In-Depth Survey Report

Engineering Control Evaluation at Veterinary Hospital E

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EPHB Report No. 380-15a
Animal Specialty & Emergency Center

Revised June 2021

Site Surveyed: Veterinary Hospital E

NAICS Code: 541940 Animal hospitals

Survey Dates: November 2017

Surveys Conducted By:

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Abstract

NIOSH researchers conducted a field survey at Veterinary Hospital E in November 2017. The purpose of the site visit was to identify and evaluate hazardous drug engineering controls as well as to sample for potential surface contamination at the hospital. NIOSH researchers also observed and interacted with the hospital's veterinarians and staff to obtain information about the hazardous drug work practices, daily activities, and oncology treatment processes.

A TSI® VelociCalc™ Plus Model 9565-P thermal anemometer was used to measure air velocities at the face of the externally exhausted Class I 3971201 biological safety cabinet (BSC), while a Wizard Stick handheld smoke generator was used to visualize air movement inside and around the periphery of the BSC. The average face velocity of the BSC was 0.66 m/s (129 fpm), which is above the minimum recommended face velocity (i.e., 0.38 m/s [75 fpm]) for a Class I BSC. The qualitative test on the BSC using a Wizard Stick handheld smoke generator indicated good capture efficiency. The air changes per hour (ACH) of the main room (including open office area) was calculated from the supply rate to be 9, which meets the minimum 4 ACH for a human patient room. The ACH of the infusion room was calculated from the supply rate to be 5, which also meets the minimum 4 ACH for a patient room. The ACH of the anteroom was calculated from the supply rate to be 101, which meets the required 12 ACH for an unclassified containment segregated compounding area. The ACH of the buffer room was calculated from the supply rate to be 81, which also meets the required 12 ACH.

The presence of potential surface contamination was evaluated with wipe samples. These were collected in areas where the staff handled chemotherapy drugs, such as the oncology department. Wipe samples were also collected in less obvious places (i.e., telephone, door handles) to determine if current workplace safety practices at the hospital were adequate to prevent inadvertent contamination of these surfaces. Sampling and analytical procedures varied by the hazardous drug for which they would be evaluated (i.e., the analyte). In some cases, a single sample could be evaluated for more than one analyte simultaneously. Vincristine and mustargen were the drugs used during the NIOSH visit. Sample analyses results revealed that 7 of 7 wipe samples submitted for toceranib analysis (an observed patient was on toceranib) tested positive (0.6 to 2.6 ng). Nine of 9 samples submitted for N-methyldiethanolamine (MDEA[1]) analyses were also positive (3.9 to 21.2 ng) while simultaneously being non-detectable (ND) for lomustine and chlorambucil. MDEA was monitored as a potential stable marker for the highly unstable antineoplastic drug mustargen as explained in the text. The ND determination means that contamination was either not present, or was present at levels below the detectable limit of the analytical method. Four out of 5 wipe samples submitted for carboplatin were positive (4.2 to 11 ng/sample). These four samples were between the limit of

[1] One field blank was positive for MDEA, 5.2 160 ng. Therefore, the positive MDEA samples originated from its prior therapeutic use, intentional component of whatever sources had contributed the other ethanolamines within the oncology department, or from an error at the analytical laboratory.

detection (LOD) and limit of quantification (LOQ). Five out of 18 samples submitted were positive for cyclophosphamide (1.7 ng/sample), vincristine (9.9 to 71 ng/sample), and epirubicin (4.3 ng/sample) while simultaneously being ND for methotrexate and doxorubicin.

Although some of the wipe sample analytical results were ND, there is no safe level of exposure when handling hazardous drugs. The epirubicin, carboplatin, vincristine, cyclophosphamide, MDEA, and toceranib presence serves as two reminders: (1) that hazardous drug contamination can sometimes linger despite cleaning efforts and (2) the detected contamination on desk and cabinet surfaces one might ordinarily think of as “safe,” emphasizes the importance of proper work practices regarding the use of gloves and shoe covers, hand washing, and food/drink prohibitions within the hazardous drug handling environments. Therefore, it is important to continue to use engineering controls (e.g., biological safety cabinets), supplementary controls (e.g., closed system drug-transfer devices), protective work practices (e.g., surface cleaning after every oncology patient, regardless of whether I.V. chemotherapy was administered), and personal protective equipment (e.g., gloves and gowns rated for chemotherapy protection, respirators, shoe covers, eye protection) to reduce unintentional exposures to the staff or pet owners.

Introduction

Background for Control Technology Studies

The National Institute for Occupational Safety and Health (NIOSH) is the primary Federal agency engaged in occupational Safety and health research. Located in the Department of Health and Human Services, it was established by the Occupational Safety and Health Act of 1970. This legislation mandated NIOSH to conduct a number of research and education programs separate from the standard setting and enforcement functions carried out by the Occupational Safety and Health Administration (OSHA) in the Department of Labor. An important area of NIOSH research deals with methods for controlling occupational exposure to potential chemical and physical hazards. The Engineering and Physical Hazards Branch (EPHB) of the Division of Field Studies and Engineering has been given the lead within NIOSH to study the engineering aspects of health hazard prevention and control.

Since 1976, EPHB has conducted a number of assessments of health hazard control technology on the basis of industry, common industrial process, or specific control techniques. Examples of these completed studies include the foundry industry; various chemical manufacturing or processing operations; spray painting; and the recirculation of exhaust air. The objective of each of these studies has been to document and evaluate effective control techniques for potential health hazards in the industry or process of interest, and to create a more general awareness of the need for or availability of an effective system of hazard control measures.

These studies involve a number of steps or phases. Initially, a series of walk-through surveys is conducted to select plants or processes with effective and potentially transferable control concept techniques. Next, in-depth surveys are conducted to determine both the control parameters and the effectiveness of these controls. The reports from these in-depth surveys are then used as a basis for preparing technical reports and journal articles on effective hazard control measures. Ultimately, the information from these research activities builds the data base of publicly available information on hazard control techniques for use by health professionals who are responsible for preventing occupational illness and injury.

Background for this Study

The 2004 *NIOSH Alert: Preventing Occupational Exposure to Antineoplastic and Other Hazardous Drugs in Health Care Settings* introduced a standard of universal precautions for handling hazardous drugs safely [NIOSH 2004]. The health effects due to occupational exposure to these drugs are extensive and can include chromosomal and other types of genetic damage, reproductive damage [NIOSH 2004], and exposure can cause adverse pregnancy outcomes [Albin 2010]. The NIOSH Alert states that its guidance applies to any worker who handles hazardous drugs, including veterinary medicine and animal care (VM/AC) workers [NIOSH

2004]. Cancer is a leading cause of death among cats and dogs and attributes to 50 percent of pet deaths each year [Crump 2013]. In addition, chemotherapy is widely used to treat animals with cancer and other ailments as owners wish to prolong the lives of their beloved pets [Fielding and Lacroix 2009]. As chemotherapy drug (most are identified as hazardous drugs) use increases and lower-cost generic drugs become available, many veterinarians are administering chemotherapy drugs on their own or through a veterinary oncologist [MacDonald 2009].

In the U.S., there are an estimated 500,000 VM/AC workers, not including young adults who work part-time or during school breaks [Mobo et. al 2010]. This project specifically benefits special population/priority population groups as 95% of veterinary technicians are women of reproductive age with a mean age of 38 [Technicians 2008]. Veterinary medicine is similar to human healthcare in that the professional objective is to provide medical, surgical, and preventive healthcare to a patient. Both veterinary medicine and human healthcare personnel are vulnerable to needlestick injuries, radiation exposure, and hazardous drugs [Hall et. al 2013]. However, VM/AC workers are more likely to have accidents and occupational diseases, as they are susceptible to animal bites, zoonoses, animal-related respiratory hazards, physical injury, and veterinary-related reproductive hazards [Epp and Waldner 2012; Hall et. al 2013]. Although both professions handle hazardous drugs, there are differences in how veterinary clinics obtain, prepare, and administer the drugs, house the dosed patient, and handle a dosed patient's excreta or vomitus [Seibert 2013]. A recent study showed that VM/AC workers were exposed to hazardous drug concentrations 15 times higher than human healthcare personnel, partly due to how chemotherapy is administered in animals versus humans [Klahn 2014]. Cost, time, inconvenience, and discomfort are just some of the reported barriers for VM/AC workers not using safety measures in their practices [Klahn 2014].

Also unlike human health care, veterinary medicine's job duties are not compartmentalized. It is common for administrative personnel to conduct day-to-day animal-care activities, especially in small clinics [Seibert 2013]. Administrative personnel may restrain animals for hazardous drug administration, clean cages, feed the animals, and assist the veterinarian. When they occur, tasks involving unsafe work practices not only affect the primary task worker, they put other VM/AC workers, such as veterinary assistants, kennel attendants, or animal care workers, at risk for occupational exposure to chemotherapy drugs. This work-task diversity emphasizes the need for a thorough evaluation (and cross-training) of safety practices in the handling of hazardous drugs (and the patients the drugs are administered to) in veterinary medicine. VM/AC workers need to be educated in: 1) the risk of the drugs they are handling; 2) how to handle the drugs safely through proper use of engineering controls and personal protective equipment (PPE); and 3) how to avoid exposure to hazardous drugs and their metabolites through carefully delineated safe work procedures.

Conversations with veterinary stakeholders revealed that the warnings and guidance in the NIOSH Alert are not effectively reaching VM/AC workers. Animal oncology clinics are staffed with general practitioners and clinic staff without

awareness of chemotherapy safety [Klahn 2014]. In one reported case study, a veterinarian admitted pouring hazardous drugs down the sink at his clinic. He then developed thyroid cancer at the age of 35, reportedly as a result of handling hazardous drugs. It was further estimated that over 4,000 veterinary practices administer chemotherapy without any safety measures [Smith 2010]. While the NIOSH Alert has had a significant impact upon hazard awareness and exposure prevention within human healthcare, there are significant differences (real and perceived) between the practices of human and veterinary medicine. These differences have reportedly been a roadblock in the NIOSH Alert's positive impact upon veterinary medicine. Controlling exposures to occupational hazards is the fundamental method of protecting workers. Traditionally, a hierarchy of controls establishes preferences in determining how to implement feasible and effective controls. The most preferred control, the elimination or substitution away from the use of hazardous drugs, is not realistic for this industry. The use of personal protective equipment is considered to be the least effective exposure control on a consistent basis [Mobo et. al 2010]. Therefore, engineering controls and work practice guidelines together form the first lines of defense for VM/AC worker protection against hazardous drug exposure.

Hospital Description

The veterinary hospital, which is the subject of the report, is referred to as Veterinary Hospital "E" in order to preserve its anonymity. The Veterinary Hospital E provides primary, specialty, and emergency care to small animal patients. The oncology department has five staff members, which include a veterinarian and technicians. The department administers chemotherapy to patients at least five times per day, three days a week. The oncology department shares a large room with the radiology department. The room consists of an office area, kennels, main room for examination (Figure 1), infusion room (Figure 2), anteroom (Figure 3), and buffer room (Figure 4). Chemotherapy drugs are prepared in a Class I biological safety cabinet (BSC) (Model 3971201, Labconco, Kansas City, MO, no certification sticker) located in the oncology department's buffer room (Figure 4). This particular model is equipped with a canopy connection for the ability to exhaust 100% to the outdoors.

