

Safe Handling Of Hazardous Drugs: Reviewing Standards for Worker Protection

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As a new generation of health care workers joins those already engaged in patient care, it is essential that they understand the occupational risks associated with the handling of hazardous drugs and the need for training in proper techniques for all handling activities to reduce occupational exposure to hazardous drugs.

These drugs, which include antineoplastic agents, antiviral agents, biological modifiers, hormones, and others, provide therapeutic benefit to patients but may result in adverse health effects for healthy workers.¹⁻⁴ Potential health risks for workers who compound and administer these drugs include adverse reproductive outcomes and the development of cancer.⁵ This review emphasizes new information about this well-recognized issue. It focuses on activities of the National Institute for Occupational Safety and Health (NIOSH) and the 2008 revision of United States Pharmacopeia (USP) Chapter <797>, which mandates compliance with environmental, engineering, and training standards for worker protection.

Routes of Occupational Exposure

Many studies have documented both surface and worker contamination with hazardous drugs.⁶⁻¹³ Standard work

practices for handling injectable drugs generate powder and liquid aerosols from vials and syringes. This drug residue may contaminate the air and surfaces in the work area.^{6-8,14,15} It has been shown that many hazardous drug vials are delivered from the manufacturer with drug residue on the outside of the vials, creating yet another opportunity for contamination.¹⁶ Certain hazardous drugs have been shown to vaporize at room temperature, resulting in drug contamination in the air.¹⁷⁻¹⁹ Workers may breathe contaminated air or touch contaminated surfaces and, subsequently, absorb hazardous drugs. Drug uptake also may occur through the ingestion of contaminated food or drink that is improperly located in or near drug-handling areas. Additionally, the transfer of contamination from hands to mouth may result in the ingestion of drugs. Needlesticks with drug-contaminated needles or cuts

from glass fragments of vials or ampules may also trigger exposure by injection.

Guidelines for the Safe Handling Of Hazardous Drugs

Guidelines for the safe handling of hazardous drugs have been issued by numerous groups since 1980. The Occupational Safety and Health Administration (OSHA) issued guidelines in 1986,²⁰ updated them in 1995,²¹ and made them available online in 1999.²² The American Society of Health-System Pharmacists (ASHP) published guidelines on the safe handling of cytotoxic agents as Technical Assistance Bulletins in 1985 and 1990, and new guidelines on hazardous drugs in 2006.²³⁻²⁵ The Oncology Nursing Society (ONS), in an attempt to influence nursing practice and protect its members from exposure, published guidelines for safe handling and also developed an extensive educational program based on “Chemotherapy and Biotherapy Guidelines and Recommendations for Practice.”²⁶⁻²⁸

Continuing Exposure

Adverse health effects and chances for exposure have been demonstrated among health care workers for more than 2 decades. Studies of surface and worker contamination conducted in the late 1990s and the early years of this decade continued to document exposure.^{6-8,10,14,15} Some possible reasons for the problem include new workers’ lack of awareness of the issue, a lack of vigilance in work practices, poor adherence to the use of personal protective equipment (PPE),²⁹⁻³³ and other potential sources of contamination that have yet to be discovered.³⁰

In 2000, NIOSH convened a working group of interested individuals to examine the issue of occupational exposure of health care workers to hazardous drugs. The Hazardous Drug Safe Handling Working Group was composed of representatives from government (OSHA, NIOSH, and FDA), industry, pharmaceutical manufacturers, academia, membership organizations (eg, American Nurses Association [ANA], ASHP, and ONS), and union leaders whose members handle hazardous drugs. The Working Group assessed existing information and formulated a plan to increase affected workers’ awareness of the risks and to reduce those risks. In 2004, as a result of the efforts of the Working Group, NIOSH issued “Preventing Occupational Exposure to Antineoplastic and Other Hazardous Drugs in Health Care Settings.”³⁴ This NIOSH Alert is similar to the OSHA documents in that it is a guidance document without enforcement authority. However, the recommendations in the NIOSH Alert and the OSHA Technical Manuals may be enforced by OSHA under the general duty clause of the Occupational Safety and Health (OSH) Act, which sets safety and health standards for US workers. Employers subject to the OSH Act have a general duty to provide work and a workplace free from recognized, serious hazards.³⁵

NIOSH actively continues to increase awareness of this issue by maintaining 2 Safety and Health Topic

pages online: “Hazardous Drug Exposures in Health Care”³⁶ and “Occupational Exposure to Antineoplastic Agents.”³⁷ These pages provide links to extensive background information, the latest studies, updates on related activities, and NIOSH publications.

