ORIGINAL ARTICLE

Facilities for chemical decontamination in accident and emergency departments in the United Kingdom

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Objective: To audit the facilities for chemical decontamination, with special reference to cyanide poisoning, in all major accident and emergency departments in the UK.
Method: A simple postal questionnaire was used to audit planning, premises, equipment, protection for staff, and stocks of specific antidotes to cyanide poisoning.
Results: 227 questionnaires from 261 departments (87%) were returned and used in the survey. Of the 227 departments who responded, 151 (66%) had a written plan; 168 (74%) departments had premises for decontamination; 55 (24%) were judged to have satisfactory premises; 146 (64%) departments had a shower or hose for decontamination; 60 (26%) departments had a decontamination trolley suitable for "stretcher" patients; 203 (89%) had some protective equipment for staff but only 77 (34%) had complete protection—that is, goggles, chemical resistant clothing, and breathing apparatus. In the authors' opinion only seven (3%) departments had satisfactory premises and equipment to treat "stretcher" patients and full protection for staff. A further 11 (5%) departments were equipped to manage ambulant patients at a similar level. Some 205 (90%) departments stocked one or more antidotes to cyanide and 77 (34%) stocked all four antidotes. Thirty four (15%) departments held all four antidotes to cyanide and had full protection for staff. Only five (2%) departments had satisfactory premises and equipment to treat "stretcher" patients, full protection for staff, and at least three of four antidotes.
Conclusions: Most departments had some equipment for chemical decontamination. However, there were major inconsistencies in the range of equipment held and these limited its usefulness. Only a small minority of departments was satisfactorily equipped to deal with a serious chemical incident.

Additional information regarding this paper is on the journal web site (www.emjonline.com).

Rapid intervention is essential in order to limit damage by chemicals and poisons. Notwithstanding this, publications from the US,[1 2] Australia,[3] and the UK[4] indicate that, in general, the facilities for the treatment of contaminated casualties are poor. The NHS guidance is clear and states that "the health authority must:

> designate an individual(s) responsible for ensuring that: ...agreements exist with acute hospital trusts...for the provision of an effective health service response in the event of a chemical incident; ...appropriate chemical incident plans are drawn up...
>
> identify and make available suitable and sufficient resources to ensure that...all health service trusts are able to fulfill their planning and response roles."[5]

Unfortunately, severe pressure on resources, together with the rarity of chemical incidents, seem to have resulted in a lack of facilities and equipment generally. This meant that when our own hospital was required to decontaminate patients after an incident with cyanide (the rodenticide *Cymag*) in which there had been a prehospital fatality, our equipment was not ideal. As a result of this experience, we decided to audit the situation nationally, with special reference to cyanide poisoning. The management of cyanide poisoning is a good model for the management of chemical contamination. Cyanide is highly toxic. It inhibits respiration at the cellular level, thus causing tissue hypoxia. It can be absorbed by every route, namely ingestion, inhalation, and through eye and skin contact. Full protection is required for rescuers and hospital staff (except in the mildest cases). There are four specific antidotes.

While this audit was in progress, an audit of decontamination facilities that concentrated on six health regions in England was published.[4] We are therefore able to compare these results with those from our own survey that covered all major accident and emergency departments in England, Scotland, Wales, and Northern Ireland.

THE "BLUEPRINT"

We devised a "blueprint" based on our understanding of best practice.[6 7] We were then able to design a simple questionnaire and audit departments against this blueprint. (National recommendations are awaited.)

The plan

There should be a written plan that covers communications; liaison with the National Poisons Information Service and other agencies; premises; equipment; protection for staff, antidotes to poisons; and the decontamination process. It should also include the return to normal working and debrief.

The premises

The premises must be rapidly available and should comprise a well ventilated area. There should be a separate "dirty" entrance and a "clean" exit such that patients can pass through the area without crossing their tracks and becoming secondarily contaminated. The premises should be isolated

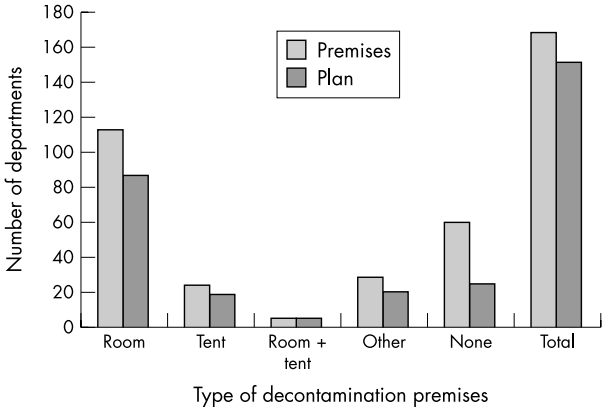

Figure 1 Relation between type of decontamination premises and the possession of a written decontamination plan.