Chemotherapy Preparation and Administration

Closed System Drug-Transfer Devices (CSTDs)

Veterinary Hospital E uses the ICU Medical closed system drug-transfer device (CSTD) system (ICU Medical, Inc., San Clemente, CA) to prepare and administer I.V. liquid forms of chemotherapy (Figure 5). By definition, a CSTD mechanically prohibits the transfer of environmental contaminants into the system and the escape of hazardous drug or vapor concentrations outside the system [NIOSH 2004]. CSTDs limit the potential for aerosolizing drug contamination and can reduce worker exposure to sharps, thus reducing the likelihood of occupational exposure to

hazardous drugs [NIOSH 2004]. Each CSTD system traditionally consists of a syringe adapter (i.e., CSTD syringe connector) plus three component adapters: vial adapter, intravenous (I.V.) port adapter or Y-site adapter, and a bag adapter or infusion adapter. Each of these adapters mates with the syringe adapter.

Oral Chemotherapy

For oral chemotherapy, the patient is given the pill in either in a flavored pill pocket or a pill gun (or piller). After the technician verifies the patient swallowed the pills, the patient is placed in a holding kennel until discharged to go home.

Chemotherapy Injection

For chemotherapy injection, the liquid drug is administered to the patient by subcutaneous or intramuscular route. No CSTD is used; only a drug-filled syringe and needle.

I.V. Chemotherapy

Sometimes a patient needs to receive chemotherapy through I.V. dosing via catheter (Figure 6). Although technique varies among technicians administering the dose, the overall process is similar. First the area is prepped by shaving the injection site and cleaning the area with alcohol. After the area is prepped, the indwelling intravenous catheter and then the T-port are inserted. Then the catheter and T-port are wrapped with bandage to keep the catheter in place. The CSTD Y-site adapter is connected to the catheter and the catheter is flushed with saline. Then the syringe with CSTD adapter is connected to the Y-site adapter, which is attached to the catheter. The chemotherapy is given until the syringe is empty. Once the drug-filled syringe is empty, it is disconnected and syringe filled with saline is connected to the Y-site. Saline from the syringe is pushed into the catheter to flush the line. T-port's line is closed and the catheter is removed from the patient's vein. The patient is bandaged and discharged to go home.

Occupational Exposure Limits and Health Effects

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH investigators use mandatory and recommended occupational exposure limits (OELs) when evaluating chemical, physical, and biological agents in the workplace. Generally, OELs suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the exposure limit. Combined effects are often not considered in the OEL. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus can

increase the overall exposure. Finally, OELs may change over the years as new information on the toxic effects of an agent become available.

Most OELs are expressed as a time weighted average (TWA) exposure. A TWA exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended short-term exposure limit (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

In the U.S., OELs have been established by Federal agencies, professional organizations, state and local governments, and other entities. The U.S. Department of Labor OSHA permissible exposure limits (PELs) [CFR 2003] are occupational exposure limits that are legally enforceable in covered workplaces under the Occupational Safety and Health Act. NIOSH recommendations are based on a critical review of the scientific and technical information available on the prevalence of health effects, the existence of safety and health risks, and the adequacy of methods to identify and control hazards [NIOSH 1992]. They have been developed using a weight of evidence approach and formal peer review process. Other OELs that are commonly used and cited in the U.S. include the threshold limit values (TLVs) recommended by ACGIH®, a professional organization [ACGIH 2010]. ACGIH TLVs are considered voluntary guidelines for use by industrial hygienists and others trained in this discipline "to assist in the control of health hazards." Workplace environmental exposure levels (WEELs) are recommended OELs developed by AIHA, another professional organization. WEELs have been established for some chemicals "when no other legal or authoritative limits exist" [AIHA 2007].

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91–596, sec. 5(a)(1)]. Thus, employers are required to comply with OSHA PELs. Some hazardous agents do not have PELs, however, and for others, the PELs do not reflect the most current health-based information. Thus, NIOSH investigators encourage employers to consider the other OELs in making risk assessment and risk management decisions to best protect the health of their employees. NIOSH investigators also encourage the use of the traditional hierarchy of controls approach to eliminating or minimizing identified workplace hazards. This includes, in preferential order, the use of: (1) substitution or elimination of the hazardous agent, (2) engineering controls (e.g., local exhaust ventilation, process enclosure, dilution ventilation), (3) administrative controls (e.g., limiting time of exposure, employee training, work practice changes, medical surveillance), and (4) PPE (e.g., respiratory protection, gloves, eye protection, hearing protection).

Occupational Exposure Limits and Hazardous Drugs

Currently there are no PELs, RELS, or TLVs® for hazardous drugs [NIOSH 2004]. However, a PEL, REL, and TLV® have been established for inorganic arsenic compounds, such as arsenic trioxide, an antineoplastic drug [NIOSH 2004]. A WEEL has been established for some antibiotics. Some pharmaceutical manufacturers develop risk-based OELs and that information may be listed on the safety data sheets (SDSs) [NIOSH 2004].

Methodology

BSC and Oncology Department Performance Evaluations

Equipment: BSC Face Velocity Measurements

A TSI® VelociCalc™ Plus Model 9565-P thermal anemometer (TSI Incorporated, St. Paul, MN) was used to measure air velocities at the face of the BSC located in the buffer room (Figure 7).

Procedure

To determine the BSC's average face velocity, the open face of the hood was divided into an equal-area grid of six squares measuring approximately 0.09 square meters (m^2) (1 square foot [ft^2]) each. A 5-second average velocity measurement was taken at the center of each square, while holding the anemometer perpendicular to the inward airflow direction. The average face velocity across the entire hood face was then determined by calculating the average of the equal-area square velocity measurements.

Equipment: BSC Qualitative Smoke Test

A Wizard Stick (Zero Toys, Inc., Concord, MA) handheld "smoke" generator was used to visualize air movement inside and around the periphery of the BSC in the buffer room (Figure 8). The wizard stick produces a stream of safe, condensed vapor droplets and contains no actual solid 'smoke' particles, however the vapor droplets float in the air, appearing similar to smoke, and their flow path is indicative of the flowpath of the air in which they are suspended.

Procedure

The "smoke" was released around the periphery of the BSC's open face and in the interior of the hood to qualitatively evaluate the capture efficiency and evaluate potential areas of concern. If the smoke was captured quickly and directly by the hood at the point where compounding operations are performed, it indicated acceptable control design and performance. If the smoke was slow to be captured or took a circuitous route to the hood exhaust intake, this indicated a potential problem. In addition, the adverse effect of cross drafts upon hood capture was evaluated by releasing smoke near the periphery of the hood face. Lack of direct capture or evidence of reverse-flow turbulence would be indicative of poor hood performance.

Equipment: Measurement of Supply and Exhaust Airflow Rates in the Oncology Department

A TSI Accubalance® Plus Air Capture Hood Model 8373 (TSI Incorporated, St. Paul, MN) was used to measure airflow for the supply and return ventilation in the oncology department (Figure 9).

Procedure

The instrument was setup according to the manual using the appropriate flow hood 0.6 m x 0.6 m (2 ft x 2 ft) or 0.6 m x 1.2 m (2 ft x 4 ft) to match the corresponding sized supply and exhaust louvers. The instrument was turned on and the hood was placed over the supply or exhaust vent. The measured airflow was displayed in cubic feet per minute (cfm) on the instrument's screen during measurement. Air measurements were taken using the instrument's backpressure compensation to ensure accurate readings.

Wipe Sampling Methods

Surface wipe samples were collected throughout Veterinary Hospital E using different sampling methods. Samples were collected in areas where drugs were handled by the workers, such as the main room, infusion room, ante and buffer rooms, and in places similar to those where traces of drugs have been found in human studies, such as door handles and telephones [Connor et. al 2010; Hon et. al 2013]. Wipe samples were also taken in less obvious places to determine if the hospital's current workplace safety practices were successful in preventing secondary contamination. NIOSH researchers were careful not to collect two samples from the same surface area. It should be noted that each of these wipe sampling methods are internal methods created specifically for this research study. There is limited data on recovery studies from various surfaces.

Wipe Sampling Method 1: Bureau Veritas North America Analytical Method

The Bureau Veritas North America wipe sample collection method uses Texwipe™ Alpha™ Polyester Series Swabs (TX715, ITW Texwipe, Kernersville, NC) and a 50:50 mixture of methanol and water (both high-performance liquid chromatography grade) solvent to collect surface wipe samples. Although the subsequent analytical methods may vary by analyte, this wipe sample collection method is applicable for analysis of carboplatin, vincristine, methotrexate, cyclophosphamide, epirubicin, doxorubicin, and vinblastine (sulfate). Carboplatin is analyzed using Bureau Veritas North America's internal method, BV-2017-30843 (Bureau Veritas North America, Novi, MI), which uses high performance liquid chromatography/mass spectrometry (HPLC/MS) to find platinum. Vinblastine (sulfate) is analyzed using Bureau Veritas North America's internal method NAT 2006-14763, which uses HPLC. Vincristine, methotrexate, cyclophosphamide, epirubicin, and doxorubicin are analyzed using Bureau Veritas North America's internal method BV-2016-29599, which also uses HPLC/MS. Table I shows the analytical limit of detection (LOD), limit of quantification (LOQ), and analytical range for each of the analytes.

Prior to the visit to Veterinary Hospital E, several 16 mL amber vials with screw caps were filled with 1 mL of a 50:50 mixture of methanol and water. During the

site visits, once a sampling location was identified, a surface wipe sample was collected using the Texwipe™ Alpha™ Polyester Series Swabs and solvent. First, the cap of the amber vial was removed and one of the swabs was inserted. After the swab was wetted with the solvent, the swab was pressed against the sample location and moved back and forth, progressing over an approximate 10 centimeter (cm) x 10 cm surface. The swab was then turned over and the same back and forth movement was repeated in a perpendicular direction to that first taken over the same 10 cm x 10 cm surface area. The excess solvent in the vial was poured onto an absorbent pad in a closable plastic bag for later disposal. The swab was placed head first partially into the vial opening and lateral pressure was applied to the swab stick to snap the head off and deposit it in the vial without touching. The cap and a label were placed on the vial. This surface wipe sampling collection method was repeated throughout the hospital. The samples were placed on ice packs until they were delivered to the NIOSH contract laboratory and stored frozen until analysis. Results are reported in nanogram of drug per sample (ng/sample). Vinblastine results are reported in microgram of drug per sample (µg/sample).

Wipe Sampling Method 2: NIOSH Internal Analytical Method

NIOSH developed a solvent system for surface wipe sampling and analysis of lomustine (or CCNU), toceranib, N-methyldiethanolamine (MDEA), and chlorambucil sampled using two different wipe sampling media: Texwipe™ Alpha™ Polyester Series Swabs and Whatman™ filter papers (number 1442-055, 55-mm ashless circles, GE Healthcare, Chicago, IL). MDEA was analyzed as a likely indicator for mustargen after the rapid degradation expected for the compound in typical open environments (see Discussion). Table II lists the LOD, LOQ, and calibration plot concentration range for each of the analytes. Sampling media used to collect this set of analytes was moistened with a solvent blend of 83% acetonitrile/17% dimethylsulfoxide/0.20% hydrochloric acid, selected through extensive experiments conducted during method development for the survey. It provided stability in solution and adequate recoveries from in-house spiked quality control samples for all four of the antineoplastic drugs in this set via control of pH, solubility and other factors. The same solvent was used to prepare calibration standards and quality control samples to ensure compatibility with field samples during analysis.