In 2007, the USP released Chapter <797>, “Pharmaceutical Compounding—Sterile Preparations,” which became effective in 2008.³⁸ This revision of the 2004 standard includes a section specific to the compounding of hazardous drug and is coordinated with much of the 2004 NIOSH Alert. More importantly, the USP Chapter <797> is an enforceable standard and establishes many of the NIOSH recommendations as requirements. The standards set by USP Chapter <797> are applicable in all settings in which sterile doses of hazardous drugs are compounded, not just hospitals and clinics.

Defining Hazardous Drugs

A number of drug types that are potent and toxic in patients have the potential to cause adverse effects in persons exposed to them occupationally. In 1990, ASHP attempted to categorize these drugs in its “Technical Assistance Bulletin on Handling Cytotoxic and Hazardous Drugs,”²⁴ for the first time using the term “hazardous drug” in reference to drugs that involve risks from occupational exposure. The terminology was selected to be inclusive of the types of drugs with safety concerns and to be compatible with the then newly developed OSHA Hazard Communication Standard (HCS).^{39,40} The HCS is intended to ensure that employers and workers who are at risk for exposure to hazardous chemicals in the workplace are informed of the specific hazardous chemicals, their associated health and safety hazards, and the appropriate protective measures to be taken.

The HCS defines a “hazardous chemical” as any chemical that poses a physical hazard or a health hazard. It further defines a “health hazard” as any chemical for which statistically significant evidence from at least one study conducted in accordance with established scientific principles is available to indicate that it may cause acute or chronic health effects in exposed employees. The HCS further notes that the term “health hazard” includes chemicals that are carcinogens, toxic or highly toxic agents, reproductive toxins, irritants, corrosives, sensitizers, and agents that produce target organ effects.

ASHP has used similar criteria to define hazardous drugs.^{23,24} Data on the side effects of a drug are collected during both the premarket investigational phase of the drug and clinical use. These data may reasonably be used to infer “health hazards” in workers occupationally exposed to the drug. As such, ASHP proposed the following criteria to define hazardous drugs²⁴:

- genotoxicity (ie, mutagenicity and clastogenicity in short-term test systems);
- carcinogenicity in animal models, in the patient population, or both, as reported by the International Agency for Research on Cancer (IARC);
- teratogenicity or fertility impairment in animal studies or in treated patients; and

Table 1. Comparison of 2004 NIOSH and 1990 ASHP Definitions

NIOSH	ASHP
Carcinogenicity	Carcinogenicity in animal models, in the patient population, or both as reported by the International Agency for Research on Cancer
Teratogenicity or developmental toxicity	Teratogenicity in animal studies or in treated patients
Reproductive toxicity	Fertility impairment in animal studies or in treated patients
Organ toxicity at low doses	Evidence of serious organ or other toxicity at low doses in animal models or treated patients
Genotoxicity	Genotoxicity (ie, mutagenicity and clastogenicity in short-term test systems)
Structure and toxicity profile of new drugs that mimic existing drugs determined hazardous by the above criteria	

ASHP, American Society of Health-System Pharmacists; NIOSH, National Institute for Occupational Safety and Health
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- evidence of serious organ or other toxicity at low doses in animal models or treated patients.
ASHP's criteria for hazardous drugs were revised by NIOSH for the 2004 Hazardous Drug Alert.