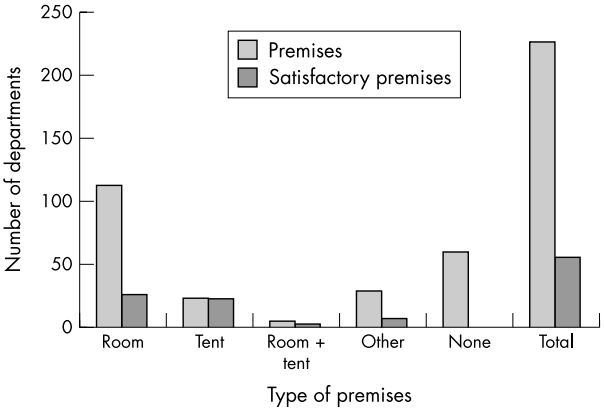

Figure 2 Decontamination premises and their suitability.

from the rest of the accident department and hospital to prevent cross contamination. If necessary, this should be achieved by sealing the area with heavy duty polythene (or brown paper) and tape. If there is an air circulation system, air from the decontamination area must be prevented from circulating through the rest of the accident department or hospital.

Decontamination equipment

A warm shower or hose is essential. Warm water is more comfortable for the patient and a better solvent for chemicals. Far greater dilution of contaminants can be achieved by continuous serial dilution from a shower or hose than is possible by immersion in a container of water of fixed volume. Liquid detergent (for example, shower gel, shampoo) is required to remove fat soluble contaminants. A decontamination trolley (shallow bath top with water drainage system) is required for showering any patient who is not well enough to stand. There should be access to resuscitation equipment and (if relevant) specific antidotes to poisons. A drainage system suitable for the collection of washings deemed to be too toxic to enter the main drainage system maybe required. (Some experts argue that dilution by other hospital effluent is sufficient to prevent damage to the environment and that specialised drainage is not usually necessary.) Equipment for dry vacuuming poisons, with high quality filtration systems to prevent the dispersal of dry poisons, is desirable.

Protection for staff

Staff should be provided with anti-chemical suits, waterproof boots, gloves, goggles, and breathing apparatus.[4] Goggles are particularly relevant for cyanide as the eyes are a route for absorbtion and exposure can cause loss of vision. We consider that full protection is always required because prolonged exposure, even to less toxic substances, may be hazardous. In the case of cyanide, the one minute LC50 in humans is estimated at 3030 ppm whereas the lethal concentration for 30 minutes' exposure is only 135 ppm.[7]

The decontamination process

At the "dirty" entrance, resuscitation and analgesia should be started as indicated. Patients should be placed on a decontamination trolley if too ill to stand. All clothes should be removed with scissors so as to avoid pulling contaminated clothing over the head. This removes about 80% of the surface contamination. Contaminated clothing should be placed in polythene bags and sealed with tape. Residual dry surface contamination can be removed by vacuuming. (This is especially relevant for cyanide as contact with water produces highly toxic hydrogen cyanide gas.) The casualty should then proceed through the "rinse, scrub, rinse cycle".[6] The initial rinse helps to remove particles and water soluble chemicals. After the first rinse, the patient should be washed with liquid detergent (for example, shower gel, shampoo, etc) to facilitate removal of fat soluble contaminants. The second rinse removes fat soluble chemicals and shower gel. This cycle can be repeated if decontamination is thought to be incomplete. The decontaminated patient should leave the decontamination premises via the clean exit.

Antidotes to poisons

There are few specific antidotes to poisons. We consider that antidotes, where they exist, should be held in accordance with known common poisons and local hazards (industry, chemicals in transit, perceived risk of terrorist attack, etc). There are four specific antidotes to cyanide:

- amyl nitrite, which forms methaemoglobin. Methaemoglobin binds cyanide ions to form cyanmethaemoglobin. This effectively displaces cyanide from cytochrome oxidase and facilitates its elimination.
- sodium thiosulphate, which increases conversion of cyanide ions to less toxic thiocyanate.
- dicobalt edetate, which chelates cyanide ions to form non-toxic compounds. Dicobalt edetate is itself very toxic in the absence of cyanide ions and its use should be reserved for severe poisoning.
- sodium nitrite, which like amyl nitrite, forms methaemoglobin and acts in the same way.