After a swab was wetted with the solvent, the wipe sample procedure was the same as that described in Wipe Sampling Method 1. Upon collection, the swab was placed (head first) over the opening of a 125 mL translucent polypropylene jar (Nalgene™ Wide-Mouth Straight-Sided Polypropylene copolymer [2118-0004], Thermo Scientific™, Rochester, NY). Lateral pressure was applied to the swab stick to snap the head off and into the jar without touching. A second swab was wetted and the surface wipe sample collection was repeated for the same area using the same technique. The two wetted swabs made up one sample.

If filter paper was used for wipe sampling, then a petri dish, separated into its top and bottom halves, was used for preparing the sample. First one Whatman™ filter paper was placed into each half of the petri dish. A pipettor and disposable pipet tip were used to measure 250 microliters (µL) of the solvent onto each filter paper. An area of approximately 10 cm x 10 cm was wiped with one wetted filter paper and

placed into a 125 mL polypropylene jar. The same 10 cm x 10 cm area was then re-sampled, in a wiping progression perpendicular to the first filter using the second wetted filter paper. The second wetted filter paper was placed into the same jar. The two wetted filter papers made up one sample.

Upon sample collection, the jar was capped and a sample label affixed. Samples were placed on ice packs and transported to a NIOSH laboratory freezer for storage at approximately -10ºC until analysis. Samples were returned to room temperature and were processed by extraction via orbital shaker using a total of 10 mL of the aforementioned solvent blend. The supernatant was filtered and 2 mL was transferred to autosampler vials and fortified with internal standard (see Discussion below) for analysis via HPLC/MS. Results are reported as mass of drug (ng).

Results

BSC Performance Evaluations

BSC Face Velocity Measurements

Hood velocity measurements were collected on a Class I BSC in the buffer room. The average face velocity of the hood (n=6 measurements) was 0.66 meters per second (m/s) (129 feet per minute [fpm]) as measured by the anemometer. The maximum face velocity was 0.74 m/s (146 fpm) with a minimum face velocity of 0.58 m/s (115 fpm).

BSC Qualitative Smoke Test

The Wizard Stick smoke generator was used to qualitatively test the capture efficiency of the lab hood. Smoke was released inside the hood at the center compounding position, inside the hood along the perimeter of the open hood face, outside of the hood along the perimeter of the open hood face, and outside of the hood directly in front of the hood face opening. In each case, the smoke was captured quickly, pulled further into the hood, and removed via the exhaust system. This showed the BSC had acceptable performance.

Measurement of Supply and Exhaust Airflow Rates in the Oncology Department

The TSI Accubalance® Plus Air Capture Hood was used to measure mechanically generated supply and exhaust airflows in the oncology department's main room, infusion room, anteroom, and buffer room. The main room (including open office area) had more supply air (0.17 m^3/s or 355 cfm) than was mechanically exhausted (0.08 m^3/s or 172 cfm). The total supply airflow and the room volume (66.0 m^3 [2,331 ft^3]) were used to calculate the ventilation rate in air changes per hour (ACH) for the room to be 9 (Equation 1). The infusion room had more supply air (0.04 m^3/s or 81 cfm) than mechanically exhausted (0.03 m^3/s or 67 cfm). The total supply airflow and the room volume (25.1 m^3 or 885 ft^3) were used to

calculate the ACH of 5. The anteroom had supply air (0.24 m^3/s or 498 cfm), room volume of (8.41 m^3 or 297 ft^3), and an ACH of 101. The buffer room had more supply air (0.34 m^3/s or 712 cfm) than was mechanically exhausted (0.25 m^3/s or 534 cfm). The total supply airflow and the room volume (15.0 m^3 or 530 ft^3) were used to calculate the ACH of 81.

Equation 1:

$$ACH = \frac{Airflow\ (^{m^3}/_{s}) \times 3600\ sec}{Room\ Volume\ (m^3)}$$

$$ACH = \frac{Airflow\ (^{ft^3}/_{min}) \times 60\ min}{Room\ Volume\ (ft^3)}$$

Wipe Sampling

Surface wipe samples were collected throughout Veterinary Hospital E's oncology department. Tables III and IV report the analytical chemistry results from these samples. Sample analyses results revealed that 7 of 7 wipe samples submitted for toceranib analysis (an observed patient was on toceranib) tested positive (0.6 to 2.6 ng). Nine of 9 samples submitted for MDEA[2] analyses were also positive (3.9 to 21.2 ng) while simultaneously being non-detectable (ND) for lomustine and chlorambucil. Four out of 5 samples submitted for carboplatin were positive (4.2 to 11 ng/sample). Five out of 18 samples submitted were positive for cyclophosphamide (1.7 ng/sample), vincristine (9.9 to 71 ng/sample), and epirubicin (4.3 ng/sample) while simultaneously being ND for methotrexate and doxorubicin. The carboplatin and cyclophosphamide wipe samples were between the LOD and LOQ. The ND determination means that contamination was either not present, or was present at levels below the detectable limit of the analytical method. Three out of the 33 samples were intentionally collected from surfaces highly anticipated to be contaminated with hazardous drugs. These three "known" samples were positive for vincristine (9.9 and 71 ng), MDEA (3.9 ng), and toceranib (1.5 ng).

[2] One field blank was positive for MDEA, 5.2 160 ng. Therefore, the positive MDEA samples originated from its prior therapeutic use, intentional component of whatever sources had contributed the other ethanolamines within the oncology department, or from an error at the analytical laboratory.

General Observations

NIOSH researchers observed and interacted with facility's veterinarians and staff to obtain information about the day-to-day activities along with oncology treatment processes. General observations are listed below:

- Rooms leading to the buffer room were mislabeled. The buffer room was labeled chemo infusion, the anteroom was called the negative buffer room, and the infusion room was called the anteroom.
- Disposable gowns were reported to be reused until they are visibly worn or a spill occurs. During the NIOSH visit, a couple of gowns had holes near the cuffs (Figure 10).
- The BSC did not have a certification sticker on it.
- BSC is reportedly turned on only when preparing drug.
- Absorbent pad in BSC with a week old date.
- The employee refrigerator did not have a sticker indicating it was for "Food Only." The refrigerator was in an area where patients are seen, blood is drawn, and the veterinarian checks medicine (Figure 11).
- The hospital does separate the chemotherapy laundry from the rest of the facility.
- During preparation of vincristine and mustargen for a patient, the technician left the buffer room wearing the same pair of gloves worn during drug preparation.
- Employees reportedly did not understand the purpose of the air pressure monitors or how they worked.
- Items such as pens and trays were properly labeled with a brightly colored tag to let employees know they have been used while or near handling of chemotherapy drugs.

Discussion

The engineering assessment showed that the Class I BSC was operating effectively. The hood's average face velocity (0.67 m/s [98 fpm]), which is above the minimum recommended face velocity (i.e., 0.38 m/s [75 fpm]) for a Class I BSC [CDC 2009; USP 2019]. The ACH for the main room (including the open office area) was 9, which meets the minimum 4 ACH ventilation rate for a human patient room [ANSI/ASHRA/ASHE 2013]. The ACH of the infusion room was calculated from the supply rate to be 5, which also meets the minimum 4 ACH for a patient room. The anteroom's 101 ACH meets the required minimum of 12 ACH for an unclassified containment segregated compounding area (C-SCA) [USP 2019]. The buffer room's

81 ACH also meets the required 12 ACH minimum for an unclassified C-SCA. A wide variation of air velocities measured across the supply diffuser to the buffer room suggested no high efficiency particulate air (HEPA) filters were installed, therefore the anteroom and buffer room were evaluated as unclassified C-SCA as opposed to a "clean room".

The NIOSH researchers' strategy was to collect surface wipe samples after each chemotherapy treatment and randomly throughout the hospital. Vincristine and mustargen were the drugs used during the NIOSH visit. Sampling for some drugs, such as carboplatin, was conducted even though the drugs was not used during the visit. Surface wipe samples were analyzed by either the NIOSH lab or a contract lab, Bureau Veritas North America. The analytical results from all of the Bureau Veritas North America's field samples were ND except for seven, which were positive for carboplatin, cyclophosphamide, epirubicin, and vincristine. The carboplatin and cyclophosphamide results were between the LOD and LOQ. These wipe samples were collected from the floor in front of the buffer room's refrigerator and pill-counting tray in the BSC and the main room's kennel, mat, and floor. The epirubicin wipe sample was collected from a used disposable chemo gown. The vincristine sample was collected from a small kennel located in the main room. The positive toceranib and MDEA results were collected throughout the buffer room, anteroom, and infusion room. The highest contamination of toceranib (2.6 ng) was found on the buffer room's floor in front of the BSC. The highest contamination of MDEA (21.2 ng) was found in the BSC's airfoil.

NIOSH researchers collected wipe samples on certain surfaces that would be a known contamination or "hot" with the drugs. This strategy was done to test the analytical methods' ability to detect a drug. The known contaminated samples are highlighted in yellow on the tables. For example, the vincristine (71 ng/sample) and mustargen (3.9 ng for MDEA and 1.5 ng for toceranib) wipe samples were positive for drug contamination. These were known contaminated samples because the samples were collected outside of syringes that were filled with vincristine and mustargen. The other known contaminated wipe sample was collected outside of the vincristine vial (9.9 ng/sample). Research studies have shown that the outside of vials can be contaminated with hazardous drugs [Nyman et. al 2007; Power et al. 2014]. This contamination could be from staff handling the vial, manufacturer, or distributer.

Field blanks were collected during the surface wipe sampling. Field blanks are used to evaluate the amount of contamination that may have occurred during sample preparation, packaging, shipping, and/or storage before laboratory analysis [NIOSH 2016]. Field blanks are prepared in the same manner as a typical wipe sample except the media does not touch any surface. Field blank results are expected to result in NDs, however, sometimes field blanks yield positive results. Of eleven field blanks generated during this survey, one field blank was positive for MDEA. The field blank was 5.2 ng. The exact cause of the contaminated field blank is difficult to determine. While meticulous procedures are in place to minimize such occurrences, contamination does sometimes occur and in this case, the contamination could have occurred anytime within the sample preparation to the sample analysis

processes. Therefore, the positive MDEA samples originated from its prior therapeutic use, intentional component of whatever sources had contributed the other ethanolamines within the oncology department, or from an error at the analytical laboratory.

In-house NIOSH HPLC/MS analyses employed controlled fragmentation (MS/MS) of the parent ion of each analyte. Two fragment ions were monitored for each, with the more intense ion used for quantification and the other for confirmation. Positive response for an analyte was indicated by quantification ion response above the calculated LOD (q.v.) and by the presence of both expected fragment ions. Additionally, the ratio of intensities of the two fragment ion responses observed for field samples was compared to the average ratio observed for pure analyte (i.e., the calibration standards) as an additional metric for assessing positive analyte response in samples. If both ions were present but their ratio differed significantly from the expected value, it suggested that the quantitative value determined for the analyte might be affected by an unresolved interference and could thus be suspect. These results are designated appropriately in Table IV (q.v.).