USP Chapter <797> has adopted the following definition of hazardous drugs, which supports both the HCS and the NIOSH Alert definitions: Drugs are classified as hazardous if studies in animals or humans indicate that exposures to them have a potential to cause cancer, developmental or reproductive toxicity, or harm to organs.³⁸

NIOSH has adopted a mechanism both to review its hazardous drug criteria and to judge newly FDA-approved drugs against these criteria on a regular basis. In 2007, a group of experts met to review the drugs that have been approved by the FDA since 2004 to evaluate which should be considered hazardous. Sixty-two drugs from many different therapeutic categories met at least 1 criterion of the hazardous definition in the preliminary analysis by NIOSH.⁴¹ The final list will be published when it is approved by the Office of Management and Budget (T. Connor, personal communication, July 10, 2008). Once published, the complete list will include nearly 200 pharmacologic agents available in the United States that are deemed hazardous to health care workers. The current NIOSH list of drugs that should be considered hazardous can be found in Appendix A of the NIOSH Alert.⁴²

Table 1 compares the 2004 NIOSH and 1990 ASHP definitions of hazardous drugs.

Recommendations

Recommendations for the safe handling of hazardous drugs have been available since the early 1980s. As more research has been conducted and more groups have

been involved, the recommendations have been coordinated in an attempt to provide uniformity. Each group, however, has a somewhat different focus. The NIOSH Alert and OSHA Technical Manuals are broad guidelines; the ONS "Chemotherapy and Biotherapy Guidelines" focus on administration and patient safety information; ASHP addresses pharmacists' concerns; and USP Chapter <797> deals exclusively with sterile compounding.

All guidelines agree that to reduce exposure to hazardous drugs in the occupational setting, a comprehensive safety program must be developed that deals with all aspects of drug handling—from selection and receipt of the product to storage, compounding, administration, spill control, and waste management. Key components of such a program are administrative controls, environmental and engineering controls, work practice controls, and PPE. These components are based on principles of industrial hygiene that have been successfully used to mitigate other risks of occupational exposure.⁴³

ADMINISTRATIVE CONTROLS

Administrative controls include policies, procedures, staff education and training, validation of competency, and medical surveillance. All aspects of hazardous drug handling must be identified, staff performance expectations clearly defined, methods for validating staff competency determined, and processes for the ongoing monitoring of adherence to policies judiciously established.

USP Chapter <797> emphasizes administrative controls for the safe compounding of hazardous drugs by mandating conditions that protect health care workers and other personnel in preparation and storage areas. Further requirements include extensive training of all

personnel who handle hazardous drugs in the storage, handling, and disposal of such drugs. USP Chapter <797> reinforces the OSHA and NIOSH recommendations by requiring training before the preparation or handling of hazardous compounded sterile preparations, and by mandating that the effectiveness of training be verified by testing specific hazardous drug preparation techniques. Ongoing training must be documented at least annually. The components of the training program are specified to include didactic overview of hazardous drugs and their mutagenic, teratogenic, and carcinogenic properties. The training program must address each new hazardous drug that enters the marketplace. Training in work practices also must include the following: aseptic manipulation; negative-pressure technique; correct use of safety equipment; containment, clean-up, and disposal procedures for breakages and spills; and treatment of personnel for contact and inhalation exposure.

OSHA and NIOSH include medical surveillance in their safety program recommendations. Medical surveillance involves collecting and interpreting data to detect changes in the health status of working populations potentially exposed to hazardous substances. In 2007, NIOSH released “Workplace Solution: Medical Surveillance for Health Care Workers Exposed to Hazardous Drugs,” which provides direction for establishing such a program and the elements that should be included.⁴⁴

USP Chapter <797> requires that all compounding personnel with reproductive capability confirm in writing that they understand the risks of handling hazardous drugs. Although USP Chapter <797> mandates this only for personnel responsible for compounding, prudent practice dictates that the requirement should extend to all personnel who handle hazardous drugs.

