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Abstract

Research has shown that human healthcare personnel working with hazardous drugs have higher instances of reproductive difficulties, fetal loss, DNA changes, and cancer. Minimal replica studies have been performed in veterinary medicine. It can be assumed that exposure of veterinary personnel handling these drugs is higher than in human medicine due to lack of regulations, patient noncompliance, frequent exposure to contaminated patient excrement, inconsistent personnel training, and variable access to safety equipment. Veterinary nurses must be educated and empowered to self-advocate to protect themselves from the risks of working with hazardous drugs.

CONTINUING EDUCATION

CLINIC SAFETY

Hazardous Drugs: The Hidden Threat to Veterinary Nurses

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Veterinary professionals tend to have 1 goal in mind: to provide the best care possible to their patients. Often this comes at a personal cost, both mentally and physically. With the many challenges veterinary nurses face, invisible threats to personal health are often forgotten or omitted from training. One such threat can be found in products veterinary nurses handle every day: hazardous drugs. The National Institute for Occupational Safety and Health (NIOSH) defines hazardous drugs as those that possess carcinogenicity, teratogenicity, genotoxicity, reproductive toxicity, or organ toxicity or that mimic existing drugs on the list.[1]

TERMINOLOGY AND CLASSIFICATION OF HAZARDOUS DRUGS

Carcinogenicity is a well-understood term—put simply, "the ability to cause cancer." Carcinogens are proven to greatly increase the probability of cancer developing (**TABLE 1**). *Genotoxicity* is a similar term; however, it refers to causing damage to the DNA or chromosomes, which is often associated with an increased cancer risk. In nearly all cases, drugs that fall into these 2 categories also create risk during pregnancy because they alter the genetic makeup, leading to either cell death or cell damage in both the mother and the fetus (**BOX 1**).

Take-Home Points

- Hazardous drugs are not limited to chemotherapy. Many of the drugs veterinary nurses work with every day are considered hazardous.
- The National Institute for Occupational Safety and Health defines a drug as hazardous if it has 1 of the following characteristics: carcinogenicity, genotoxicity, teratogenicity (or other developmental toxicity), reproductive toxicity, organ toxicity at low doses, or mimicking of existing hazardous drugs in structure or toxicity.
- The United States Pharmacopeia updated its General Chapter 800 (USP 800) to set standards for handling hazardous drugs; however, most states do not have an enforcement agency to ensure compliance in veterinary facilities.
- USP 800 provides safety guidelines on all aspects of handling hazardous drugs from the time the drug is received in clinic to decontamination after the drug has been administered.

TABLE 1 International Agency for Research on Cancer Classifications of Carcinogenic Agents[2]

GROUP	DESCRIPTION
Group 1	Carcinogenic to humans
Group 2A	Probably carcinogenic to humans
Group 2B	Possibly carcinogenic to humans
Group 3	Not classifiable as carcinogenic

Reproductive toxicity and *teratogenicity* both refer to effects seen before or during pregnancy, respectively. Teratogenic drugs are those that increase the risk of birth defects by interfering with the normal development of a fetus. Reproductive toxicity is a broad description that refers to any adverse effect on the reproductive system such as fetal loss, stillbirth, infertility, and lactation concerns.

Organ toxicity refers to drugs that cause adverse effects to organs at low doses in either animal models or treated patients.

The NIOSH List of Hazardous Drugs in Healthcare Settings is made up of 3 groups: (1) antineoplastic drugs, (2) non-antineoplastic drugs that meet 1 or more criteria for a hazardous drug, and (3) drugs that primarily pose a reproductive risk.[1] The most dangerous drugs for healthcare personnel to handle are antineoplastic drugs. To fully understand the risk, it is important to understand how these drugs work.