No isotopically labeled standards for the analytes of interest were available for the HPLC/MS analysis. To monitor instrument stability during quantification, samples were fortified with 5 ng/mL of hexamethylphosphamide, a compound which responds strongly in LC-MS under the conditions of analysis, as an internal standard. However, this compound did not coelute with any of the analytes. Therefore, its response could not be used directly to correct for analyte signal drift, but did provide some indication of instrument stability over the course of analysis. Additionally, low-level calibration standards were periodically interspersed with field samples and responses were compared to expected levels. Quality controls were prepared in triplicate by spiking three levels of analytes onto applicable blank wipe media, which were processed and run with field samples to demonstrate extraction procedure efficacy and instrument performance. Finally, several field samples were rerun to determine whether reanalysis produced analyte values similar to initial values; in these cases both separate results are listed in Table IV.

Instability has been anecdotally observed for lomustine and chlorambucil in the course of NIOSH analytical method development, and documented for doxorubicin and other drugs elsewhere [NIOSH 2012]. Degradation of unstable compounds is expected to be especially rapid in open workplace environments absent controlled parameters. Mustargen is also very reactive in uncontrolled environments and rapidly decays to several products, of which the ethanolamine MDEA is the most important in environments with typical humidity levels. Since it was unlikely that intact mustargen would be detected at a workplace site if sampling and/or analysis took place long after a contamination event, the decision was made to quantify MDEA, which was readily detectable via HPLC/MS, as a potential marker for the original compound. However, positive sample results for MDEA may not be indicative of actual mustargen contamination, since ethanolamine compounds (of which MDEA is one) are often used in modern manufacturing techniques and cleaning media. For purposes of this investigation, MDEA presence in workplace samples should only serve as a potential warning and cannot be conclusively linked

to a particular source. After quantification of the antineoplastic drugs was completed via the NIOSH method, several of the field samples were subsequently screened for other ethanolamine compounds, which were generally found to be present. However, no meaningful quantitative correlations existed between these compounds and MDEA, suggesting that when MDEA was present it could not be automatically regarded as a contaminant or intentional component of whatever sources had contributed the other ethanolamines. It is therefore not possible to guarantee or to dismiss that detection of MDEA in a field sample, as occurred in the present survey, signals the presence of a prior mustargen spill event.

It is common to have a wipe sample analyses for hazardous drug contamination result in a ND finding, even in the presence of a hazardous drug manipulations [NIOSH 2012]. Some of the hazardous drugs, such as doxorubicin, are not stable and can decay rapidly as noted above [NIOSH 2012]. These drugs are less likely to be detected from surface wipe samples. The hospital also used CSTDs to prepare and administer chemotherapy, which studies have shown can reduce surface contamination [Sessink and Bos 1999; Nygren et al. 2002; NIOSH 2004; Harrison et al. 2006; Nyman et al. 2007; Yoshida et al. 2009; Sessink et al. 2010; Vyas 2013]. Another possible reason most of the samples did not detect any drug is that the level of hazardous drugs on surfaces may vary over time. This variation is influenced by drug amounts handled, patient load, cleaning, and work practices [NIOSH 2012].

One limitation of the study is there are currently only a handful of analytical methods covering a small fraction of the 218 hazardous drugs on the *NIOSH List of Antineoplastic and Other Hazardous Drugs in Healthcare Settings* [NIOSH 2016]. The hospital uses several hazardous drugs for which the NIOSH researchers were not able to sample due to the absence of an analytical method. An additional limitation is the time between sample collection and analysis. Although surface wipe samples are shipped on ice within 24-hours of their collection, it may much longer before the analytical laboratories can analyze the samples. This delay in sample analysis could decrease the chances of detecting a positive wipe sample due to analyte instability as discussed above.

Conclusions and Recommendations

The epirubicin, carboplatin, vincristine (in the kennel), cyclophosphamide, MDEA, and toceranib presence serves as two reminders: (1) that hazardous drug contamination can sometimes linger despite cleaning efforts and (2) the detected contamination on surfaces one might ordinarily think of as “safe,” emphasizes the importance of proper work practices regarding the use of gloves and shoe covers, hand washing, and food/drink prohibitions within the hazardous drug handling environments. Therefore, it is important to continue to use engineering controls (biological safety cabinets), supplementary controls (CSTDs), protective work practices (surface cleaning after every oncology patient, regardless of whether I.V. chemotherapy was administered) and PPE (gloves and gowns rated for

chemotherapy protection, respirators, shoe covers, eye protection) to reduce unintentional exposures to the staff and other patients.

NIOSH researchers observed proper work practices that Hospital E had in place during the visit. The hospital is encouraged to:

- Continue using the hospital's standard operating procedures for administering of drugs, spills, post administration of drug cleaning, and patient management [USP 2019].

- Continue to use the BSC to prepare chemotherapy treatments for patients [NIOSH 2004; USP 2019].

- Continue to clean the BSC each time a hazardous drug is used inside the cabinet even if there is no noticeable spill or leak. United States Pharmacopeia (USP) <797>, Pharmaceutical Compounding: Sterile Preparations, has a section on cleaning and disinfecting compounding areas [USP 2019].

- Continue to use PPE for handling hazardous drugs [NIOSH 2004; NIOSH 2010; USP 2019].

- Continue to use gloves during all tasks involving a chemotherapy patient [USP 2019]. Staff should wear American Society for Testing and Materials (ASTM)-tested chemotherapy gloves [USP 2019]. Change gloves every 30 minutes unless otherwise recommended by the glove manufacturer or if contaminated, torn, or punctured [USP 2019].

- Continue to use CSTDs during compounding and administering of hazardous drugs [NIOSH 2004; USP 2019]. Although CSTDs may reduce worker exposure to hazardous drugs, they may not entirely eliminate exposure [Sessink and Bos 1999; Nygren et al. 2002; NIOSH 2004; Harrison et al. 2006; Nyman et al. 2007; Yoshida et al. 2009; Sessink et al. 2010; Vyas 2013]. The NIOSH Alert identifies CSTDs as supplemental controls that should only be used in combination with ventilated primary engineering controls (i.e., biological safety cabinets and containment isolators) to further protect against worker exposures to hazardous drugs [NIOSH 2004]. Therefore, it is important to continue to use the BSC and proper PPE to protect the staff, even when CSTDs are used.

- Continue with washing hands after compounding, administering, or handling hazardous drugs [USP 2019].

- Continue to use the *Chemotherapy Treatment in Process* sign [NIOSH 2010; USP 2019].

Below are a few recommendations for consideration within the hospital's work practices as well as towards the facility design that could reduce unintentional exposures to hazardous drugs:

- Ensure that all employees expected to wear respiratory protection are trained and fit-tested on the specific respirator in use. The respirator must be used as part of a comprehensive respiratory protection program and the user must be enrolled into a Respiratory Protection Program in accordance with the requirements of OSHA 1910.134 [OSHA 2011].

  Respirators should be used in a proper respirator program under the supervision of a properly trained respirator program administrator. Respirators used without such a program, with all its essential elements, cannot be relied upon to protect workers.

  Each worker required to wear a respirator must be medically evaluated and cleared by a physician to wear the specific respirator before performing assigned tasks. For respirators to be effective and protect workers from harmful exposures, they must be selected, inspected, and maintained properly. Respirators should be inspected by the worker prior to each use for any defects. Reuseable respiratory protective equipment should also be cleaned, disinfected, and re-inspected after each use. Respiratory protective devices should never be worn when a satisfactory face seal cannot be obtained. Many conditions may prevent a good seal between the worker's face and the respirator. Some of these conditions include facial hair, glasses, or an unusually structured face. All workers required to wear a respirator must be properly trained on the selection, use, limitations, and maintenance of the respirator. They also must be fit–tested to assure a proper seal between the workers face and the specific make/model of respirator assigned for their use, prior to performing work tasks in a contaminated area.

  All workers should receive annual fit–testing with a quantitative testing device. When not in use, respirators must be stored in a clean environment located away from any source of contamination.

- Develop an SOP for receiving a hazardous drug shipment [USP 2019].

- Ensure that the BSC is certified on a yearly basis and after it has been repaired or relocated [CDC 2009]. Ensure that the hood certification process includes the most recent edition of the National Sanitation Foundation (NSF) Standard 49, Biosafety Cabinetry Certification [NSF/ANSI 2016].

- Perform heating, ventilating, and air conditioning (HVAC) air balancing on the secondary engineering controls (buffer room) and the infusion room to establish negative air pressure within these rooms while remaining compliant with their respective ACH requirements.

- Do not reuse disposable gowns. Use gowns once and throw them away in chemotherapy waste [USP 2019].

- Gloves and other PPE worn while handling hazardous drugs should be removed before leaving the oncology department [USP 2019].

- Gloves should also be worn when unpacking hazardous drug shipment [USP 2019].

- Clean area after each chemotherapy administration [USP 2019].

- Clean scissors and other tools after each use with chemotherapy patients [NIOSH 2010; USP 2019].

- Wash clothing and blankets that could be contaminated with drug separately from items with no anticipated drug contamination [USP 2019].

- Ensure dedicated cleaning supplies (mops, rags, buckets, etc.) used within chemotherapy treatment areas are not used in other areas of the hospital [NIOSH 2004].
- Prevent other staff from entering the room unprotected during chemotherapy administration [NIOSH 2010; USP 2019].

- Place color-coded neckbands on patients recently treated with chemotherapy drugs [NIOSH 2012].

- Do not allow drinks (caps and no caps) to be in areas where chemotherapy is prepared or administered.

Acknowledgements

NIOSH researchers would like to thank the staff at Veterinary Hospital E. The staff allowed the researchers to observe their work practices, complete an engineering assessment, collect wipe samples, and ask questions. Without the staff's willingness to participate in the research, the project's goals are not possible. The NIOSH researchers would also like to thank Jack Pretty, Ph.D., of NIOSH/HELD/CBMB and the Bureau Veritas North America contract laboratory for their analysis of the field samples.

References

ACGIH [2010]. 2010 TLVs® and BEIs®: threshold limit values for chemical substances and physical agents and biological exposure indices. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.

AIHA [2007]. 2007 Emergency Response Planning Guidelines (ERPG) & Workplace Environmental Exposure Levels (WEEL) Handbook. Fairfax, VA: American Industrial Hygiene Association.

Albin K [2010]. Administrating chemotherapy: is it safe for pregnant or breast-feeding veterinary technicians? Vet Tech October 2010.

ANSI/ASHRAE/ASHE [2013]. American national standard ventilation of health care facilities. Atlanta, GA: ASHRAE, Inc. No. 170-2013.

CDC [2009]. Biosafety in microbiological and biomedical laboratories. 5th ed. Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, HHS Publication No. (CDC) 21-1112.

CFR [2003]. 29 CFR 1910.1000. Code of Federal Regulations. Washington, DC: U.S. Government Printing Office, Office of the Federal Register.

