A Suggested Approach to the Selection of Chemical and Biological Protective Clothing—Meeting Industry and Emergency Response Needs for Protection Against a Variety of Hazards

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The paper describes the development of a comprehensive decision logic for selection and use of biological and chemical protective clothing (BCPC). The decision logic recognizes the separate areas of BCPC use among emergency, biological, and chemical hazards. The proposed decision logic provides a system for type classifying BCPC in terms of its compliance with existing standards (for emergency applications), the overall clothing integrity, and the material barrier performance. Type classification is offered for garments, gloves, footwear, and eye/face protection devices. On the basis of multiple, but simply designed flowcharts, the type of BCPC appropriate for specific biological and chemical hazards can be selected. The decision logic also provides supplemental considerations for choosing appropriate BCPC features.

biological protective clothing chemical protective clothing emergency response industrial protection selection, decision logic

1. INTRODUCTION

Many regional directives require that the employer conduct a hazard assessment to identify hazards and then base protective clothing (and equipment) selections on the information from the hazard assessment [1, 2]. Unfortunately, in the absence of specific information for applying BCPC standards there is little guidance provided for selecting the correct BCPC. While several manufacturers have created selection guides for either clothing or gloves, these guides are specific to the manufacturer's product offering. There is no current comprehensive selection guide that covers the full range of BCPC. In the USA, the National Institute for Occupational Safety and Health (NIOSH) undertook a project to develop a decision logic to aid in the selection of BCPC [3]. The aim of this project was to provide a simple series of flowcharts involving decisions that end users could readily make through information gathered in their hazard assessments of specific workplaces. A further goal of the project was to provide BCPC choices that could be readily identified based on key characteristics or available standards. In the paper, the results of this project have

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been modified to reference international standards where available, and refer to regional standards, only in the absence of international standards. The decision logic may be adapted to accommodate regional standards, when the same BCPC performance features are matched with appropriate regional standards.

2. DECISION LOGIC DEVELOPMENT

The following steps were used for developing a BCPC decision logic in the project.

1. The scope of the decision logic was determined.
2. Key factors in making BCPC selection and use were identified.
3. The expected output of the decision logic was defined.
4. The necessary inputs to the decision logic were established.
5. The hierarchy for the decision logic was created.

3. DECISION LOGIC SCOPE

The field of BCPC is especially broad. In order to realize the objective of this project, it was necessary to carefully define the scope of the decision logic. For example, the decision logic was required to deal with both biological and chemical hazards; however, healthcare applications were excluded (with the exception of emergency medical services as part of a chemical response). It was also decided to omit cleanroom applications where the key consideration is protection of the environment. However, the decision logic as developed was applied to both emergency and non-emergency situations though separate decision trees for each type of application. Therefore, the decision logic covers a large number of BCPC applications, ranging from industrial chemical situations to biosafety in laboratories to first responders at a chemical spill. The decision logic is also intended to be potentially useful as much for planning, in the procurement of protective clothing, as it is for actual selection decisions in the field, when organizations must decide on the appropriate PPE for a particular situation.

4. IDENTIFICATION OF KEY BCPC SELECTION AND USE FACTORS

With the exception of cost, the primary factors affecting BCPC selection were considered in the development of a decision logic. When based on performance, these factors include:

- Clothing integrity,
- Material barrier properties,
- Physical ruggedness and durability (single-use versus reusable products),
- Ease of decontamination, cleaning, or sterilization,
- Protection from other hazards,
- Integration with other equipment,
- Impact on wearer.

There are also a number of design attributes to be considered, but for the purpose of this effort, product design features were considered options for specific categories of BCPC. In this fashion, the decision logic does not become design-restrictive.

5. DEFINITION OF EXPECTED DECISION LOGIC OUTPUTS

A key part of developing the BCPC decision logic was to classify biological and chemical protective clothing to serve as the outputs of any decision making process. Both the International Safety Equipment Association

(ISEA) in the USA and the European Committee for Standardization (CEN) have proposed systems for classifying chemical protective clothing based on overall integrity and material chemical resistance performance. These regional systems, taking into account related elements for biological protection against both airborne and liquidborne hazards, form the basis of the available types of protective clothing to choose from.

Existing clothing standards, such as ISO 16602:2004 [4] and the various National Fire Protection Association (NFPA) standards on emergency responder clothing, were specified where available, but specifications did not exist to fill the entire range of BCPC covered in all applications and for all parts of the body. To complete the range of BCPC choices, a classification system was developed based on the two selection factors associated with barrier protection—product integrity and material barrier performance. In addition, it was necessary to establish different classes for chemical and biological hazards (based on the differences in exposure).

For each type of protection offered or protection level, acceptable product designs must be identified spanning the different types of BCPC to be used (full-body garments, partial body garments, gloves, footwear, and eye/face protection). Tables 1 through 3 provide the specific types of emergency, biological, and chemical protective clothing, which are the possible outputs or "choices" of the decision logic. The BCPC designations used in these tables are used throughout the flowcharts for specific BCPC choices.

TABLE 1. Emergency Protective Clothing Choices

Type	General Description/Clothing Items	Integrity	Material Barrier
E1	Vapor protective suit with attached gloves; footwear, covers wearer and respirator (meets NFPA 1991: 2000 [5] or EN 943-2:2002 [6])	Gas/vapor (passes inflation test) Liquid (passes sustained shower test)	Permeation-resistant to 21-chemical battery (garment, visor, gloves, footwear, seams)
E1a	Type E1 suit also providing flash fire escape protection	Same as above	Same as above
E1b	Type E1 suit also providing liquefied gas protection	Same as above	Same as above; also against 6 liquefied gases in liquid form
E1c	Type E1 suit with providing both flash fire escape and liquefied gas protection	Same as above	Same as above
E2	Encapsulating liquid splash-protective suit, with gloves, footwear (meets NFPA 1992:2000 or EN 466:1995 [17])	Liquid (passes shower test)	Penetration-resistant to 7-chemical battery (garment, visor, gloves, footwear, seams)
E2a	Type E2 non encapsulating suit, separate gloves and footwear	Same as above	Same as above
E2b	Type E2 suit also providing flash fire escape protection	Same as above	Same as above
E3(1)	Protective ensemble consisting of encapsulating suit with attached gloves, also footwear (meets NFPA 1994:2001 [3], Class 1)	Gas/vapor (passes inflation test and inward leakage <0.02%)	Permeation resistant to 9 liquid and gas chemical battery (high exposure level)

TABLE 1. (*continued*)

Type	General Description/Clothing Items	Integrity	Material Barrier
E3(2)	Protective ensemble consisting of encapsulating suit with attached gloves, also footwear (meets NFPA 1994:2001 [3], Class 2)	Gas/vapor (inward leakage <0.02%) Liquid (passes shower test)	Permeation resistant to 9 liquid and gas chemical battery (moderate exposure level); Viral penetration-resistant
E3(3)	Full body garment, may or may not cover wearer respirator; separate gloves and footwear (meets NFPA 1994:2001 [3], Class 3)	Liquid (passes short-term shower test)	Permeation resistant to 5 liquid chemical battery (low exposure level); Viral penetration-resistant
E4a	Full-body or partial body garments (meets NFPA 1999:2003 [14] or EN 14126:2004 [15])	Liquid (passes short-term shower test)	Viral penetration-resistant
E4b	Gloves, disposable (meets NFPA 1999:2003 [14], EN 374 :2003 [18] or EN 455:2000 [19])	Liquid (no leaking when filled with liquid)	Viral penetration-resistant
E4c	Face protection devices (meets NFPA 1999:2003 [14])	Liquid (spray impact)	Viral penetration-resistant