Conclusion of the episode

Premises and staff should be decontaminated. There should be a debrief.

METHODS

A simple questionnaire was designed to audit the main components of the blueprint, namely planning, premises, equipment, protection for staff, and antidotes (a copy of the questionnaire is on the journal web site). During August 2000, a copy of the questionnaire together with a covering letter was sent to the senior nurse manager of every major accident and emergency department in England, Scotland, Wales, and Northern Ireland listed in the *British Association for Accident and Emergency Medicine Directory, 1999–2000*. Paediatric departments seeing less than 20 000 new patients per annum were excluded from the survey, as was a department that identified itself as a community hospital. The reply from one paediatric department seeing more than 20 000 new patients per annum was also discarded because the department stated that all chemical incidents were managed by a neighbouring adult department. A final total of 261 departments was included in the survey. Reply envelopes were supplied and numbered. This

Table 1 Decontamination premises and equipment

	Room	Tent	Room and tent	Other	None	Total	%
Premises	113	23	4	28	59	227	
Dry vacuum	15	1	0	1	1	18	8
Shower/hose	105	22	3	13	3	146	64
Specialised drainage	57	17	2	6	5	87	38
Shower gel, etc	85	12	3	16	21	137	60
Decontamination trolley	40	6	0	7	7	60	26

The percentage of departments possessing each type of equipment is shown in the last column (for example, of 227 departments 60 (26%) had a decontamination trolley).

Table 2 Departments with satisfactory premises and essential equipment

	Satisfactory room	Satisfactory tent	Satisfactory room and tent	Satisfactory other	Total
Premises	26	23	1	6	56
Shower/hose	24	21	1	3	49
Shower and shower gel	20	11	1	2	34
Decontamination trolley	10	5	0	1	16

Table 3 Decontamination premises and protection for staff

	Room	Tent	Room and tent	Other	None	Total	%
Premises	113	23	4	28	59	227	
Protective clothing	80	23	3	12	27	145	64
Goggles	105	23	4	21	45	198	87
Breathing apparatus	54	15	1	9	15	94	41

The percentage of departments possessing each category of protective equipment for staff is shown in the last column.

enabled us to send a second questionnaire to all non-responders one month later. The questionnaires themselves were unmarked and were removed from the envelopes without identification.

Positive answers to each question were recorded on 10×10 grids to facilitate analysis of the results. All results were rechecked to ensure accuracy. Most questionnaires were completed unequivocally but in the rare event a question was left unanswered we assumed the answer was "no". We scored on the actual situation at the time the questionnaire was completed but noted that several departments commented that they had plans to modernise and seven had ordered tents. Adjustment was made for departments for whom questions 4 and 5 were not applicable. Thus, a department with a decontamination tent or other outside decontamination area could score as highly as a department with a room.

As the questionnaires were received, it became apparent that there were significant inconsistencies. For example, some hospitals held antidotes to cyanide but had no protective clothing to safeguard staff from secondary contamination. We therefore looked at consistency of facilities, equipment, and protection for staff. We then identified the number of departments satisfactorily able to treat stretcher and ambulant patients, and those able to treat ambulant patients only.

RESULTS

A total of 227 questionnaires from 261 departments (87%) were returned and used in the survey. There were similar response levels from all geographical areas.

Planning

Of the 227 departments who responded, 151 (66%) had a written plan. A total of 168 departments had decontamination premises and these were more likely to have a plan ($p<<0.001$, χ^2). Thus, of 113 departments with a decontamination room, 86 (76%) had a plan. Of 23 departments with a tent, 18 (78%) had a plan. Of four departments with a room and a tent, all (100%) had a plan. Of 28 departments with other premises, 19 (68%) had a plan. There were 59 departments who had no decontamination premises. Some 41% of these had a written plan (fig 1).

Premises

Of the 227 departments who responded, 168 (74%) had premises for decontamination. A total of 13 (50%) departments had a room, 23 (10%) had a tent, four (1.8%) had a room and a tent, and 28 (17%) had other premises, many of which were specified by respondents, for example, outside area, corridor, cubicle, etc. Altogether 59 (26%) departments had no decontamination premises. Only 55 (24%) departments had satisfactory premises—that is, with a separate dirty entrance and clean exit; sufficient polythene (or brown paper) and tape to seal the area if necessary; and a separate air circulation system. In most cases, rooms and other premises were not ideal. Departments with a tent were the most likely to have satisfactory arrangements (96%, $p<<0.001$, χ^2) (fig 2).