Connor TH, DeBord G, Pretty JR, Oliver MS, Roth TS, Lees PSJ, Krieg EF, Rogers B, Escalante CP, Toennis CA, Clark JC, Johnson BC, McDiarmid MA [2010]. Evaluation of antineoplastic drug exposure of health care workers at three university-based US cancer centers. Am College of Occup Environ Med 52(10):1019-1027.

Crump KT [2013]. Veterinary oncology. [http://www.vspn.org/Library/Misc/VSPN_M02045.htm]. Date accessed: December 2013.

Epp T, Waldner C [2012]. Occupational health hazards in veterinary medicine: physical, psychological, and chemical hazards. Can Vet J 53: 151-157.

Fielding SL, Lacroix C [2009]. Chemotherapy safety in small animal practice. The NAVTA J Fall 2009:44-49.

Hall AL, Davies HW, Demers PA, Nicol AM, Peters CE [2013]. Occupational exposures to antineoplastic drugs and ionizing radiation in Canadian veterinary settings: findings from a national surveillance project. Can J Public Health 104(7):e460-e465.

Harrison BR, Peters BG, Bing MR [2006]. Comparison of surface contamination with cyclophosphamide and fluorouracil using a closed-system drug transfer device versus standard preparation techniques. Am J Health-Syst Pharm 63: 1736-1744.

Hon C, Teschke K, Chu W, Demers P, Venners S [2013]. Antineoplastic drug contamination of surfaces throughout the hospital medication system in Canadian hospitals. J Occup Environ Hygiene 10: 374–383.

Klahn S [2014]. Chemotherapy safety in clinical veterinary oncology. Vet Clin Small Anim 44: 941–963.

MacDonald V [2009]. Chemotherapy: managing side effects and safe handling. Can Vet J 50:665-668.

Mobo BHP, Rabinowitz PM, Conti LA, Taiwo OA [2010]. Occupational health of animal workers. In: Rabinowitz PM, Conti LA, eds. Human-animal medicine: clinical approaches to zoonoses, toxicants and other shared health risks. Maryland Heights: Saunders Elsevier, pp. 343-371.

NIOSH [1992]. Recommendations for occupational safety and health: compendium of policy documents and statements. Cincinnati, OH: U.S. Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 92-100.

NIOSH [2004]. NIOSH alert: preventing occupational exposures to antineoplastic and other hazardous drugs in health care settings. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2004-165.

NIOSH [2010]. NIOSH workplace solutions: safe handling of hazardous drugs for veterinary healthcare workers. By Connor TH and Cordes B. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH) Publication No. 2010-150.

NIOSH [2012]. Hazard evaluation and technical assistance report: Chemotherapy drug evaluation at a veterinary teaching hospital, Michigan. rev. April 2013. By Couch J, Gibbins J, Connor T. Cincinnati, OH: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, NIOSH HETA Report No. 2010-0068-3156.

NSF/ANSI [2016]. Biosafety cabinetry: design, construction, performance, and field certification. Ann Arbor, MI: NSF International/American National Standard.

Nygren O, Gustavsson B, Ström L, Eriksson R, Jarneborn L, Friberg A [2002]. Exposure to anti-cancer drugs during preparation and administration. Investigations of an open and a closed system. J Environ Monit 4: 739–742.

Nyman HA, Jorgenson JA, Slawson MH [2007]. Workplace contamination with antineoplastic agents in a new cancer hospital using a closed-system drug transfer device. Hos Pharm 2(3): 219-225.

OSHA [2011]. 29 CFR 1910.134 Personal protective equipment. Washington, DC: U.S. Department of Labor, Occupational Safety and Health Administration, https://www.osha.gov.

Power LA, Sessink PJM, Gesy K, Charbonneau F [2014]. Hazardous drug residue on exterior vial surfaces: evaluation of a commercial manufacturing process. *Hosp Pharm* 49(4):355-362.

Seibert P [2013]. Telephone conversation on December 18, 2013, between P. Seibert, Safety Vet, and D. Hirst, Division of Applied Research and Technology, National Institute for Occupational Safety and Health, Centers for Disease Control, U.S. Department of Health and Human Services.

Sessink PJM, Bos RP [1999]. Evaluation of methods for monitoring occupational exposure to cytostatic drugs. Drug Safety 20(4): 347-359.

Sessink PJM, Connor TH, Jorgenson JA, Tyler TG [2010]. Reduction in surface contamination with antineoplastic drugs in 22 hospital pharmacies in the US following implementation of a closed-system drug transfer device. J Oncol Pharm Pract 0: 1-10.

Smith C [2010]. Chemo drugs a concern for veterinary workers, too. [http://www.mlive.com/living/kalamazoo/index.ssf/2010/07/chemo_drugs_a_concern_for_vete.html] Date accessed: February 2016.

Technicians Respond! National Demographic Survey Summary [2008]. TNJ Spring 2008:17-20.

USP [2019]. <797> Pharmaceutical compounding—sterile preparations. Rockville, MD: U.S. Pharmacopeia.

USP [2019]. <800> Hazardous drugs—handling in healthcare settings. Rockville, MD: U.S. Pharmacopeia.

Vyas N, Yiannakis D, Turner A, Sewell GJ [2013]. Occupational exposure to anti-cancer drugs: A review of effects of new technology. J Oncol Pharm Pract 20(4): 278-287.

Yoshida J, Genshin T, Mochizuki C, Masu Y, Koda S, Kumagai S [2009]. Use of a closed system device to reduce occupational contamination and exposure to antineoplastic drugs in the hospital work environment. Ann Occup Hyg 53(2): 153-160.

Appendixes

Table I. LOD[3]/LOQ[4] and analytical ranges of analyte for Bureau Veritas North America's Internal Methods

Analyte	LOD (ng)[5]	LOQ (ng)	Analytical Range (ng)
Carboplatin	2	15	2 to 200
Cyclophosphamide	0.8	2.7	0.8 to 200
Doxorubicin	1	3.4	1 to 200
Epirubicin	1	3.5	1 to 200
Methotrexate	0.9	3.1	0.9 to 200
Vincristine	1	4.0	1 to 200

Table II. LOD/LOQ and analytical ranges of analyte for NIOSH Method

Analyte	LOD (ng)	LOQ (ng)	Analytical Range (ng)
Methyldiethanolamine (MDEA: marker for mustargen)	3.8	13	5 to 2500
Lomustine	8.3	28	50 to 20000
Chlorambucil	0.11	0.36	5 to 2500
Toceranib	0.49	1.6	5 to 325

[3] LOD = limit of detection
[4] LOQ = limit of quantification
[5] ng = nanogram of drug

Table III. Chemotherapy Drugs in Surface Wipe Samples

Location and Sample Identification	Sample Description	Wipe Sampling Method	Results (ng/sample)[6]
Buffer Room	Floor in front of refrigerator (Figure 12)	BV-2017-30843[7] (Carboplatin)	(8.8) [8]
Buffer Room	Refrigerator handle	BV-2017-30843	ND[9]
Main Room	Kennel (Figure 13)	BV-2017-30843	(4.2)
Main Room	Mat on examination table (Figure 14)	BV-2017-30843	(4.2)
Main Room	Floor by examination table (Figure 15)	BV-2017-30843	(11)
Anteroom	Disposable gown	BV-2016-29599 (vincristine, methotrexate, cyclophosphamide, epirubicin, doxorubicin)	ND
Anteroom	Door handle to buffer room	BV-2016-29599	ND
Anteroom	Disposable gown (Figure 16)	BV-2016-29599	4.3 (epirubicin); ND for the other drugs
Anteroom	Examination table after mustargen and vincristine administration	BV-2016-29599	ND
Buffer Room	Lower airfoil in hood	BV-2016-29599	ND
Buffer Room	Pill counting tray (Figure 17)	BV-2016-29599	(1.7) (cyclophosphamide)
Buffer Room	Lower counter in front of drug storage shelf	BV-2016-29599	ND
Buffer Room	Front edge of second and third shelves in front of drug storage	BV-2016-29599	ND
Buffer Room	Floor in front of BSC	BV-2016-29599	ND
Buffer Room	Outside of vincristine syringe (Figure 18)	BV-2016-29599	71 (vincristine); ND for the other drugs
Buffer Room	Outside of vincristine vial (Figure 19)	BV-2016-29599	9.9 (vincristine); ND for the other drugs
Infusion Room	Bottom of kennel	BV-2016-29599	ND
Infusion Room	Telephone	BV-2016-29599	ND
Main Room	Small cat kennel (Figure 20)	BV-2016-29599	38 (vincristine); ND for the other drugs
Main Room	Stethoscope	BV-2016-29599	ND
Main Room	Computer	BV-2016-29599	ND
Main Room	Refrigerator where food is stored	BV-2016-29599	ND

[6] ng/sample = nanogram of drug per sample
[7] Bureau Veritas North America's Internal Method
[8] ( ) = Result between the limit of detection (LOD) and limit of quantification (LOQ)
[9] ND = results are not detected at the LOD
Yellow shading represents known sample with drug contamination

Table IV. Chemotherapy Drugs in Surface Wipe Samples using NIOSH Methods

Location and Sample Identification	Sample Description	Wipe Sampling Method	Results (ng)[10]
Anteroom	Floor leaving buffer room (Figure 21)	NIOSH Method (filter paper)	(9.5) (MDEA); 1.8 (toceranib); ND for chlorambucil and lomustine
Buffer Room	Drug storage shelf (tray with toceranib) (Figure 22)	NIOSH Method (Swabs)	(5.2)[11] MDEA[12]; ND for toceranib, chlorambucil, and lomustine
Buffer Room	BSC's airfoil (Figure 23)	NIOSH Method (filter paper)	(19.2) and 21.2 (MDEA); 1.8 and 1.9 (toceranib); ND for chlorambucil and lomustine
Buffer Room	Floor in front of BSC (Figure 24)	NIOSH Method (filter paper)	(6.9) and (6.7) (MDEA); 2.6 and 2.4 (toceranib); ND for chlorambucil and lomustine
Buffer Room	Floor in front of refrigerator (Figure 12)	NIOSH Method (filter paper)	11.4 (MDEA); *1.1*[13] (toceranib); ND for chlorambucil and lomustine
Infusion Room	Examination table after patient was administered mustargen/vincristine (Figure 25)	NIOSH Method (filter paper)	(7.1) (MDEA); *0.6* (toceranib); ND for chlorambucil and lomustine
Infusion Room	Floor by examination table where mustargen/vincristine was administered to a patient (Figure 25)	NIOSH Method (filter paper)	16.1 and 15.8 (MDEA); *1.0* and *1.1* (toceranib); ND for chlorambucil and lomustine
Buffer Room	BSC's airfoil (Figure 23)	NIOSH Method (filter paper)	(4.0) (MDEA); ND for toceranib, chlorambucil, and lomustine
Buffer Room	Outside of mustargen syringe (Figure 26)	NIOSH Method (filter paper)	(3.9) (MDEA); *1.5* (toceranib); ND for chlorambucil and lomustine