TABLE 2. Biological Protective Clothing Choices

Clothing Item	Type	General Description	Integrity	Material Barrier
Garments	B1	Total encapsulating suit, covers both wearer and breathing apparatus	Particulate (passes inflation test)	Viral penetration-resistant
	B2	Hooded coverall, multi-piece clothing outfit	Particulate (resists inward leakage)	Particulate penetration-resistant
	B3	Coverall, gown, smock, apron, sleeve protector, boot/shoe covers	Liquid (passes sustained shower test)	Viral penetration-resistant
	B4	Coverall, gown, smock, apron, sleeve protector, boot/shoe covers	Liquid (passes shower test)	Fluid penetration-resistant
	B5	Coverall, gown, smock, apron, sleeve protector, boot/shoe covers	Covers body area of interest	Fluid-repellent
Gloves	BG1	Unsupported glove	Liquid (will not leak when filled with liquid)	Viral penetration-resistant
	BG2	Unsupported glove	Liquid (will not leak when filled with liquid)	Fluid penetration-resistant
Footwear	BF1	Boot, over boot or over shoe, boot or shoe cover	Liquid (will not leak when filled with liquid)	Viral penetration-resistant

TABLE 2. (*continued*)

Clothing Item	Type	General Description	Integrity	Material Barrier
	BF2	Boot, over boot or over shoe, boot or shoe cover	Liquid (will not leak when filled with liquid)	Fluid penetration-resistant
	BF3	Boot or shoe cover	Covers foot/ankle area	Fluid-repellent
Eye/face protection	BE1	Hood with visor or respirator full facepiece	Gas/vapor, particulate (resists inward leakage)	Viral penetration-resistant
	BE2	Respirator full facepiece	Particulate (resists inward leakage)	Fluid penetration-resistant
	BE3	Faceshield or faceshield with goggles	Liquid splash-resistant	Fluid penetration-resistant
	BE4	Faceshield	Covers face area	Fluid penetration-resistant
	BE5	Face mask	Covers face or part of face area	Fluid-repellent

TABLE 3. Chemical Protective Clothing Choices

Clothing Item	Type	General Description	Integrity	Material Barrier
Garments	C1	Total encapsulating suit, covers both wearer and breathing apparatus	Gas/vapor (passes inflation test)	Permeation-resistant
	C2	Total encapsulating suit, covers both wearer and breathing apparatus	Gas/vapor (cannot be inflation tested, but passes inward leakage test)	Permeation-resistant
	C2v	Total encapsulating suit, covers both wearer and breathing apparatus	Gas/vapor (cannot be inflation tested, but passes inward leakage test)	Vapor-penetration-resistant
	C3	Hooded coverall, multi-piece splash suit (e.g., hooded jacket with pants or bib pants)	Liquid (passes sustained shower test)	Permeation-resistant
	C3p	Partial body clothing items: apron, jacket, hood, pants, overalls, sleeve protector, shoe/boot cover	Liquid (for body area covered by item)	Permeation-resistant
	C4	Hooded coverall, multi-piece splash suit (e.g., hooded jacket with pants or bib pants)	Liquid (passes shower test)	Liquid penetration-resistant
	C4p	Partial body clothing items: apron, jacket, hood, pants, overalls, sleeve protector, shoe/boot cover	Liquid (for body area covered by item)	Liquid penetration-resistant

TABLE 3. (*continued*)

Clothing Item	Type	General Description	Integrity	Material Barrier
	C5	Hooded coverall or encapsulating suit, may not cover breathing apparatus	Particulate (provides acceptable particle hold out)	Particulate penetration-resistant
	C6	Coverall, jacket/pant sets	Covers body area of interest	Liquid-repellent
	C6p	Partial body clothing items: apron, jacket, hood, pants, overalls, sleeve protector, shoe/boot cover	Covers body area of interest	Liquid-repellent
Gloves	CG1	Unsupported, supported, or flat-film glove	Gas/vapor (can be air tested)	Permeation-resistant
	CG2	Unsupported, supported, or flat-film glove	Liquid (will not leak when filled with liquid)	Liquid penetration-resistant
	CG3	Supported glove	Coves hand/wrist area	Liquid penetration-resistant
Footwear	CF1	Boot, overboot, or boot/shoe cover	Gas/vapor (can be air-tested)	Permeation-resistant
	CF2	Boot, overboot, or boot/shoe cover	Liquid (will not leak when filled with liquid)	Liquid penetration-resistant
	CF3	Boot/shoe cover	Covers foot/ankle area	Liquid-repellent
Eye/face protection	CE1	Hood with visor or respirator full facepiece	Gas/vapor, particulate (resists inward leakage)	Permeation-resistant
	CE2	Hood with visor or respirator full facepiece	Gas/vapor, particulate (resists inward leakage)	Penetration-resistant
	CE3	Faceshield or faceshield with goggles	Liquid splash-resistant	Penetration-resistant
	CE4	Faceshield	Covers face area	Penetration-resistant

6. DEFINITION OF NECESSARY DECISION LOGIC INPUTS

The inputs to the decision logic must come from a hazard assessment. The hazard assessment identifies:

- The type of hazard(s) present in the workplace,
- The form of exposure to the type of hazard,
- The severity of the hazard (or potential consequences of exposure),
- The portions of the body that are likely to come in contact with the hazard.

In addition, the hazard assessment must account for the characteristics of the work environment and the type or nature of the activity that is being performed. Important considerations include:

- The work place location (indoors or outdoors),
- Presence of other hazards (heat, cold, physical, etc.),
- The requirements of the task (as may be affected by using BCPC),
- The length of the task.

The net result of the hazard assessment must be information that can serve as input to the decision logic. However, at the same time, the inputs to the decision logic must include the essential elements of the hazard assessment while some information must be relegated to secondary decisions for choosing BCPC.

The input information required by the decision logic is structured to be readily determined by individuals responsible for making clothing selection and use decisions. Some of this information may require some research (obtaining data about a specific substance), but can be obtained within a reasonable amount of time.

7. CREATION OF DECISION LOGIC HIERARCHY

The decision logic design is based on a simplified flowchart format. This format includes boxes for operations or information gathering steps, diamonds for decisions, and rounded rectangles for output. The format clearly identifies inputs, decisions, and output. Since the decision logic covers a wide range of information needs, decisions, and BCPC types, the process is illustrated on multiple pages allowing different branching that is difficult to organize into a single flowchart. It also includes tables when multiple factors need to be considered in selecting BCPC. As the primary decision logic focuses on BCPC integrity and barrier properties, other BCPC factors can be accounted for separately in supplemental checklists to further provide discrimination of BCPC selection decisions.

A critical part of the design of the decision logic is the provision of explanatory information and definitions. For each step of the process, relevant notes and definitions are provided on or near the specific page where the information is needed. Descriptive information is also provided as part of the decision logic.

8. USE OF THE DECISION LOGIC

The first branch of the decision is based on the general hazard classification as shown in Figure 1:

1. Emergency,
2. Biological,
3. Chemical.

The first decision is to determine if the situation is an emergency. If an emergency, then a separate decision logic is followed. This is primarily because specific BCPC standards are defined in this area, which help define the type of BCPC, and also because emergencies generally involve less characterized physical surroundings and environmental conditions.