BOX 1

U.S. Food and Drug Administration Drug Pregnancy Risk Categories[3]

- **Category A:** No risk in human studies
- **Category B:** No risk in animal studies (no adequate studies in humans)
- **Category C:** Risk cannot be ruled out (no adequate studies in humans, but animal studies demonstrated fetal risk)
- **Category D:** Evidence of risk (studies in pregnant women have demonstrated a risk)
- **Category X:** Contraindicated in pregnant women (risks of the drug outweigh potential benefits)

GROUP 1: ANTINEOPLASTIC DRUGS

History

Cancer has been documented as a disease for as long as humans have existed. It was initially believed that cancer consisted of a tumor that grew from a single location. This belief led to the primary cancer treatment being surgical removal. However, the surgical treatment of breast cancer led to the discovery that cancer is not that simple. No matter how radical the surgery became, patients progressed and eventually died of the disease. It was soon realized that surgery alone was not sufficient to treat cancer and, even with the addition of radiation therapy, patients continued to die. Human medical professionals began to discover metastasis and realized that cancer is often a systemic disease; thus, it needs systemic treatment.

Systemic treatments for cancer have not been easy to find. In the 1940s, doctors began using cytotoxic (cell toxic) drugs for cancer treatment in patients. These drugs were very experimental and were often discovered accidentally. In fact, the first cytotoxic drug ever discovered is still being used today. During World War II, it was discovered that soldiers exposed to mustard gas developed significantly reduced white blood cell counts.[4] This led researchers to examine the therapeutic effects of mustard agents in the treatment of lymphoma. And with that, the first chemotherapeutic was created: mechlorethamine (Mustargen).[4] While cancer treatment has made many advancements over the years, the chemotherapy drugs available today are largely unchanged and focus on cytotoxicity to induce a response. This is particularly true in veterinary medicine, where progress is often slow and tends to follow far behind the steps of human medicine.

Much about cancer was not understood early on, and the drugs used in cancer treatment were also not well understood. It was not until roughly 30 years after cytotoxic therapies entered human medicine that medical professionals discovered that the risk of chemotherapy exposure was not limited to the patient receiving the drug.[5]

Method of Action

Antineoplastic (or cytotoxic) drugs work by interfering with parts of the cell cycle regardless of whether the cell is a healthy cell or a cancer cell. For a cell to be affected by the genetic damage these drugs cause, it must progress to the part of the cell cycle that the particular

drug is targeting. This is why rapidly dividing cells are most affected: The rate of cell death is directly correlated with the rate of cell division.[6] This is also represented in the fact that neoplasias classified as chemosensitive are often the ones that have the fastest rate of cell division. For example, cancers of the blood or bone marrow are known to be mostly responsive to chemotherapy, as the cell division rate is measured in hours. Comparatively slow-growing tumors that have a slower proliferation rate, such as soft tissue sarcomas, tend to be chemoresistant.

The death of rapidly dividing healthy cells is what leads to common chemotherapy side effects such as nausea, diarrhea, hair loss, and bone marrow suppression. Balanced cell death is the goal of cytotoxic therapies, but not every affected cell will die as a result of the DNA damage that these drugs induce. Instead, patients are also left with damaged cells that may or may not have long-term effects. In pediatric oncology, one of the risks of treating with chemotherapy is causing cancer later in life. The very drugs used to treat cancer can result in cancer-causing DNA damage. The same phenomenon is seen in canine and feline patients, although not as often due to their comparatively shorter lifespan (**TABLE 2**).

TABLE 2 NIOSH Group 1 Hazardous Drugs Commonly Used in Veterinary Practice[a]