[10] ng = mass of drug
[11] () = indicate that value may be questionable based on fragment ion ratio
[12] MDEA = N-methyldiethanolamine; One field blank was positive for MDEA, 5.2 160 ng. Therefore, the positive MDEA samples originated from its prior therapeutic use, intentional component of whatever sources had contributed the other ethanolamines within the oncology department, or from an error at the analytical laboratory.
[13] *Italics = Result between the limit of detection (LOD) and limit of quantification (LOQ)*

Figure 1. Oncology Department's main room (Photo Credit: NIOSH)

Figure 2. Oncology Department's infusion room (Photo Credit: NIOSH)

Figure 3. Oncology Department's anteroom (Photo Credit: NIOSH)

Figure 4. Oncology Department's buffer room with BSC (Photo Credit: NIOSH)

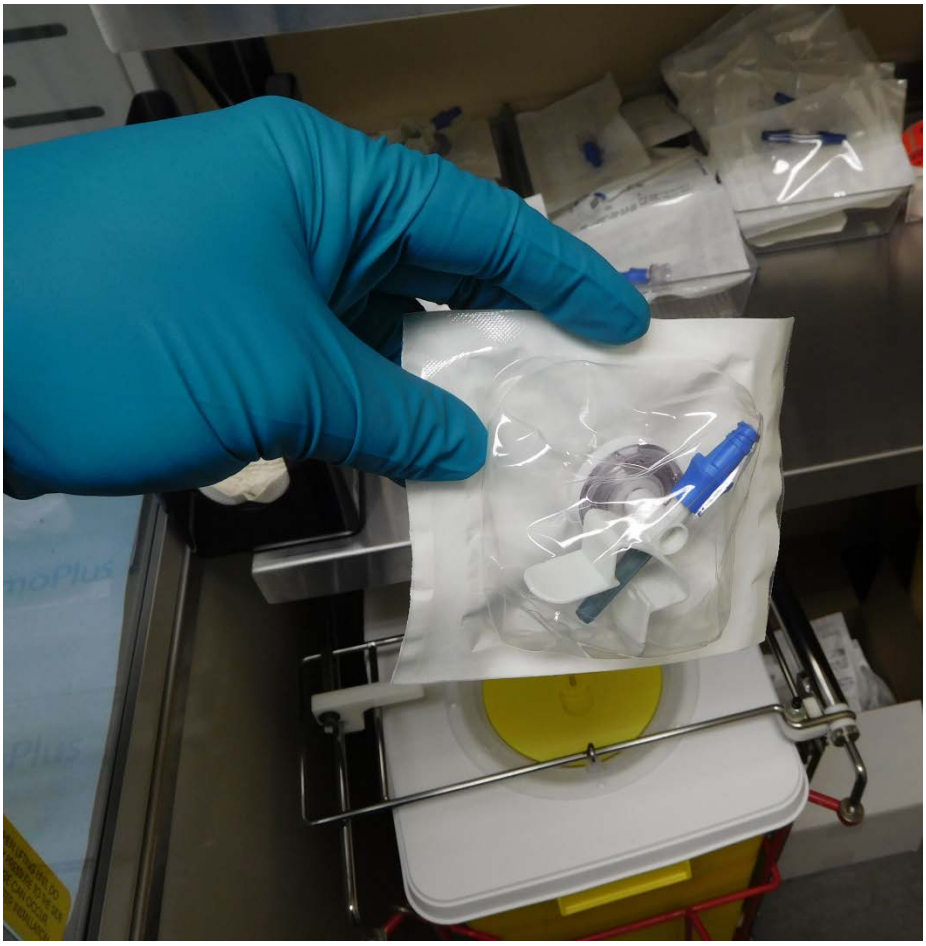

Figure 5. One of ICU Medical CSTD system adapters (Photo Credit: NIOSH)

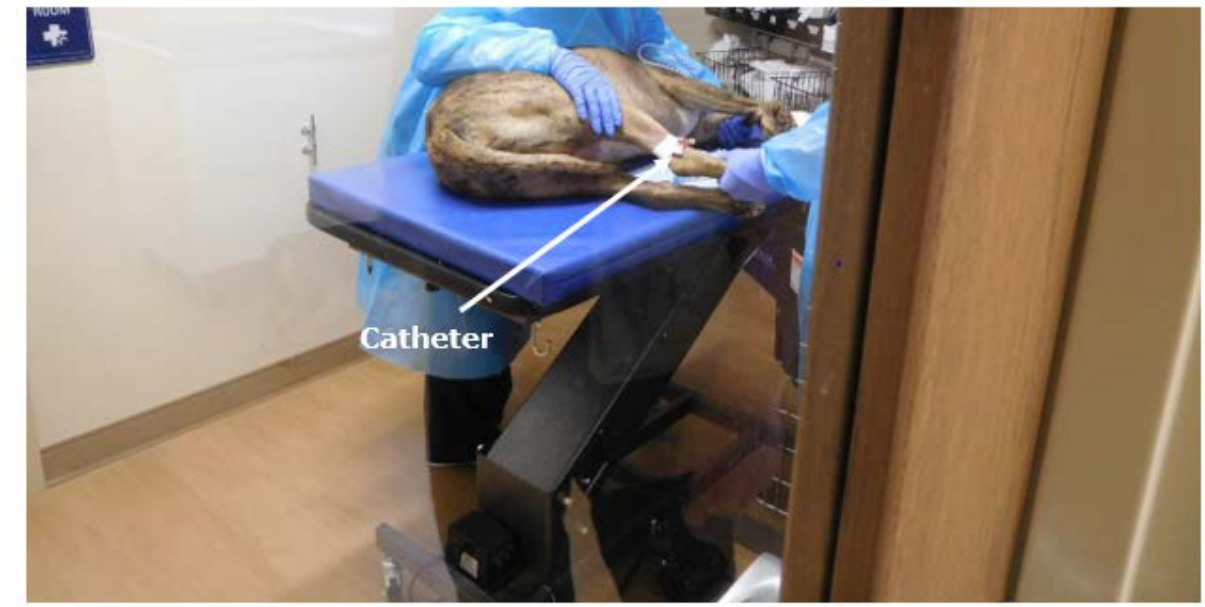

Figure 6. Patient about to receive chemotherapy through I.V. dosing via catheter (Photo Credit: NIOSH)

Figure 7. Example of a TSI® VelociCalc™ Plus Model 9565-P thermal anemometer (Photo Credit: NIOSH)

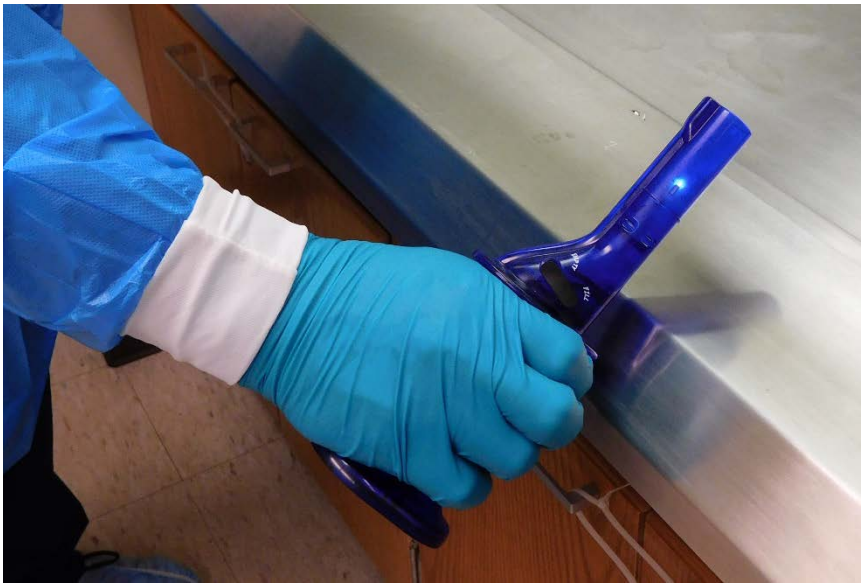

Figure 8. Example of a qualitative smoke test with Wizard Stick Smoke Generator (Photo Credit: NIOSH)

Figure 9. Example of a TSI Accubalance® Plus Air Capture Hood (Photo Credit: NIOSH)

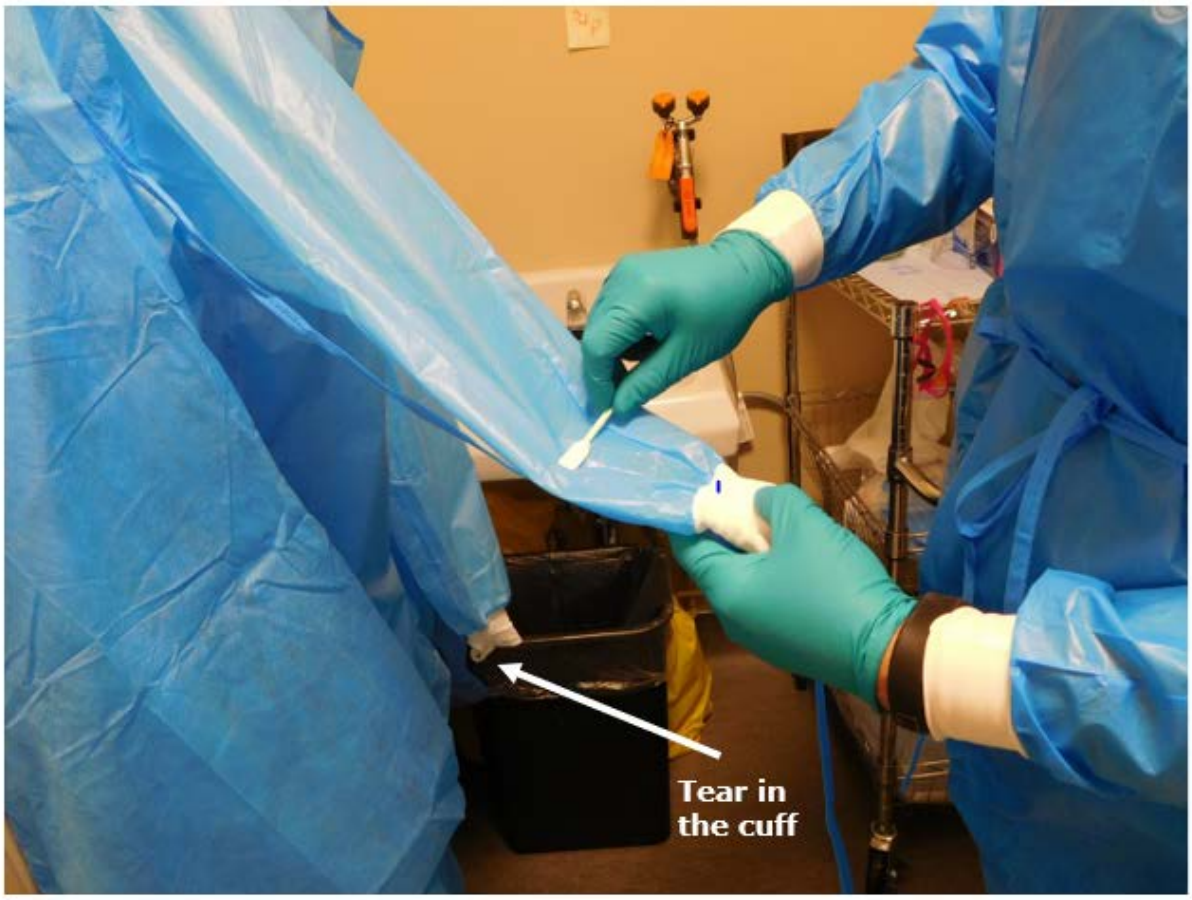

Figure 10. Disposable gown with a tear in the cuff (Photo Credit: NIOSH)