If the situation or use of BCPC is not an emergency, then the second choice is whether the substances involved are biological or chemical. It is possible that a situation could involve both biological and chemical hazards. If this is the case, then the recommendation is made to go through both decision logic sequences and select the most protective based BCPC.

9. EMERGENCY RESPONSE DECISION LOGIC

As with the start of all of the selection guides, the decision logic begins with information

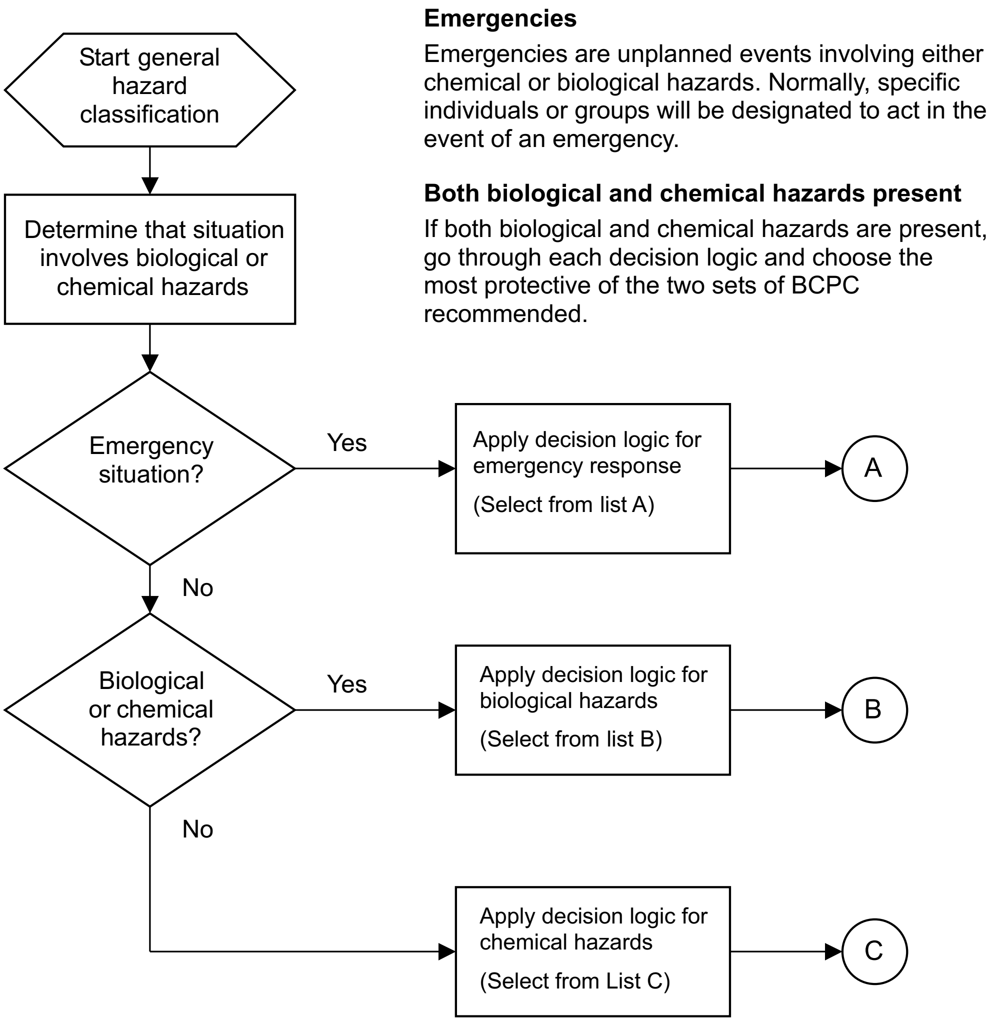


Figure 1. General hazard classification. *Notes.* BCPC—biological and chemical protective clothing.

gained from the hazard assessment. Because the circumstances involving an emergency response can be uncertain, the first branch occurs with identifying the hazards (Figure 2). If the hazards cannot be identified, then the question is posed whether site entry is needed. Usually site entry would only be required for rescue or if a specific intervention or mitigation task is required in the "hot" zone.

- If entry is not warranted, then no site entry is made and BCPC is not needed.
- If entry is required, then the highest level of performance, an NFPA 1991:2000 [5] or EN 943-2:2002 [6] compliant vapor-protective suit is suggested. Preferably, this suit should be equipped with flash fire escape protection.

Separate decisions are then needed to determine if there is a reactive hazard (explosion) based on the measurement of the lower explosive limit (LEL) and whether the situation presents a toxic threat. The latter would involve chemicals that at IDLH concentrations or are skin toxic chemicals. If toxic chemicals are not involved, then it is possible to respond in regular firefighter protective clothing (compliant with ISO 11613:1999 [7], ISO 15538:2001 [8],