DRUG	CLASSIFICATION
Bleomycin	• IARC Group 2B carcinogen • FDA Pregnancy Category D
Carboplatin	• FDA Pregnancy Category D
Chlorambucil	• IARC Group 1 carcinogen • FDA Pregnancy Category D
Cyclophosphamide	• IARC Group 1 carcinogen • FDA Pregnancy Category D
Cytarabine	• FDA Pregnancy Category D
Doxorubicin	• IARC Group 2A carcinogen • FDA Pregnancy Category D
Lomustine	• IARC Group 2A carcinogen • FDA Pregnancy Category D
Melphalan	• IARC Group 1 carcinogen • FDA Pregnancy Category D
Mitoxantrone	• IARC Group 2B carcinogen • FDA Pregnancy Category D
Procarbazine	• IARC Group 2A carcinogen • FDA Pregnancy Category D
Vinblastine	• FDA Pregnancy Category D
Vincristine	• FDA Pregnancy Category D
Vinorelbine	• FDA Pregnancy Category D

[a]*Not all inclusive. The complete list of hazardous drugs is available at https://www.cdc.gov/niosh/docs/2016-161*
FDA = Food and Drug Administration; IARC = International Agency for Research on Cancer; NIOSH = National Institute for Occupational Safety and Health

Published Studies of Hazards to Healthcare Workers

In the 1970s, concerns started to rise for healthcare workers handling antineoplastic agents after the discovery of an association between chemotherapy and secondary cancers. In 1979, a study based out of Finland found mutagenicity in the urine of nurses handling chemotherapeutic drugs, proving that merely handling these drugs results in enough uptake for genetic mutations to be present in urine.[5] Many replica studies have since been performed looking at both urine and blood samples from healthcare workers.

In 2014, a Canadian study obtained 201 urine samples from healthcare workers at 6 facilities: 5 acute care sites and 1 cancer treatment center. In this study, various job categories were selected, including pharmacists, pharmacy technicians, ward aides, dietitians, oncologists, and volunteers. In this study, cyclophosphamide (a common chemotherapeutic) was detected in the urine in 55% of participants. Furthermore, individuals who had not received safety training had a higher percentage of the drug detected in their urine (64%) than those who had. Also concerning was that participants from departments where drug preparation and administration did not take place had the highest average urinary concentration levels.[7] This study shed light on the fact that even individuals who are not directly handling chemotherapy were being exposed to these drugs enough to detect traces of the drugs in their urine.

Chromosomal aberrations are mistakes in, or alterations to, the chromosomes. In cancer patients undergoing chemotherapy, chromosomal aberrations are commonly seen as a result of the drugs inducing genetic damage. With advancing methods for monitoring DNA damage, scientists began to explore the presence of chromosomal aberrations in healthcare workers. In 2019, a meta-analysis of 17 of the known 39 studies assessed the link between occupational exposure to antineoplastic drugs and chromosomal aberrations in healthcare workers. The results of this analysis showed that the level of chromosomal aberrations in healthcare workers exposed to antineoplastic drugs was significantly higher than in controls.[8] Additionally, chromosomal aberrations have been associated with an

increased cancer risk, with 1 study finding that a 1% increase in chromosomal aberrations was followed by a 64% increase in cancer risk.[9]

Many similar studies have looked at the risks of working with antineoplastics in the healthcare setting, and nearly all have consistent findings: Workers continue to be exposed to these drugs across various hospital settings, occupations, and known protective measures. However, few studies have evaluated hazardous drugs in the veterinary setting.

GROUP 2: NON-ANTINEOPLASTIC DRUGS

NIOSH defines Group 2 drugs as those that are not used to treat cancer but meet 1 or more of the criteria for a hazardous drug. Many of the drugs on this list can be found in veterinary practices (**TABLE 3**). In veterinary medicine, clinics tend to keep medications in stock and veterinary personnel are often the ones handling the medications. Without awareness of the drugs on this list and their effects, veterinary teams continue to be chronically exposed.

GROUP 3: NON-ANTINEOPLASTIC DRUGS THAT PRIMARILY HAVE ADVERSE REPRODUCTIVE EFFECTS

NIOSH defines Group 3 drugs as those that pose primarily a reproductive risk to men and women who are actively trying to conceive and women who are pregnant or breastfeeding. Some of the drugs in this group may be present in the breastmilk of individuals handling these drugs (**TABLE 4**).