Figure 11. Refrigerator that is used for food but located where patients are seen (Photo Credit: NIOSH)

Figure 12. Floor in front of refrigerator in buffer room (Photo Credit: NIOSH)

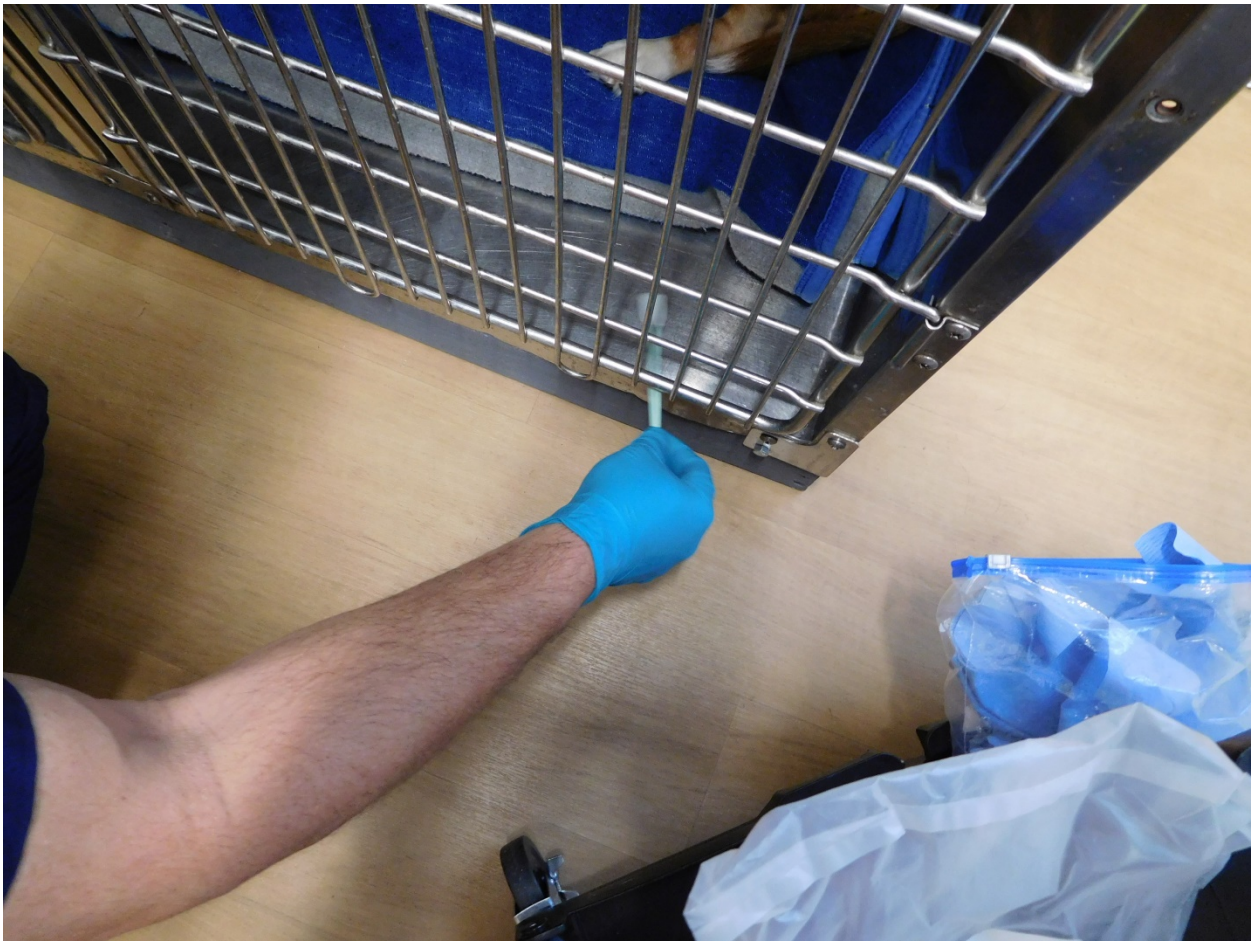

Figure 13. Kennel in Main Room (Photo Credit: NIOSH)

Figure 14. Mat on examination table in Main Room (Photo Credit: NIOSH)

Figure 15. Floor by examination table in Main Room (Photo Credit: NIOSH)

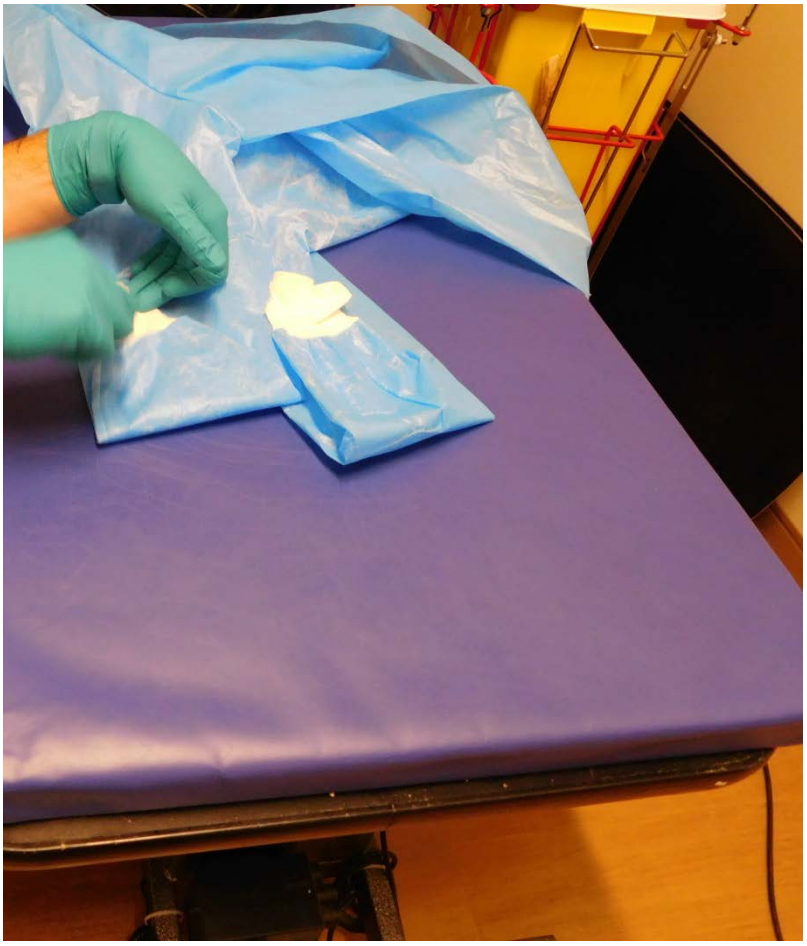

Figure 16. Disposable gown in Infusion Room (Photo Credit: NIOSH)

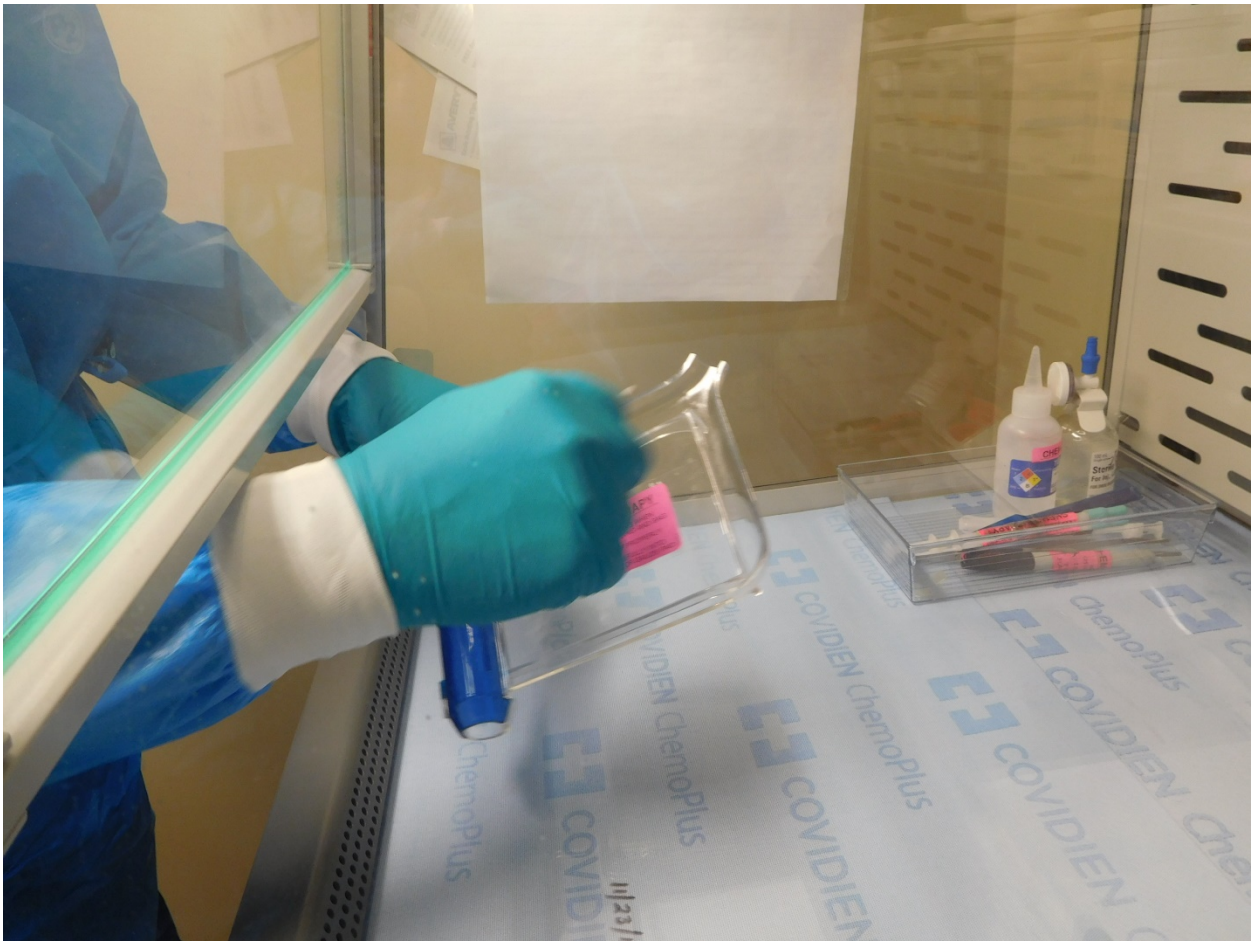

Figure 17. Pill counting tray in Buffer Room's BSC. Also shown are properly labeled items that have been in contact with chemotherapy drugs (labels are in pink). (Photo Credit: NIOSH)