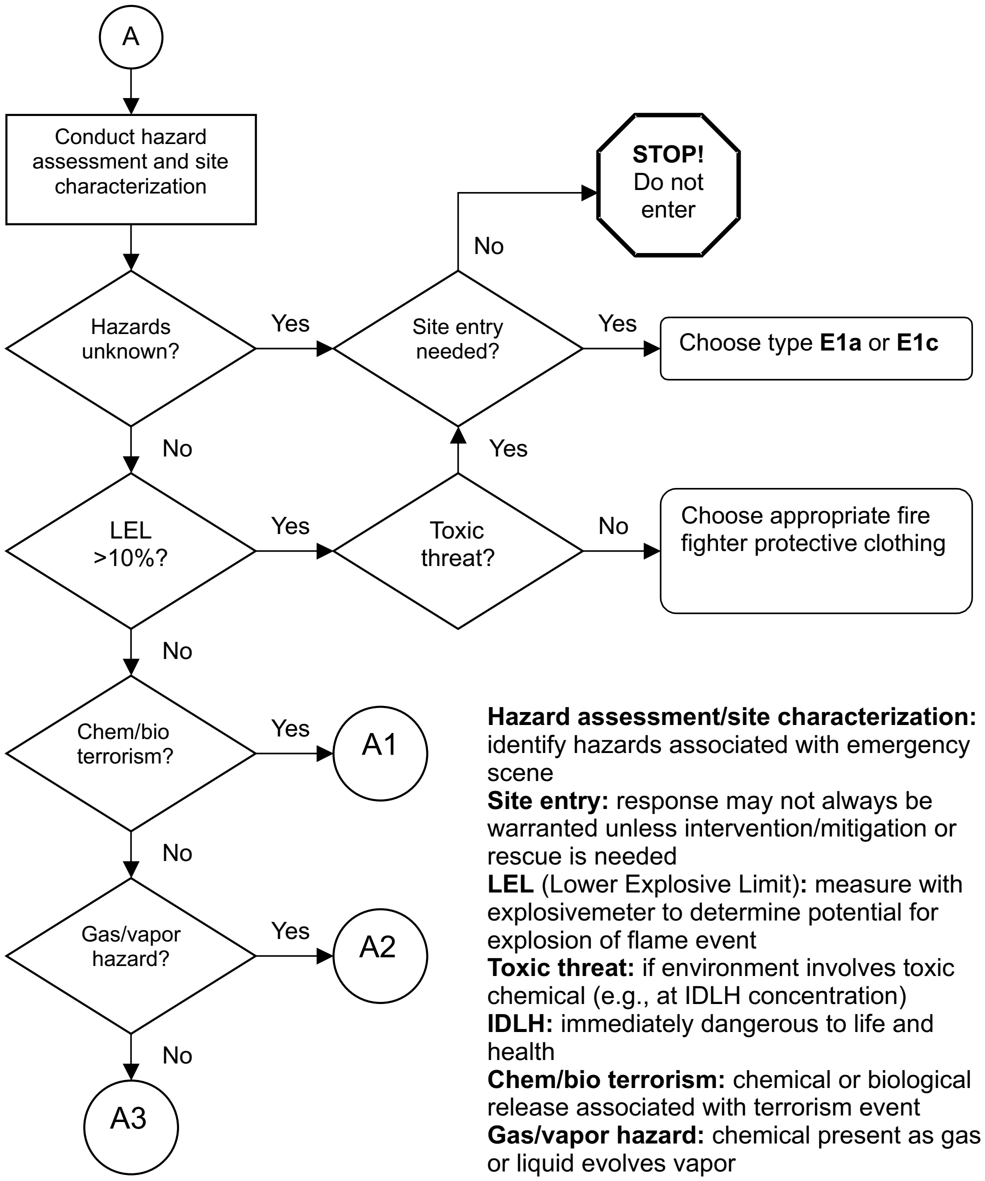


Figure 2. Step A: emergency response: part 1 (initial assessments).

EN 469:1995 [9], EN 1486:1996 [10], NFPA 1971:2000 [11], or NFPA 1976:2000 [12]).

Additional assessments are made for the identification of the incident as involving chemical or biological terrorism agents (Figure 3) or gas/vapor hazards (Figure 4).

- If chemical or biological terrorism agents are involved, a number of considerations are provided in tabular form (Table 4) to choose the appropriate class of NFPA 1994:2001 [13] compliant ensembles.
- If gas/vapor hazards are involved, separate determinations are made to determine if the vapor is toxic, flammable, or a liquefied gas. The answers to these questions determine the specific type of NFPA 1991:2000 [5] vapor-protective ensemble to use. (NFPA 1991:2000 includes different options for the certification of vapor-protective ensembles.)

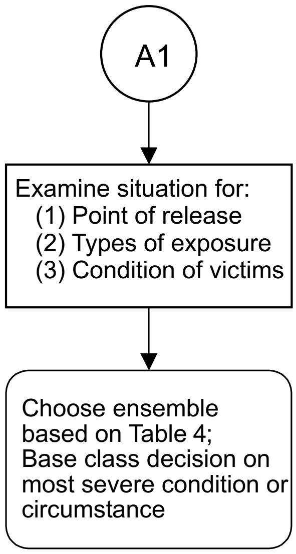


Figure 3. Step A1: select appropriate ensemble for chem/bio terrorism incident.

If none of the aforementioned characterizations apply, the decision tree focuses on liquid hazards (Figure 5). Specific determinations are made with regard to medical hazards (i.e., bloodborne pathogens) warranting use of NFPA 1999:2003 [14] or EN 14126:2004 [15] protective clothing, flammable liquids (warranting NFPA 1992:2000 [16], or EN 466:1995 [17], clothing that is also certified for flash fire escape protection), and the type of liquid exposure. Liquid exposures are characterized as “direct” or “indirect”:

- Direct exposures involve multiple splashes, large liquid volumes, or liquid contact under pressure.
- Indirect exposures involve a few splashes and incidental contact with no pressure.

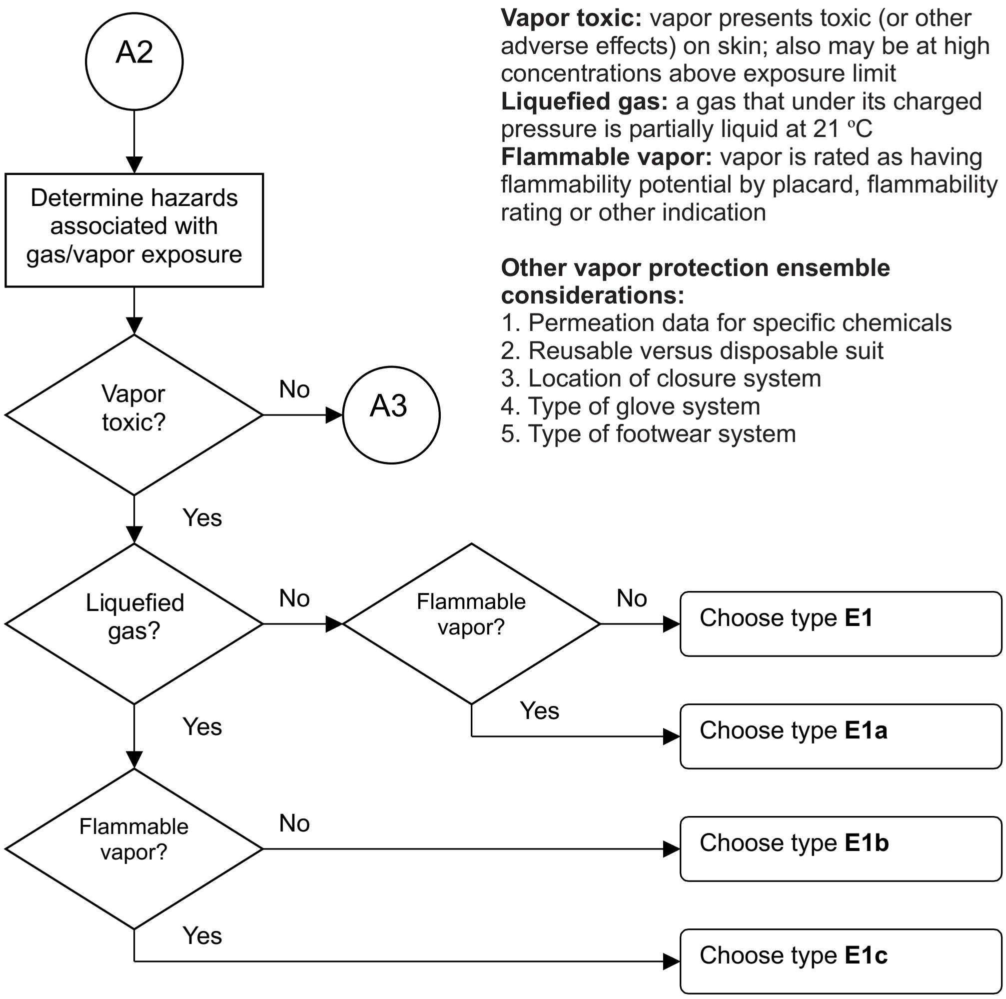


Figure 4. Step A2: select appropriate ensemble for vapor protection.