SAFETY IN THE VETERINARY SETTING

The first guidelines for the management of cytotoxic drugs were published in 1983 by the American Society of Health-System Pharmacists. They were followed by additional guidelines from the Occupational Safety and Health Administration (OSHA) in 1986. Between 1986 and 2004, both NIOSH and the United States Pharmacopeia (USP) highlighted the risks of and provided guidelines for the handling and management of hazardous drugs, largely focusing on chemotherapeutics. Since that time, there have been numerous regulations updates to reflect advancements in knowledge about drugs, routes of exposure, and effects. The most current guidelines available today come from the USP General Chapter 800 (USP 800) and are outlined below.[11]

It is important to realize that existing guidelines are largely focused on human medicine. It can be argued that the exposure risk faced by veterinary teams is higher due to variable education and training, a less regulated environment, variable access to safety equipment, patient noncompliance, and frequent exposure to patient excrement.

Hazardous Drug Exposure in Veterinary Practice

In 2019, the author conducted a survey of 201 U.S. veterinary nurses/technicians who work with chemotherapeutics. Respondents answered a variety of questions regarding their experience working with hazardous drugs, with the following results:

- Almost a third (29.35%) of respondents reported that they had worked with chemotherapy drugs for more than 10 years.
- Only 49.25% of respondents reported that they were made aware of the risks of working with chemotherapeutics upon hire.
- Safety devices were frequently used by respondents and included Luer-Lok tip syringes (74%), needleless devices (57.7%), closed-system transfer devices (93%), and biological safety cabinets (84%).
- The use of personal protective equipment was variable among respondents, with 67% reporting the use of chemotherapy gloves but only 36% reporting the use of double gloving. Gowns were used by 84% of respondents, while only 42% reported face protection.
- When asked about their health, about 25% of respondents reported mild to severe changes in health, 10% reported infertility/miscarriage/birth defects, and 3.5% reported a cancer diagnosis.

See the **HAZARDOUS DRUG EXPOSURE IN VETERINARY PRACTICE** sidebar for an anecdotal study completed by the author.

Routes of Exposure

Exposure to hazardous drugs can occur at any point from the receipt of the drug to when it is excreted from the animal and into the environment. The routes of exposure for healthcare workers include:

- **Skin or eye contact:** Direct skin contact or splashing of eyes with hazardous drugs can occur during spills, leaks, or handling of patient excrement containing drug metabolites. Direct skin contact may also occur when contaminated items travel beyond the preparation or administration areas.
- **Inhalation:** Drugs can aerosolize during preparation, administration, or disposal and then be inhaled by healthcare workers.
- **Ingestion:** Healthcare workers can ingest drugs by eating, drinking, or touching their mouth with contaminated hands or items.
- **Sharps injury:** Healthcare workers can be exposed through an accidental needle-stick injury when handling contaminated needles.

Safety Guidelines

Personal Protective Equipment Requirements

There are guidelines for the types of personal protective equipment (PPE) used in all aspects of handling hazardous drugs. Gloves must be chemotherapy safe and meet American Society for Testing and Materials standard D6978. Gowns must be disposable and impermeable (no cloth), closed in the back, and be used only once. Eye protection must completely enclose the eyes; surgical face masks can be used to protect the face. When respirators are required, surgical N95

TABLE 3 NIOSH Group 2 Hazardous Drugs Commonly Used in Veterinary Practice[a]

DRUG	CLASSIFICATION
Apomorphine	• FDA Pregnancy Category C, genotoxic in several in vitro assays
Chloramphenicol	• IARC Group 1 carcinogen • FDA Pregnancy Category C
Cyclosporine	• IARC Group 1 carcinogen • FDA Pregnancy Category C
Dexrazoxane	• FDA Pregnancy Category C, genotoxic in vitro and in vivo
Diethylstilbestrol	• IARC Group 1 carcinogen • FDA Pregnancy Category X
Methimazole	• FDA Pregnancy Category D
Phenoxybenzamine	• IARC Group 2B carcinogen • FDA Pregnancy Category C
Spironolactone	• FDA Pregnancy Category C • Tumor producing in lab studies[10]