ENVIRONMENTAL AND ENGINEERING CONTROLS

The recent revision to USP Chapter <797> contains extensive mandates to improve the environment in which sterile doses of hazardous drugs are compounded. These directives are designed to increase safety for patients by reducing the potential for the microbial contamination of sterile dosage forms, and to improve worker safety by addressing design concerns in traditional, positive-pressure compounding environments. Table 2 compares the NIOSH, ASHP, and USP Chapter <797> recommendations for the environment in which hazardous drugs are compounded.

Hazardous drugs must be stored separately from other inventory in a manner to prevent contamination and exposure of personnel. Because of the concerns of volatilization at room temperature, storage is preferably within a containment area such as a negative-pressure room with sufficient exhaust ventilation and at least 12 air changes per hour (ACPH) to dilute and remove airborne contaminants.

An International Organization for Standardization (ISO) class 5 primary engineering control (PEC) is

required for hazardous drug compounding that both protects sterile preparations from microbial contamination and protects workers and the environment by preventing the escape of hazardous drug aerosols or residue. Appropriate PECs for compounding sterile hazardous drug preparations include class II biological safety cabinets (BSCs) and compounding aseptic containment isolators (CACIs) meeting or exceeding the standards set forth in USP Chapter <797>.

Isolators are recommended as a PEC in both the NIOSH Alert and the ASHP hazardous drug guidelines. The USP Chapter <797> revision sets performance standards for isolators used to compound sterile preparations, for compounding aseptic isolators (CAIs), and for isolators used to compound sterile hazardous drug preparations (CACIs). To meet the criteria of USP Chapter <797>, an isolator must provide isolation from the room and maintain ISO class 5 air quality within the cabinet during dynamic operating conditions. CAI and CACI air quality must be documented by particle counts during compounding operations and during material transfer in and out of the isolator. Recovery time to ISO class 5 air in the main chamber must be documented after material is transferred in and out of the main chamber. Work practices must be developed to reduce disruption of the air quality in the isolator and to minimize recovery time.

A CACI meeting all of these conditions, as detailed in USP Chapter <797>, is exempt from the requirement of placing the CACI in an ISO class 7 buffer area. For hazardous drug compounding, however, the compounding area must maintain negative pressure and have a minimum of 12 ACPH.

A class II BSC has an open front and depends on an air barrier to prevent hazardous drug contamination from escaping the cabinet.⁴⁵ This air barrier can be compromised by worker technique, allowing escape of the contaminated air.⁴⁶ The design of this type of cabinet is questionable for product protection because the air barrier is composed of air coming from the buffer area around the BSC. As air is pulled into the BSC, poor air quality in the buffer area may compromise the ISO class 5 compounding environment within the class II BSC. A class II BSC or CACI not meeting the conditions listed in USP Chapter <797> must be placed in an area that is physically separated from other compounding areas and has air quality of ISO class 7. Optimally, this area should be at negative pressure relative to adjacent positive-pressure ISO class 7 or better ante-areas, thus providing inward airflow to contain airborne drug. Optimally, a PEC used for compounding sterile hazardous drug preparations should be 100% vented to the outside air through high-efficiency particulate air (HEPA) filtration.

All environments where sterile preparations are compounded must be provided with HEPA-filtered air from outside the environment. The PEC may not be the sole source of HEPA-filtered air and it may not provide more than 50% of the ACPH in that environment. The ISO class 7 buffer area and ante-area must be supplied with

Table 2. Comparison of the NIOSH, ASHP, and USP Chapter <797> Recommendations for the Hazardous Drug-Compounding Environment