Decontamination equipment

Table 1 shows the relation between the type of equipment and premises. Of the 227 departments who responded, very few (18 or 8%) had equipment for dry vacuuming. A total of 146 (64%) departments had a shower (or showers) or hose—deemed to be essential, see "blueprint". (Some alternative arrangements for washing, for example, paddling pool, were cited.) Eighty seven (38%) departments had specialised drainage. Altogether 137 (60%) departments had shower gel/

Table 4 Departments with satisfactory premises and full protection for staff

	Room	Tent	Room and tent	Other	Total
Satisfactory premises	26	22	1	6	55
Full protection	11	14	0	1	26

Of 227 departments, 55 (24%) had satisfactory premises of which 26 (11%) had full protection for staff.

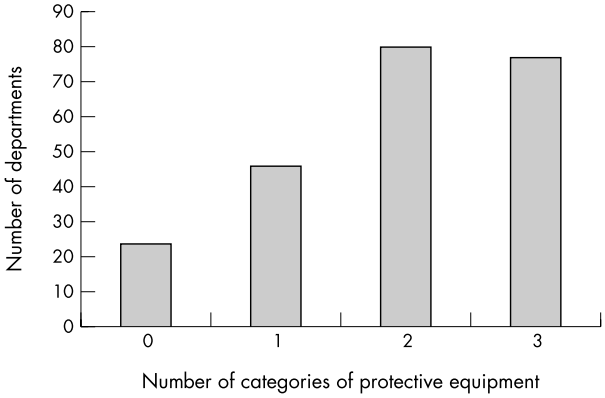

Figure 3 Number of categories of protective equipment (goggles; protective clothing; breathing apparatus) held by each department.

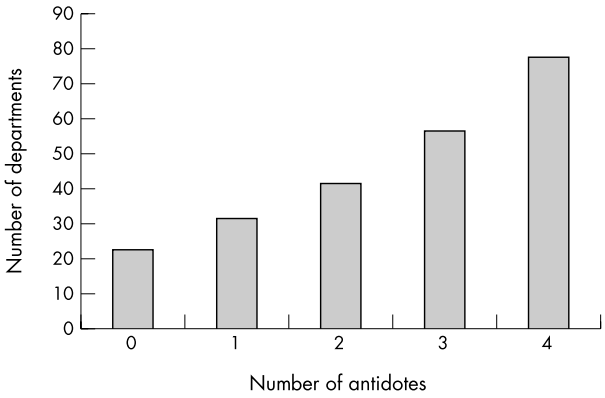

Figure 4 Number of types of antidote to cyanide held by each department.

shampoo/soap—one or more—which we also considered to be essential. Sixty (26%) departments had a decontamination trolley, essential for treating stretcher patients. Table 2 shows departments with satisfactory premises and essential decontamination equipment. Of the 227 departments who responded, 49 (22%) had both satisfactory premises and a shower. Thirty four (15%) departments had satisfactory premises in conjunction with both a shower and shower gel. Only 16 (7%) departments had a decontamination trolley in conjunction with suitable premises and only 13 (6%) also had a shower and shower gel.

Protection for staff

Of the 227 departments who responded, 198 (87%) had goggles. A total of 145 (64%) departments had protective clothing for staff. Ninety four (41%) departments had breathing apparatus. The relation between decontamination premises and possession of protective equipment for staff is shown in table 3. Goggles were the most widely held category of protective equipment. Figure 3 shows the distribution of the categories of protective equipment between departments. Thus, 24 (11%) departments had no protective equipment; 46 (20%) departments had one category of protective equipment; 80 (35%) departments had two categories; only 77 (34%) had all three categories, namely goggles, protective clothing, and breathing apparatus. Only 26 (11%) departments had all three categories in conjunction with satisfactory premises (table 4). Of these, only seven (3%) departments had satisfactory equipment including a decontamination trolley.