[a]Not all inclusive. The complete list of hazardous drugs is available at https://www.cdc.gov/niosh/docs/2016-161
FDA = Food and Drug Administration; IARC = International Agency for Research on Cancer; NIOSH = National Institute for Occupational Safety and Health

TABLE 4 NIOSH Group 3 Hazardous Drugs Commonly Used in Veterinary Practice[a]

DRUG	CLASSIFICATION
Clonazepam	FDA Pregnancy Category D
Fluconazole	FDA Pregnancy Category C
Misoprostol	FDA Pregnancy Category X
Pamidronate	FDA Pregnancy Category D
Zoledronic acid	FDA Pregnancy Category D
Zonisamide	FDA Pregnancy Category D

[a]Not all inclusive. The complete list of hazardous drugs is available at https://www.cdc.gov/niosh/docs/2016-161
FDA = Food and Drug Administration; IARC = International Agency for Research on Cancer; NIOSH = National Institute for Occupational Safety and Health

respirators are often best at protecting against both aerosols and direct exposure.

Receiving and Storage

Clinics must have a designated area for the receipt and unpacking of hazardous drugs. Antineoplastic drugs must be unpacked in an externally vented negative-pressure room, also known as the containment secondary engineering control (C-SEC). A spill kit must be available to assist with any spills or damaged packaging. Personnel must wear chemotherapy gloves when unpacking hazardous drugs. Clinics must have written standard operating procedures (SOPs) for the receipt of hazardous drugs and for handling damaged packages.

Antineoplastic hazardous drugs that require manipulation must be stored separately from other drugs in an externally vented negative-pressure room. Often, these drugs must be refrigerated, so there must be a dedicated refrigerator in the C-SEC. Non-antineoplastic hazardous drugs or antineoplastic hazardous drugs that are in their final form may be stored with other drugs with no issue. For example, cyclophosphamide capsules in their final form (no splitting, crushing, or cutting required) may be stored with nonhazardous drugs. However, the medication must be clearly labeled as a hazardous drug, and it may be beneficial to store it in a dedicated area.

Manipulation of Hazardous Drugs

Compounding hazardous drugs carries a high risk of exposure for the handling personnel. For the purpose of this article, compounding will be defined as the act of preparing, mixing, assembling, or packaging drugs. Compounding may or may not be done sterilely, depending on the medication and route of administration. Manipulating oral chemotherapeutics (pill splitting) should be avoided, but if it is required, then it must be performed according to the same requirements of compounding hazardous drugs.

Compounded sterile products are classified into 3 contamination risk levels: low, medium, and high. Facility engineering requirements vary depending on whether low- or medium-risk sterile compounding or high-risk sterile compounding is being performed. Low- to medium-risk sterile compounding covers the bulk of the compounding performed in veterinary hospitals. This includes the single-volume transfer using sterile supplies (e.g., vincristine), the transfer of no more than 3 packages of sterile products (e.g., dilution of doxorubicin), and the transfer from multiple ampules into 1 or more sterile container(s).

For low- to medium-risk compounded sterile products, 2 engineering controls must be present for compounding: the C-SEC and the containment primary engineering control (C-PEC). The C-PEC is the biological safety cabinet or "hood" used to minimize exposure, which must be placed in the C-SEC. It is recommended to have 2 C-PECs (1 for sterile compounds and 1 for nonsterile compounds), although this is not required if high-risk sterile compounding is not a factor. Supplementary controls are also required where applicable. Supplementary controls refers to the use of needleless systems and closed-system transfer devices.

PPE must be worn during the compounding process. Personnel must wear hair/beard covers and double-shoe covers while in the C-SEC. When preparing any medication in the C-PEC, double-gloving with chemotherapy gloves and wearing a gown are required. If preparing medication for IV administration, double-gloving with sterile chemotherapy gloves is required.