	NIOSH	ASHP	USP Chapter <797>
Storage environment	Store hazardous drugs separately from other drugs in an area with sufficient general exhaust ventilation to dilute and remove any airborne contaminants.	Segregate hazardous drug inventory and store in an area with sufficient general exhaust ventilation to dilute and remove any airborne contaminants.	Hazardous drugs shall be stored separately from other inventory, preferably within a containment area such as a negative-pressure room.
Compounding	Prepare hazardous drugs in an area that is devoted to that purpose alone and is restricted to authorized personnel.	Hazardous drugs should be compounded in a controlled area where access is limited to authorized personnel trained in handling requirements.	Hazardous drugs shall be prepared in a PEC, which shall be placed in an ISO class 7 area that is physically separated from other preparation areas.
Ventilation	Where feasible, exhaust 100% of the filtered air to the outside.	Because of the hazardous nature of these preparations, a contained environment where air pressure is negative relative to that of the surrounding areas or that is protected by an air lock or anteroom is preferred.	<i>Storage:</i> area should have exhaust ventilation of at least 12 air changes per hour. <i>Compounding:</i> optimally at negative pressure relative to adjacent positive-pressure ISO class 7 or better ante-areas.

ASHP, American Society of Health-System Pharmacists; ISO, International Organization for Standardization; NIOSH, National Institute for Occupational Safety and Health; PEC, primary engineering control; USP, United States Pharmacopeia
Based on references 23, 34, and 38.

HEPA-filtered air providing a total of at least 30 ACPH. Table 3 compares the NIOSH, ASHP, and USP Chapter <797> recommendations for hazardous drug PECs.

WORK PRACTICE CONTROLS

Work practices must be designed to minimize the generation of hazardous drug contamination and maximize the containment of inadvertent contamination that occurs during routine handling or in the event of a spill. The compounding techniques described by Wilson and Solimando continue to be the standard for any procedure in which needles and syringes are used to manipulate sterile dosage forms of hazardous drugs.⁴⁷ These techniques, when performed accurately, minimize the escape of drug from vials and ampules.

Many adjunct devices have been developed to reduce the generation of contamination during the compounding process. Vented needles with 0.2-micron hydrophobic filters were designed to reduce the powder and liquid drug residue that escapes from vials through standard vented needles. Dispensing pins with small spikes and hydrophobic filters were introduced to make the compounding process more efficient. One study documents the effectiveness of one of these devices, but the investigators used only a visual inspection process

because no sensitive drug assays were available at the time of the study.⁴⁸

Since then, sensitive, drug-specific assays have been developed that provide a means to validate work practice controls at different work sites. The persistent presence of contamination in hospitals and pharmacies generated interest in an adjunct device, generically named by NIOSH in the 2004 Alert as a “closed-system drug-transfer device” (CSTD). NIOSH defines a CSTD as a drug-transfer device that mechanically prevents the transfer of environmental contaminants into the system and the escape of hazardous concentrations of drug or vapor from the system.³⁴ These systems provide some of the benefits of the earlier devices, but with the added protection that they can be locked into place on the drug vial. CSTD components also provide protection during the administration of IV push and IV infusion doses, which was previously unavailable.

Numerous studies using hazardous drug marker drugs have demonstrated the effectiveness of a CSTD in reducing hazardous drug contamination in the workplace.^{6,14,15} At clinical practice sites representing inpatient and outpatient compounding and administration, the implementation of a CSTD reduced surface contamination significantly compared with standard practice.^{6,14,15,49}

Table 3. Comparison of NIOSH, ASHP, and USP Chapter <797> Recommendations for Primary Engineering Controls

	NIOSH	ASHP	USP Chapter <797>
Primary engineering controls	<ul style="list-style-type: none"> • Aseptic containment ventilation control class II BSC-type B2 is preferred. • Class III BSC or CACI 	<ul style="list-style-type: none"> • Class II BSC-type B2 with outside exhaust is preferred. • Total exhaust is required if the hazardous drug is known to be volatile. • Class III BSC or CACI 	<ul style="list-style-type: none"> • BSC or CACI that meets or exceeds the standards for CACI in USP Chapter <797>
Ventilation	<ul style="list-style-type: none"> • Do not use a ventilated cabinet that recirculates air inside the cabinet or exhausts air back into the room environment if a drug is volatile. 	<ul style="list-style-type: none"> • Without special design considerations, class II BSCs are not recommended in traditional, positive-pressure clean rooms. 	<ul style="list-style-type: none"> • BSCs and CACIs optimally should be 100% vented to the outside air through HEPA filtration.