Specific antidotes to cyanide

Table 5 shows that many departments hold antidotes to cyanide regardless as to whether or not they have premises for decontamination. Dicobalt edetate was the most widely stocked antidote and was held by 182 of the 227 departments who responded. Of those, 21 departments held it as their sole antidote. There were 10 other departments who held only one antidote of which seven held sodium thiosulphate as sole agent and three held amyl nitrite. A more detailed analysis of the data showed that 22 (10%) departments had no antidotes; 31 (14%) had one antidote; 41 (18%) had two antidotes; 56 (25%) had three antidotes; and 77 (34%) had four antidotes (fig 4). Of the 227 departments who responded, only 19 (8%) departments had satisfactory premises, full protection for staff (that is, all three categories of protective equipment) and at least three of four antidotes. Of these, only five (2%) departments had satisfactory equipment including a decontamination trolley.

Number of casualties able to be decontaminated in two to three hours

The estimates for the number of casualties able to be decontaminated in two to three hours (assuming no life threatening injuries) varied from zero to 50. Five departments cited actual incidents where they had decontaminated 1, 1, 5, 11, and 50 patients respectively. One of these incidents resulted in secondary contamination of members of staff and premises and the closure of the resuscitation room.

Geographical distribution of satisfactory premises

Many departments identified themselves. Of these, there was one department with satisfactory premises in Cleveland, one in Cumbria, one in Hampshire, one in Hereford, one in Hertfordshire, two in Kent, two in Lancashire, three in Lincolnshire, four in London, one in Merseyside, one in Norfolk, one in North Yorkshire, one in Shropshire, one in Somerset, two in South Yorkshire, one in Suffolk, one in Tyne and Wear, three in

Table 5 Decontamination premises and antidotes to cyanide

	Room	Tent	Room and tent	Other	None	Total	%
Premises	113	23	4	28	59	227	
Amyl nitrite	61	16	3	18	28	126	56
Sodium thiosulphate	83	17	4	19	38	161	71
Dicobalt edetate	95	21	4	21	41	182	80
Sodium nitrite	59	15	3	16	26	119	52

The percentage of departments possessing each type of antidote is shown in the last column.

West Midlands, two in Northern Ireland, two in Scotland, and one in Wales.

DISCUSSION

Our results suggest that more than 90% of accident and emergency departments in the UK are currently unable to manage a serious chemical incident. Seventy six per cent did not have satisfactory premises. Sixty six per cent could not adequately protect their staff. Ninety seven per cent departments could not decontaminate "stretcher" patients safely. Ninety eight per cent could not manage a "stretcher" patient contaminated by cyanide.

A similarly parlous state of affairs was found by Horby *et al* who recently conducted a detailed, high quality audit of the capability of accident and emergency departments in six health regions in England to decontaminate.[4] Some of the similarities between the results of this audit and our own are worth noting and justify Horby's suggestion that the situation in these six health regions might be representative of that in the UK generally. In our study 66% departments had a written plan compared with 71% departments in Horby's study. Seventy four per cent of departments in our study had premises (rooms, tents, other) for decontamination compared with 77%—this is a derived value—in Horby's study. The audits of suitability of premises and protective equipment are not directly comparable because slightly different criteria were used. None the less, it is of interest that Horby *et al* judged that only 10% units in their study had decontamination premises and adequate personal protection for staff while, according to our criteria, we found that 11% units in the UK had satisfactory premises and protection for staff.

With respect to cyanide poisoning, the UK guidance advocates that when sodium nitrite is used it should be followed by sodium thiosulphate. Dicobalt edetate can be used as sole agent but it is toxic in the absence of cyanide ions and can only be used in the case of very severe poisoning.[6] Amyl nitrite can be given by inhalation as a first aid measure. Thus, the possession of most or all of the available antidotes confers flexibility of management. It was therefore a matter of concern that 22 departments had no antidotes to cyanide; 21 departments held dicobalt edetate as sole agent and could only treat patients with proven cyanide poisoning who were in extremis; and that seven held sodium thiosulphate as sole agent without sodium nitrite. (Hydroxocobalamin is not yet available in the UK.)

No department scored full marks on our questionnaire although there were a few that only lacked one item. Unfortunately, in many cases, the choice of equipment was inconsistent, for example, there were departments with a decontamination trolley but no decontamination premises; departments with antidotes to cyanide but no protection for staff. It is self evident that, in most cases, the current situation is unsafe. National agreement is required as to premises, essential equipment, staff protection, and recommended stocks of antidotes to poisons. When these important points are decided, measures will be needed to ensure that trusts comply.

Contributors

GG designed the audit and questionnaire, assisted by the other authors. All authors prepared and mailed questionnaires. DV and GG collated the data and GG wrote the paper. The authors would like to thank Mr Bryan Todd and Dr Alasdair Coles for criticising the manuscript and for assistance with data presentation and statistics.

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