The final step of compounding that must be considered is the packaging and labeling of hazardous drugs. This is particularly important in hospitals in which the administration area is not near the compounding area or when multiple personnel are involved. The drugs must be clearly labeled as hazardous and placed in appropriate containment packaging, such as a ziplock bag with chemotherapy warning labels.

Administration

The requirements under USP 800 regarding the administration of hazardous drugs vary depending on the route of administration.

- **Oral administration:** Oral administration requires only the use of chemotherapy gloves, although additional PPE may be ideal. Gloves should be worn until the patient has swallowed the medication, and caution should be used to avoid the animal biting the medication, which could lead to direct exposure. Once administration is complete, the chemotherapy gloves must be disposed of in an approved container for trace-contaminated waste.
- **Injectable chemotherapy:** Closed-system transfer devices must be used to minimize the risk of

exposure. Such devices also minimize the use of needles, which directly decreases the risk to personnel. Double-gloving with chemotherapy gloves, wearing disposable chemotherapy gowns, and wearing eye/face protection are all required under USP 800 during administration. Once administration has concluded, hazardous drug waste (including PPE) should be disposed of in a container(s) approved for trace-contaminated waste.

Cleaning Steps

Deactivating, decontaminating, cleaning, and disinfecting are important parts of exposure control. All areas in which hazardous drugs were handled, including equipment, must be cleaned following use. PPE is required during this step and includes double-gloving with chemotherapy gloves, as well as wearing a chemotherapy gown and eye and face protection. For the cleaning of spills, a respirator is also required. To minimize aerosolization, spraying products onto spills or contaminated areas must be avoided, and only wipes should be used.

- **Step 1:** Deactivation using an Environmental Protection Agency (EPA)–registered oxidizer
- **Step 2:** Decontamination using sterile alcohol, sterile water, or peroxide
- **Step 3:** Cleaning with a germicidal detergent and sterile water
- **Step 4:** Disinfecting with sterile alcohol or an EPA-registered disinfectant

Hazard Communication Program and Documentation

Each facility should have a designated supervisor who is qualified and trained to be responsible for hazardous drugs. This supervisor should assist in the development and implementation of SOPs. They should help ensure compliance with laws and training of personnel.

SOPs should be developed for all aspects of hazardous drug handling and should be reviewed and updated by the supervisor every 12 months. Personnel training must include an overview of hazardous drugs and risks; review of SOPs; proper use of PPE, equipment, and devices; response to exposure; spill management; and disposal. Personnel must be assessed for competency every 12 months.

A Hazard Communication Program (osha.gov/hazcom) must be developed that includes labeling of all hazardous drug containers, easily accessible safety data sheets, personnel training upon hire, and written confirmation from personnel that they understand the risks of working with hazardous drugs.

Documentation of spills and management is a requirement under USP 800. Additionally, any personnel with known exposure must be evaluated immediately. USP 800 also recommends, but does not require, medical surveillance. This generally involves the hiring of a contracted employee health service that monitors the health status of personnel. It is also recommended that environmental wipe sampling for hazardous drug residue be performed every 6 months to verify containment.

USP 800 presents challenges to veterinarians that are not seen to the same extent in human medicine. These challenges make it quite difficult and expensive for clinics to continue working with and administering chemotherapy to cancer patients. However, it is essential that safety guidelines are followed to minimize exposure to veterinary personnel. Veterinary personnel are encouraged to determine in what ways their clinics are currently noncompliant and decide if they can become compliant to continue offering hazardous drug treatments through their own facility.

SUMMARY

When it comes to safety regulations, veterinary medicine is often considered the "Wild West"; many clinics operate independently, with variations in training and protocols. Currently, no enforcement agencies are responsible for ensuring USP 800 compliance at veterinary facilities. However, USP 800 compliance is required for AAHA accreditation, and disregard for staff safety is reportable to OSHA.

