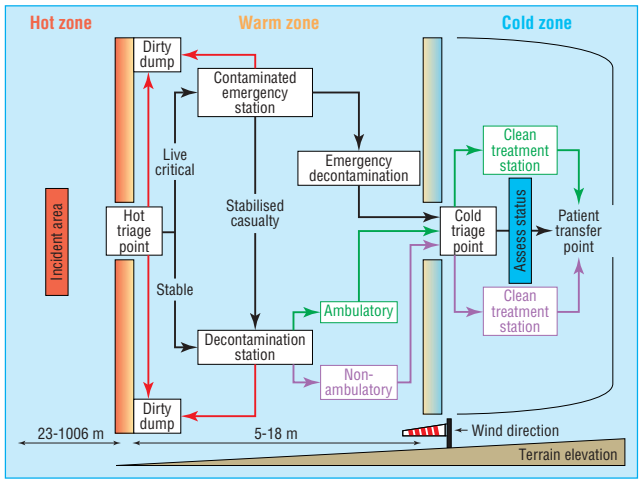
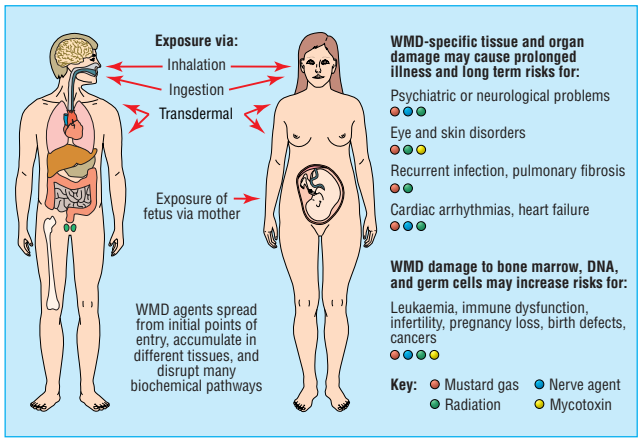


Procedure for dealing with casualties from a WMD incident



Long term effects of WMD. These may be serious, depending on the agent, route of exposure, dose, and individual susceptibility. Prompt actions, such as decontamination, help to mitigate against long term health problems

Further reading

- Ellison, DH. *Handbook of chemical and biological warfare agents*. Boca Raton, FL: CRC Press, 2000
- Dwyer A, Eldridge J, Kernan M. *Jane's chem-bio handbook international*. 2nd ed. Coulsdon: Jane's Information Group, 2003
- National Guideline Clearinghouse. Guidelines on bioterrorism. www.guideline.gov/resources/bioterrorism.aspx
- Health Protection Agency. www.hpa.org.uk
- CDC Centers for Disease Control and Prevention. Emergency preparedness and response. www.bt.cdc.gov
- World Health Organization. *Public health response to biological and chemical weapons: WHO guidance*. Geneva: WHO, 2004. (www.who.int/csr/delibepidemics/biochemguide/en/)

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