ASHP, American Society of Health-System Pharmacists; BSC, biological safety cabinet; CACI, compounding aseptic containment isolator; HEPA, high-efficiency particulate air; NIOSH, National Institute for Occupational Safety and Health; USP, United States Pharmacopeia
Based on references 23, 34, and 38.

USP Chapter <797> similarly defines CSTDs as “vial-transfer systems that allow no venting or exposure of hazardous substance to the environment.” USP Chapter <797> further states that CSTDs must be used within the ISO class 5 environment of a BSC or CACI. In facilities that prepare a low volume of hazardous drugs, the use of 2 tiers of containment (eg, a CSTD within a BSC or a CACI that is located in a non-negative-pressure room) is acceptable. The NIOSH Alert specifies that CSTDs should be used *only* within a ventilated cabinet.

Neither USP Chapter <797> nor NIOSH has developed performance standards for any device marketed as a CSTD. Because the configurations of available CSTDs vary from that of the tested device, it is unclear how effective these devices are in reducing environmental contamination resulting from the compounding and administration of hazardous drugs. Any device marketed as a CSTD should be clinically tested.

PERSONAL PROTECTIVE EQUIPMENT

In addition to environmental and engineering controls, PPE is required to provide a barrier between the health care worker and the hazardous drug during episodes of potential contact. This is especially important during administration, spill control, handling of drug waste, and handling of patient waste because no PECs are in place for these activities. All PPE should be selected for effectiveness. Glove and gown materials should be able to withstand permeation by a selection of hazardous drugs. Several hazardous drugs require nonaqueous diluents for patient use, which may permeate PPE more readily than others. The American Society for Testing and Materials has developed a standard for testing chemotherapy gloves.⁵⁰ There is no standard for chemotherapy gowns, but recommendations have

been made based on several studies.⁵¹⁻⁵³ See Table 4 for a comparison of PPE recommendations.

During sterile compounding, barrier garments must be worn to prevent the shedding of human skin and hair cells and the deposition of mucus or respiratory residue into the compounding area. USP Chapter <797> specifies that compounding garb must include the following: dedicated shoes or shoe covers, face masks, head and facial hair covers (eg, beard covers in addition to face masks), a nonshedding gown that has sleeves that fit snugly around the wrists and is enclosed at the neck, and *sterile* powder-free gloves.

Appropriate PPE must be worn when the sterile compounding of hazardous drugs is performed in a BSC or CACI and when CSTDs are used. PPE includes coated gowns, masks or respirators, eye protection, hair covers, shoe covers, and double gloving with sterile hazardous drug-tested gloves.

New Technologies

Technologic advances include robotic automation that can compound sterile doses of hazardous and non-hazardous drugs. By replacing the human compounder, these robots reduce the occupational exposure of health care workers during the compounding process. Robotic units provide contained ISO class 5 environments and use techniques to reduce the generation of hazardous drug residue during compounding. Robots operate with sophisticated mechanics and software and provide a degree of accuracy and patient safety not available with manual compounding. CytoCare from Health Robotics, IntelliFill Chemo from ForHealth Technologies, Inc, and RIVA (Robotic IV Administration) from Intelligent Hospital Systems all provide robotic solutions to the compounding of sterile preparations of hazardous drugs.

Table 4. Comparison of NIOSH, OSHA, ASHP, And USP Chapter <797> Recommendations for PPE