With overwhelming evidence suggesting that hazardous drug exposure and uptake in human healthcare workers continue despite the utmost safety precautions, there is little doubt that the same phenomenon is occurring in veterinary medicine. This, combined with the lack of regulation and compliance throughout the veterinary community, makes it essential for veterinary nurses to become fully educated on the risks of handling these drugs and the steps required to protect themselves. More than ever, veterinary nurses must be advocating for their own safety and wellbeing regarding this hidden threat. TVN

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CONTINUING EDUCATION

Hazardous Drugs: The Hidden Threat to Veterinary Nurses

TOPIC OVERVIEW

Research has shown that human healthcare personnel working with hazardous drugs have higher instances of health issues. Despite limited studies, exposure to veterinary team members is assumed to be higher. It is therefore important for veterinary team members to understand how to minimize exposure.

LEARNING OBJECTIVE

After reading this article, participants will be able to identify hazardous drugs and their risks, as well as be able to recognize which safety equipment is recommended to minimize exposure.

This article has been submitted for **RACE approval for 1 hour of continuing education credit** and will be opened for enrollment upon approval. To receive credit, take the test at **vetfolio.com** by searching the name of the article or scanning the QR code below. Free registration is required. Questions and answers online may differ from those below. Tests are valid for 2 years from the date of approval.

1. **Which of the following is false regarding the effects of antineoplastics on patients?**
   a. The goal of chemotherapy is a balanced cell death.
   b. All cells affected by chemotherapy will die.
   c. The cell division rate is directly correlated to the rate of cell death.
   d. The side effects of chemotherapy are generally secondary to the death of healthy cells.

2. **Group 3 hazardous drugs classified by NIOSH are:**
   a. Antineoplastics that primarily have adverse reproductive effects
   b. Non-antineoplastics that primarily have adverse reproductive effects
   c. Antineoplastics that primarily have carcinogenic effects
   d. Non-antineoplastics that primarily have carcinogenic effects

3. **Which of the following is not considered when classifying a drug as hazardous?**
   a. Teratogenicity
   b. Carcinogenicity
   c. Genotoxicity
   d. Organ toxicity at high doses

4. **The studies presented in this article showed evidence of chemotherapy being detected in:**
   a. The urine of healthcare workers
   b. The blood of healthcare workers
   c. The saliva of healthcare workers
   d. A & B

5. **All of the following are potential routes of exposure to hazardous drugs except:**
   a. Ingestion of contaminants by drinking in the administration area
   b. Inhalation of aerosols during disposal
   c. Direct skin contact by cleaning up urine from a chemotherapy patient without gloves
   d. Using a closed-system transfer device during administration

6. **What are the 4 steps of cleaning hazardous drug areas in chronological order?**
   a. Decontamination, deactivation, disinfection, cleaning
   b. Deactivation, decontamination, cleaning, disinfection
   c. Cleaning, disinfection, decontamination, deactivation
   d. Deactivation, disinfection, cleaning, decontamination

7. **According to USP 800, what are the PPE requirements for handling oral chemotherapeutics?**
   a. Latex gloves only
   b. Chemotherapy gloves only
   c. Chemotherapy gloves, gown, mask, and goggles
   d. Chemotherapy gloves and gown

8. **According to USP 800, what are the safety requirements for preparing injectable chemotherapy?**
   a. Closed-system transfer devices and needleless systems must be used.
   b. An externally vented, negative-pressure room (or C-SEC) must be used.
   c. A biological safety cabinet (or C-PEC) must be used.
   d. All of the above

9. **What PPE is required when administering injectable chemotherapy?**
   a. Double chemotherapy gloves, disposable gown, and eye/face protection
   b. Single chemotherapy gloves, disposable gown, and eye/face protection
   c. Double chemotherapy gloves, disposable gown, and N95 mask
   d. Double chemotherapy gloves and eye/face protection