TABLE 4. Parameters for Choosing Emergency Protective Clothing for Chemical/Biological Terrorism Incidents

Class	Point of Release	Types of Exposure	Conditions of Victims
1 Type E3(1)	Responders close to point of release in both time and distance	Vapors and gases (high concentrations) Aerosols, liquid dispersions Liquid puddles Liquid containing pathogens	Most of victims dead or showing serious signs and symptoms
2 Type E3(2)	Responders separated from point of release by either time, or distance	Vapors and gases (low concentrations) Aerosols, liquid dispersions (low concentrations) Liquid residue Liquid containing pathogens	Majority of victims survive, but non ambulatory
3 Type E3(3)	Responders separated from point of release by both time and distance	Liquid residue Liquid containing pathogens	Mostly ambulatory

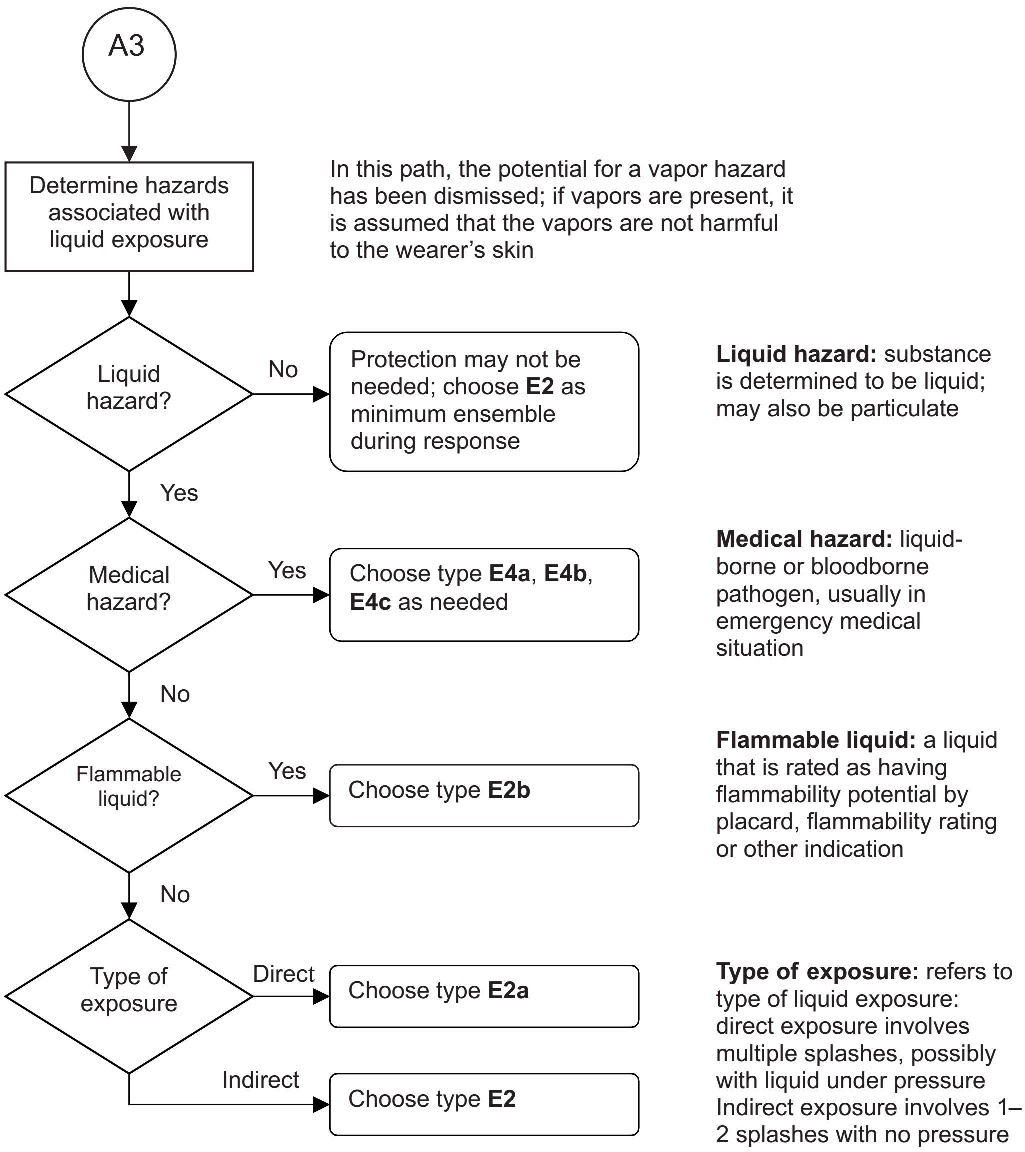
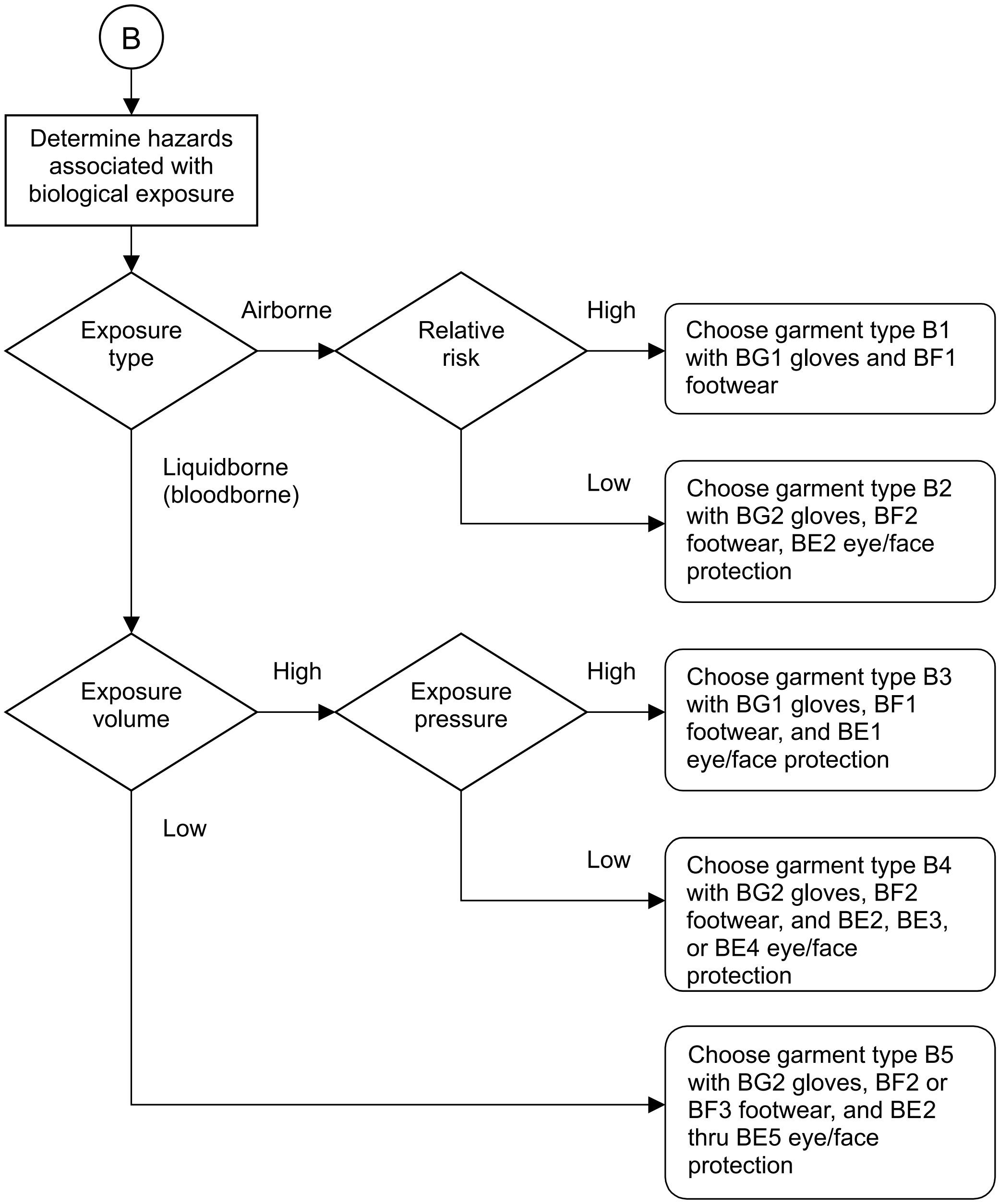


Figure 5. Step A3: select appropriate ensemble for liquid protection.