	NIOSH/OSHA	ASHP	USP Chapter <797>
General handling	<ul style="list-style-type: none"> Use double gloving for all activities involving hazardous drugs. <p>OSHA:</p> <ul style="list-style-type: none"> Protective equipment, including PPE for eyes, face, head, and extremities, protective clothing, respiratory devices, and protective shields and barriers shall be provided, used, and maintained in a sanitary and reliable condition wherever it is necessary by reason of hazards of processes or environment, chemical hazards, radiologic hazards, or mechanical irritants encountered in a manner capable of causing injury or impairment in the function of any part of the body through absorption, inhalation, or physical contact. 	<ul style="list-style-type: none"> Wear double gloves for all activities involving hazardous drugs. Guidelines for the safe handling of hazardous drugs recommend the use of gowns for compounding in the BSC, administration, spill control, and waste management to protect the worker from contamination by fugitive drug generated during the handling process. 	<ul style="list-style-type: none"> Hazardous drugs shall be handled with caution at all times with the use of appropriate chemotherapy gloves during receiving, distributing, stocking, taking inventory, preparing for administration, and disposal.
Receiving and storage	<ul style="list-style-type: none"> Wear chemotherapy gloves, protective clothing, and eye protection when opening containers to unpack hazardous drugs. 	<ul style="list-style-type: none"> Gloves must be worn at all times when drug packaging, cartons, and vials are handled, including during the performance of inventory control procedures and the gathering of hazardous drugs. 	
Compounding	<ul style="list-style-type: none"> Wear PPE (including double gloves and protective gowns) while reconstituting and admixing drugs. Make sure that gloves are labeled as chemotherapy gloves. Use disposable gowns made of polyethylene-coated polypropylene material (which is nonlinting and nonabsorbent). 	<ul style="list-style-type: none"> Select disposable gowns of material tested to be protective against the hazardous drugs to be used. Coated gowns must be worn for no longer than 3 hours during compounding and changed immediately when damaged or contaminated. Gowns worn as barrier protection in the compounding of hazardous drugs must never be worn outside the immediate preparation area. 	<p>Sterile compounding:</p> <ul style="list-style-type: none"> Shoe covers, head and facial hair covers (eg, beard covers in addition to face masks), and face masks; a nonshedding gown that has sleeves that fit snugly around the wrists and is enclosed at the neck; sterile powder-free gloves. <p>Hazardous drug compounding:</p> <ul style="list-style-type: none"> Appropriate PPE shall be worn during compounding in a BSC or CACI and during the use of CSTDs. PPE should include gowns, face masks, eye protection, hair covers, shoe covers or dedicated shoes, double gloving with sterile chemotherapy-type gloves, and compliance with manufacturers' recommendations when a CACI is used.
Administration	<ul style="list-style-type: none"> Wear PPE (including double gloves, goggles, and protective gowns) for all activities associated with drug administration. 	<ul style="list-style-type: none"> Gowns worn during administration should be changed when the patient care area is left and immediately if contaminated. 	

ASHP, American Society of Health-System Pharmacists; **BSC**, biological safety cabinet; **CACI**, compounding aseptic containment isolator; **CSTD**, closed-system drug-transfer device; **OSHA**, Occupational Safety and Health Administration; **NIOSH**, National Institute for Occupational Safety and Health; **PEC**, primary engineering control; **PPE**, personal protective equipment; **USP**, United States Pharmacopeia

Based on references 22, 23, 34, and 38.

Like most technology, these robots are not perfect. They require human staff to load and clean them. Hazardous drug contamination may be generated in the compounding environment and transferred to the final product. Cleaning of the compounding environments requires both disinfection and the decontamination of hazardous drug residue. No particular cleaner has been shown to effectively deactivate all known hazardous drugs,¹¹ so routine cleaning and spill control are still challenges to the health care personnel working with these robots. The robots help only with the compounding process, leaving the workers administering hazardous drugs without protection. Spill control and waste handling also remain issues for human workers to address.

Conclusion

Despite almost 3 decades of data on the adverse health effects of occupational exposure to hazardous drugs, skepticism about the risks continues, as evidenced by the failure to implement programmatic controls for reducing exposure. NIOSH has renewed its dedication to this health risk by continuing to promote worker awareness of safety. USP Chapter <797> has elevated many of the NIOSH recommendations to a standard, ensuring both awareness and compliance with at least the compounding segment of safety program controls.

Each new generation of health care workers needs to be educated about the risks of handling hazardous drugs and the importance of training in the proper techniques to reduce their exposure. Employers and employees must implement all aspects of hazardous drug safety programs to reduce occupational exposure and its potential adverse effects.

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