Exposure Type: differentiate between pathogens that are spread by air (including by coughing or sneezing) versus those that are spread by liquid contact, i.e., blood or body fluids
Relative Risk: risk of contact with pathogen. Many pathogens pose respiratory hazards only with no risk for disease or effects through skin contact. However, if work clothing or skin becomes contaminated by airborne pathogens and can be rereleased to wearer's respiratory system when unprotected, risk for dermal exposure is high. Likewise, some pathogens may provide cutaneous or dermal routes of exposure, especially to cuts or abrasions on wearer's skin
Exposure Volume: based on relative volume of liquidborne pathogens. Some organizations have suggested that 500 ml can be difference between high and low volume exposures. However, the decision between a high and low volume should be based relative to the pathogen of concern. Exposure volume may occur in single exposure or over multiple exposures in single wearing of BCPC item
Exposure Pressure: pressure in work task that may be accompanied by kneeling or leaning in contaminated liquid, or as might occur with release of fluid, such as spurting artery. Tasks involving these exposures would be considered high pressure. Low pressure involves minor contact with little or no force against contaminated fluids

Figure 6. Step B: select biological protective clothing.

All selection decisions end with either "no response" or use of an ensemble or BCPC that is compliant with the relevant standard. The minimum response clothing is an NFPA 1992:2000 [16] or EN 466:1995 [17] compliant set of protective clothing.

10. BIOLOGICAL HAZARDS DECISION LOGIC

A relatively simple decision logic is used for the selection of BCPC for biological hazards (Figure 6). The first decision is to determine whether the biological hazards are airborne or liquidborne (bloodborne). For airborne hazards, the relative risk associated with skin exposure is ranked with high or low. The input to this decision depends on several factors. Some airborne pathogens are primarily hazardous through inhalation and thus require respiratory protection. Nevertheless, for some of these pathogens, it is still desirable to keep the pathogens off of the skin, especially when in particulate form, as re-aerosolization of the pathogen can lead to wearer exposure once the respirator is removed. In these cases, it is important to cover the skin with some form of protective clothing; however, it is not essential that the protective clothing be viral penetration resistant.

Under more severe circumstances, the airborne pathogen may present cutaneous or dermal hazards. In these cases, a higher level of protection is needed to prevent any contact of the wearer with the pathogen. This may be achieved by using encapsulating suit that passes an inflation test. Under the worst case circumstances, there may be no reliable treatment for some pathogens, dictating the need for an encapsulating suit.

Selection of BCPC for liquidborne pathogens requires two general decisions, based on the volume of liquid encountered and the pressures involved in the exposure:

- High volume exposures dictate a more protective form of BCPC in terms of both the integrity provided and the material barrier performance.
- Exposures to liquidborne pathogens under pressure (such as kneeling or leaning against a fluid suspected to contain pathogens) also requires higher performing BCPC.

The resulting decision logic dictates one of three levels of BCPC for liquidborne pathogen exposures:

1. BCPC that offers liquid integrity demonstrated in a sustained "shower"- or "spray"-like test and materials that demonstrate viral penetration resistance.
2. BCPC that offers limited liquid integrity demonstrated in short-term shower test with materials that are fluid penetration resistant.
3. BCPC that covers the portion of the body that is intended for protection by the item with materials that are fluid repellent.

There are other variants of these liquid protective clothing items. For example, some garments may offer viral penetration resistance only in certain portions of the garment. These garments are so constructed as to permit greater comfort, but the end user may not always be certain of the intended areas of protection. Table 5 summarizes the test methods that can be used to demonstrate clothing integrity and material performance levels in the different categories.

11. CHEMICAL HAZARDS DECISION LOGIC

Selection of BCPC for chemical protection uses a more complex decision logic owing to the larger variety of hazards that may be

TABLE 5. Recommended Test Methods for Demonstrating Biological Protective Performance

Property	Test Method	How Applied
Integrity	Inflation: use ISO 17491:2002 [20], Method A	Use minimum pressure drop to determine acceptable suit performance
	Inward leakage of aerosols: Devise test with aerosol challenge (see ISO 17491:2002 [20], Method B)	Determine acceptable levels of leakage based on biological hazard
	Liquid: ISO 17491:2002 [20], Method D	Permit no water spotting of inner test garment
	Liquid (short duration): ISO 17491:2002 [20], Method F	Permit no water spotting of inner test garment
Barrier	Viral penetration resistance: ISO 16604:2004 [21]	Require no viral penetration
	Fluid penetration resistance: ISO 16603:2004 [22]	Set minimum acceptable penetration pressure
	Particulate penetration resistance: ISO 22612:2004 [23]	Base filtration efficiency on particulate hazards
	Fluid resistance: ISO 22610:2004 [24]	Set minimum weight of penetrating fluid

encountered. For this area, a modified form of the type classification system proposed in ISO 16602:2004 [4] is used. This scheme provides six different types of BCPC, which were previously defined in Table 2 using different levels of garment integrity and material barrier performance. Included among this scheme are the following BCPC types for chemical protection:

- Type 1—Encapsulating vapor-protective suits that can be inflation tested and use permeation-resistant materials,
- Type 2—Encapsulating vapor-protective suits that offer inward leakage resistance (cannot be inflation tested) and use permeation-resistant materials,
- Type 2v—A variation of Type 2 that used vapor penetration-resistant materials,
- Type 3—A clothing outfit that offers liquid protection demonstrated through a sustained shower test and uses permeation-resistant materials,
- Type 4—A clothing outfit that offer liquid protection based on a shower test and liquid-penetration resistant materials,
- Type 5—A clothing outfit that provides resistance particulate inward leakage with materials that also resistant particulate penetration,
- Type 6—A clothing outfit that offers limited liquid protection based on body coverage and liquid repellent materials.

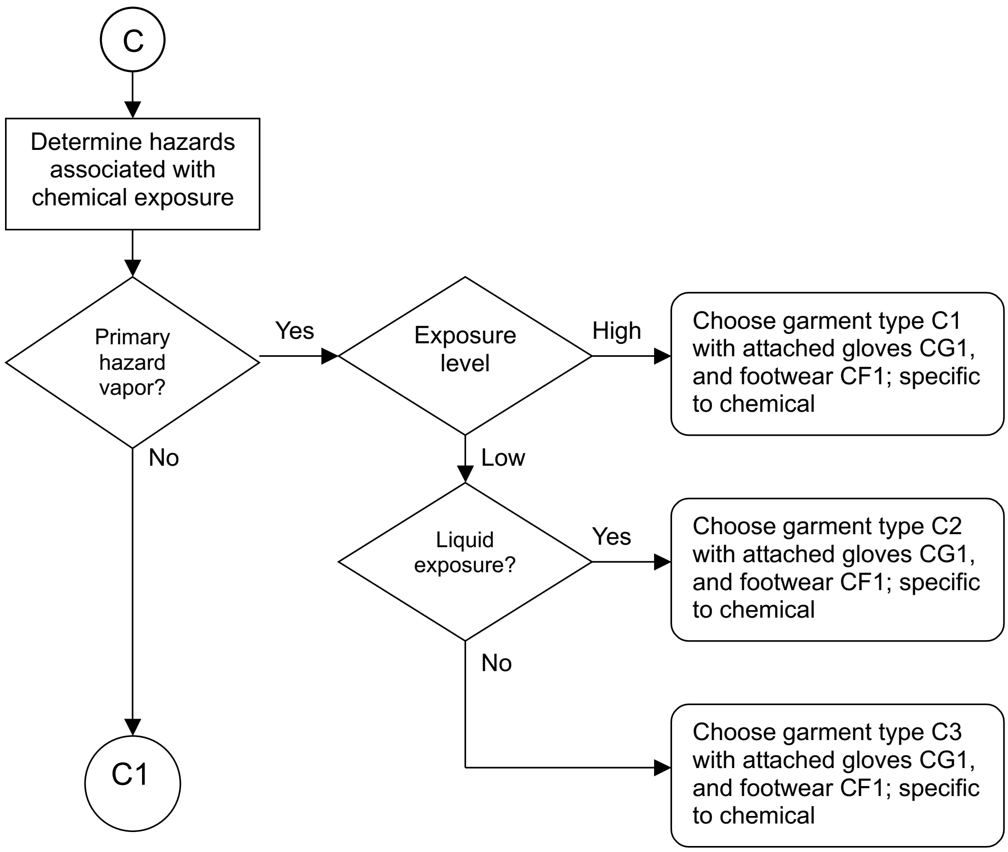
There are also variations for Types 3, 4, and 6 that involve partial body clothing items with the specific BCPC item providing the same integrity and material barrier performance, but only for the portion of the body that is covered by the item (e.g., a sleeve protector provides liquid protection for the arm area only).

Concurrent with the definition of garment types are a similar array of defined BCPC types for gloves, footwear, and eye/face protection. In general, there are fewer types for these items; however, they are matched in the decision logic with garment types so that the end user can choose those items that are needed to provide the desired areas of body protection. This approach also reinforces the concept that chemical protection often requires an ensemble of BCPC and related equipment.

For selecting BCPC for chemical protection, the initial decisions are based on the principal hazard presented by the chemical(s) in terms of the physical state encountered. Consequently, chemical hazards are classified as:

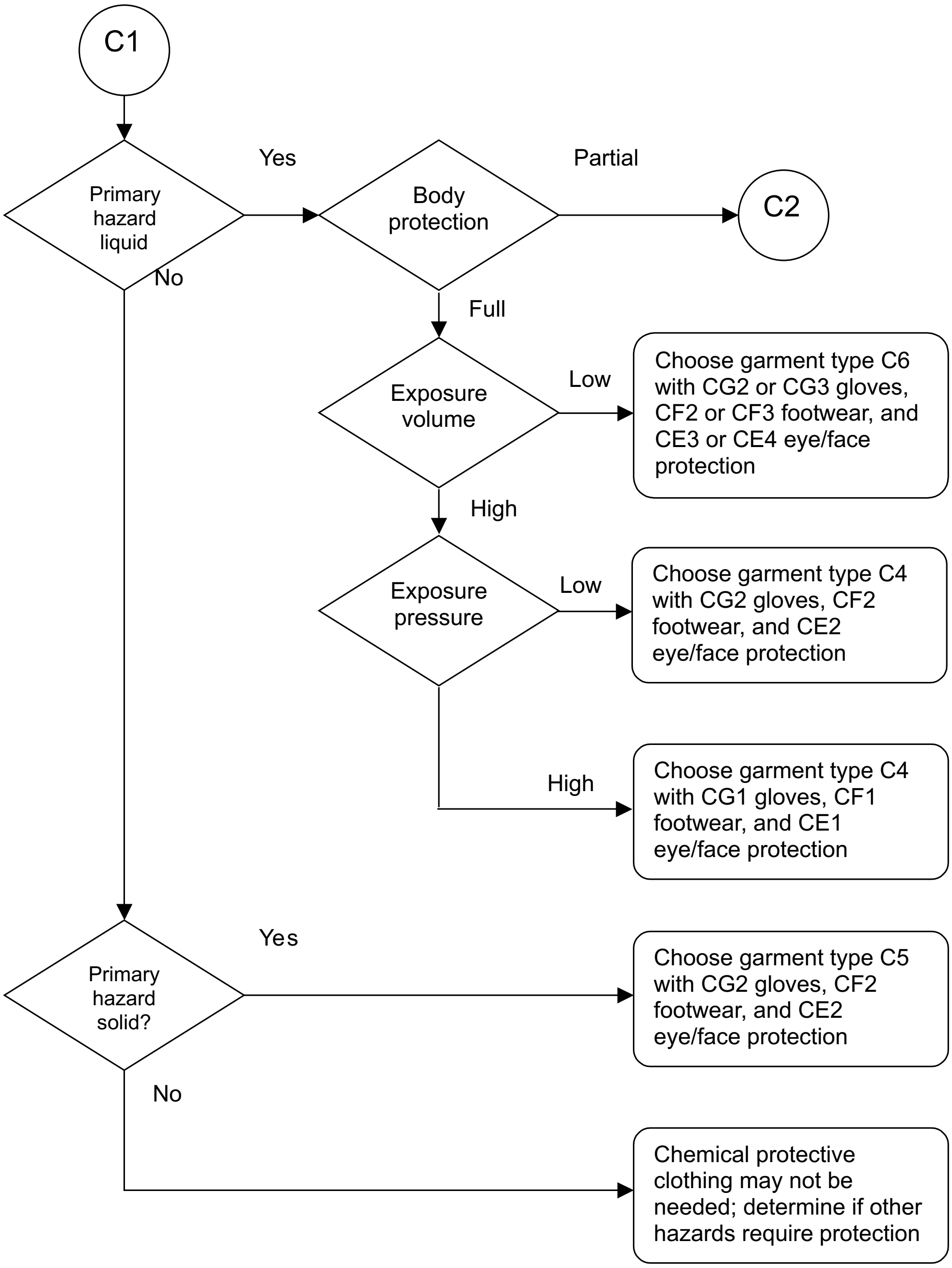
- Vapor hazards,
- Liquid hazards,
- Particulate hazards.

If vapor hazards are present (Figure 7), the BCPC selected is based on exposure level and whether liquid will also be present. For vapors at high exposure levels (as determined by the relative concentration of the chemical vapor as compared to an established exposure limit), then the most protective BCPC level—Type 1 is suggested. For lower exposure levels, Type 2 clothing may be acceptable and the variant level, Type 2v, may be used when there is no potential for liquid exposure. This is because Type 2v materials are based on adsorbents that work well for capturing some chemicals but quickly become saturated during a liquid exposure. At the current time, this type of



Primary Vapor Hazard: if principal hazards associated with chemical exposure occur via gas, vapor, or vapor associated with liquid
Exposure Level: judge exposure level based on concentration of gas or vapor in air at work site; compare to exposure limits set using those permitted by the regional health and safety organization for your area, or other action levels appropriate to organization; also applies to chemicals known to be toxic through skin absorption
Liquid Exposure: if liquid is also present and if potential also exists for direct exposure to liquid; this is significant because liquid may saturate capability of resistant garment in preventing vapor penetration

Figure 7. Step C: select chemical protective clothing.



Primary Liquid Hazard: if principal hazard associated with chemical is through liquid contact, may be continuous, or via splashes; does not pertain to complete immersion, except for portions of hands and feet
Body Protection: distinguish between protection of full body, requiring ensemble of clothing and equipment, or partial body protection, such as protecting the hands, feet, or front torso, where partial body garments would be used
Exposure Volume: based on relative volume of liquid chemical. Some organizations have suggested that 500 ml can be difference between high and low volume exposures. However, the decision between a high and low volume should be based relative to the chemical of concern. Exposure volume may occur in single exposure or over multiple exposures in single wearing of BCPC item
Exposure Pressure: pressure in work task that may be accompanied by kneeling or leaning in chemical, or as might occur with release of chemical, such as from burst pipe. Tasks involving these exposures would be considered high pressure. Low pressure involves minor contact with little or no force against chemicals
Principal Particulate Hazard: principal hazard is from particulates, that either pose hazard by direct contact or reaction with the skin, or by their re-release to the atmosphere and exposure to the wearer’s respiratory system. Does not include nuisance particles such as dust, dirt, or debris

Figure 8. Step C1: select full-body chemical protective clothing for liquid and particulate hazards.

clothing is not very common in industry, though it is extensively used in the military and may have application for agricultural pesticide operations.

If liquid hazards are the principal hazards faced (Figure 8), then a decision logic similar to BCPC selection for liquidborne pathogens is used. In this approach, the respective type of BCPC (Types 3, 4, and 6) are based on the volume of liquid that occurs during the exposure and if the liquid exposure involves pressure. One other decision involves whether full body or partial body protection is desired. The variants of the three types pertaining to partial body protective clothing are specified if only partial body area protection is needed (Figure 9).

Particulate protection is provided by one type of outfit that is defined for environments where exposure to the particulate is harmful. This includes particulates that primarily present respiratory hazards, which should be kept off the wearer's skin as a matter of hygiene and prevention of re-exposure, and particulates that affect the skin either through dermal absorption or reactivity concerns. No

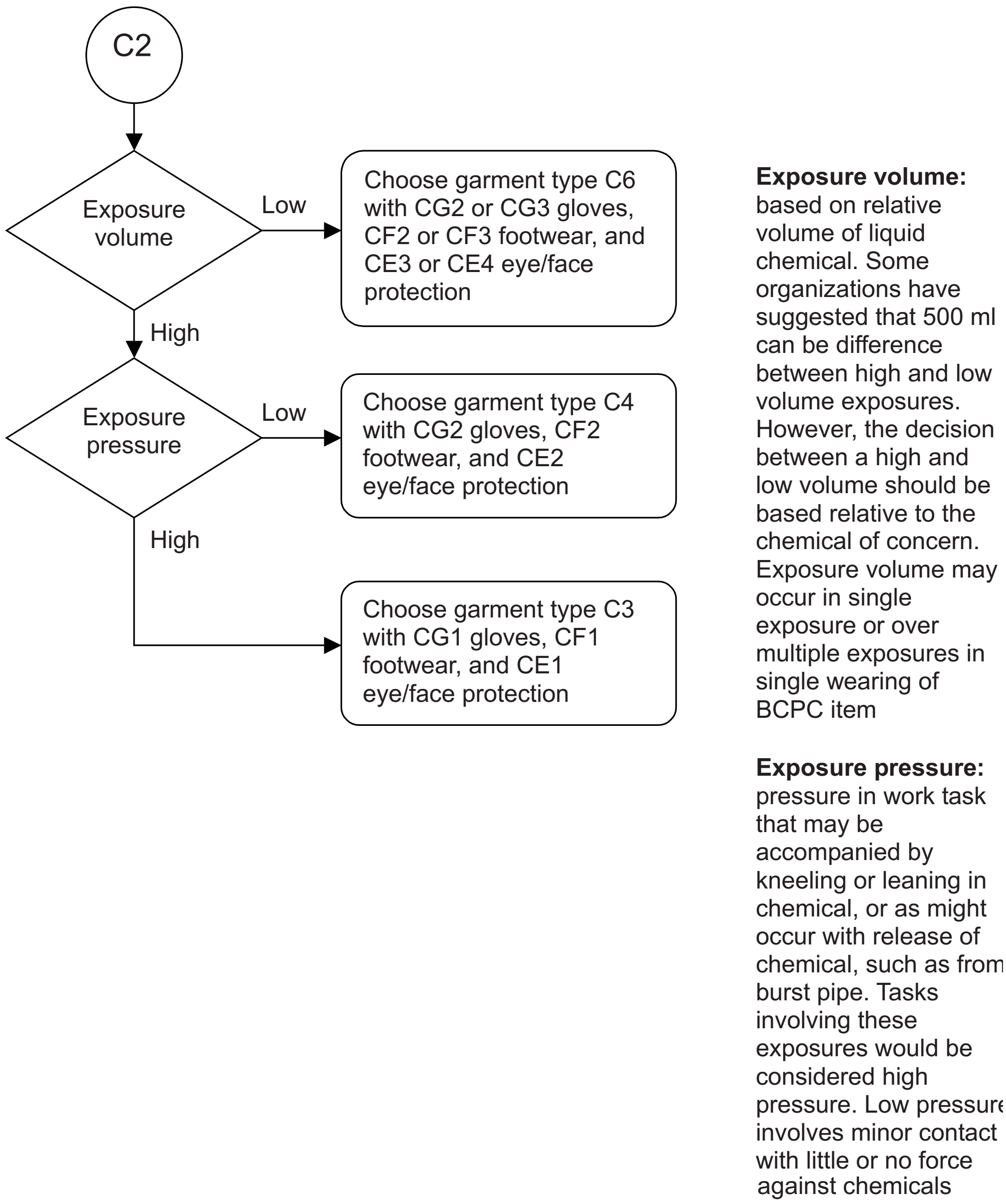


Figure 9. Step C2: select partial-body chemical protective clothing for liquid.

distinction is made with particulate exposures for substances that are considered nuisance materials (dust, dirt, or debris), as these substances are not considered chemical hazards.

Parallel decisions are made with respect to gloves, footwear, and eye/face protection as these items are used in conjunction with garments or by themselves depending on the protection needed as defined in hazard assessment.

12. SUMMARY

The decision logic described in this paper recognizes the separate areas of BCPC use among emergency, biological, and chemical hazards. The proposed decision logic provides a system for type classifying BCPC in terms of its compliance with existing standards (for emergency applications), the overall clothing integrity, and the material barrier performance. Type classification is offered for garments, gloves, footwear, and eye/face protection devices. On the basis of multiple, but simply designed flowcharts, the type of BCPC appropriate for specific biological and chemical hazards can be selected. The decision logic also provides supplemental considerations for choosing appropriate BCPC features. Certainly the decision logic does not address all situations and variations of protection needs, but it can provide the basis for many different selection decisions requiring BCPC.

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2 This standard is still under development.

3 This standard is still under development.