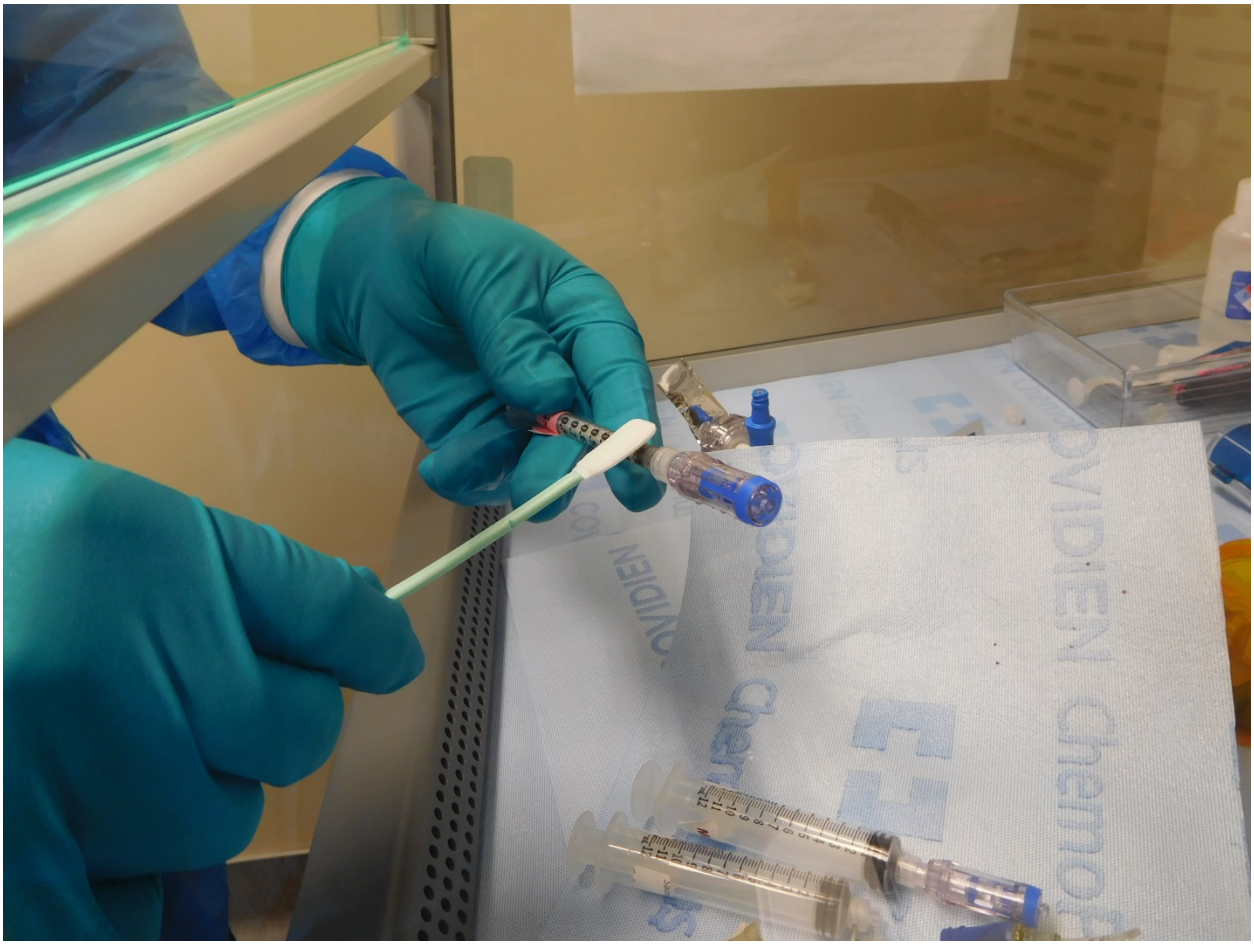

Figure 18. Vincristine syringe (Photo Credit: NIOSH)

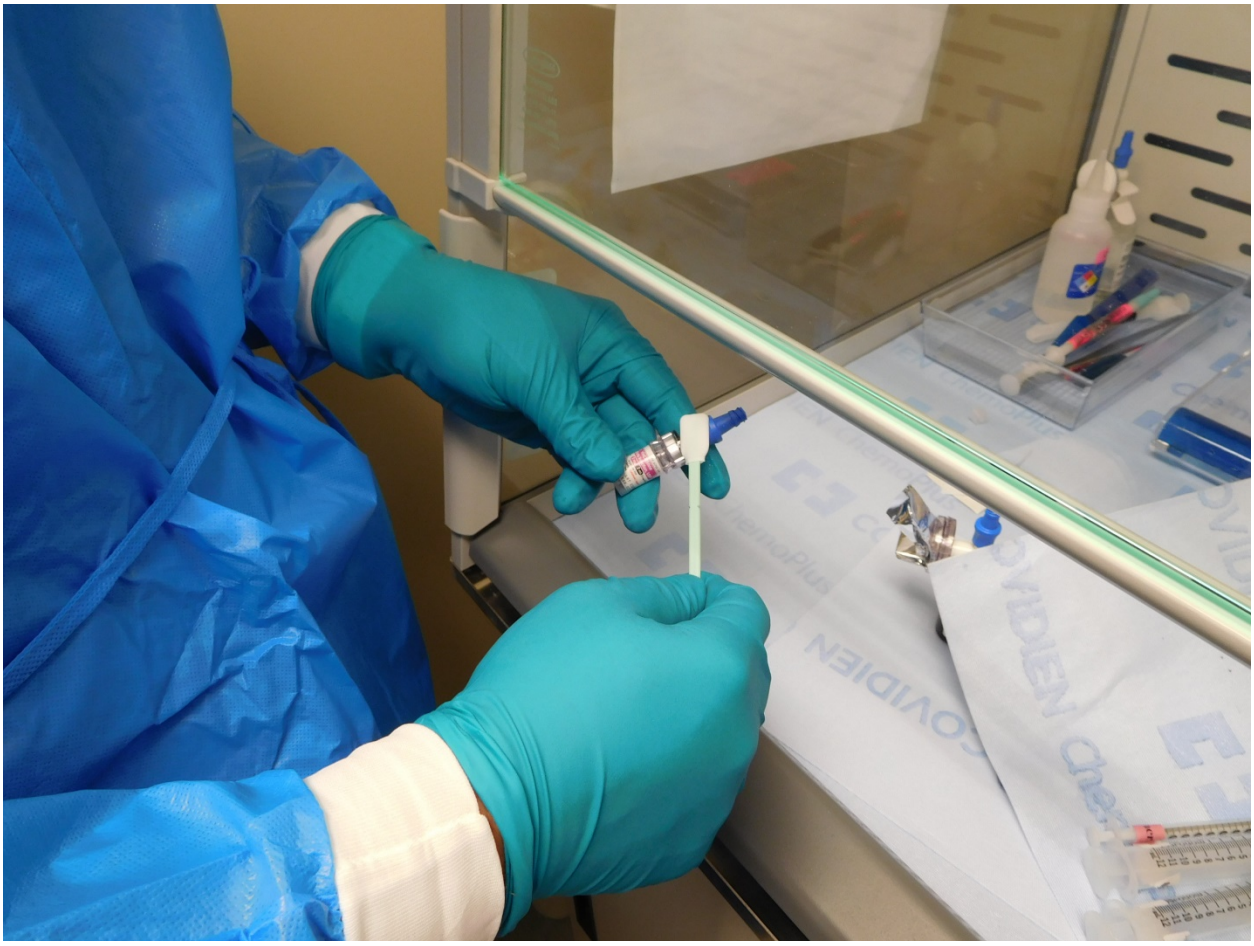

Figure 19. Vincrstine vial. Also shown are properly labeled items that have been in contact with chemotherapy drugs (labels are in pink). (Photo Credit: NIOSH)

Figure 20. Small cat kennel (Photo Credit: NIOSH)

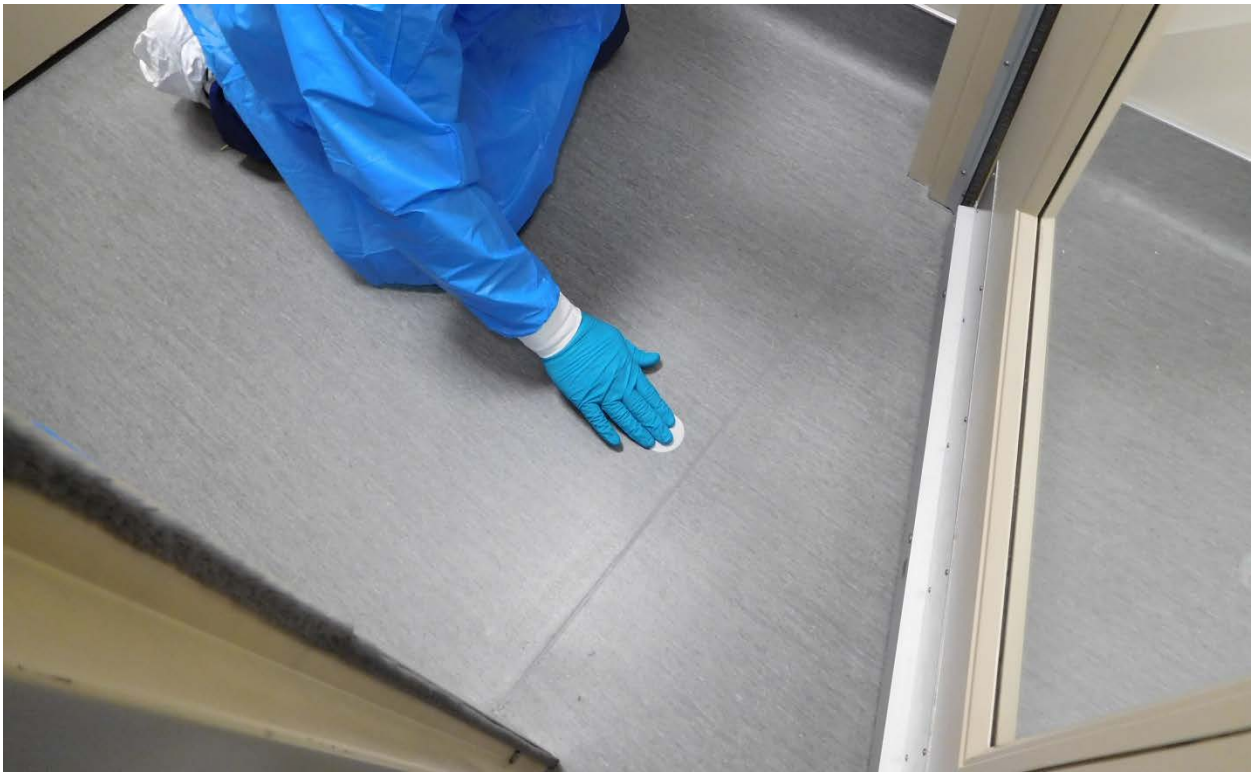

Figure 21. Floor leaving buffer room (Photo Credit: NIOSH)

Figure 22. Drug storage shelf (tray with toceranib) (Photo Credit: NIOSH)

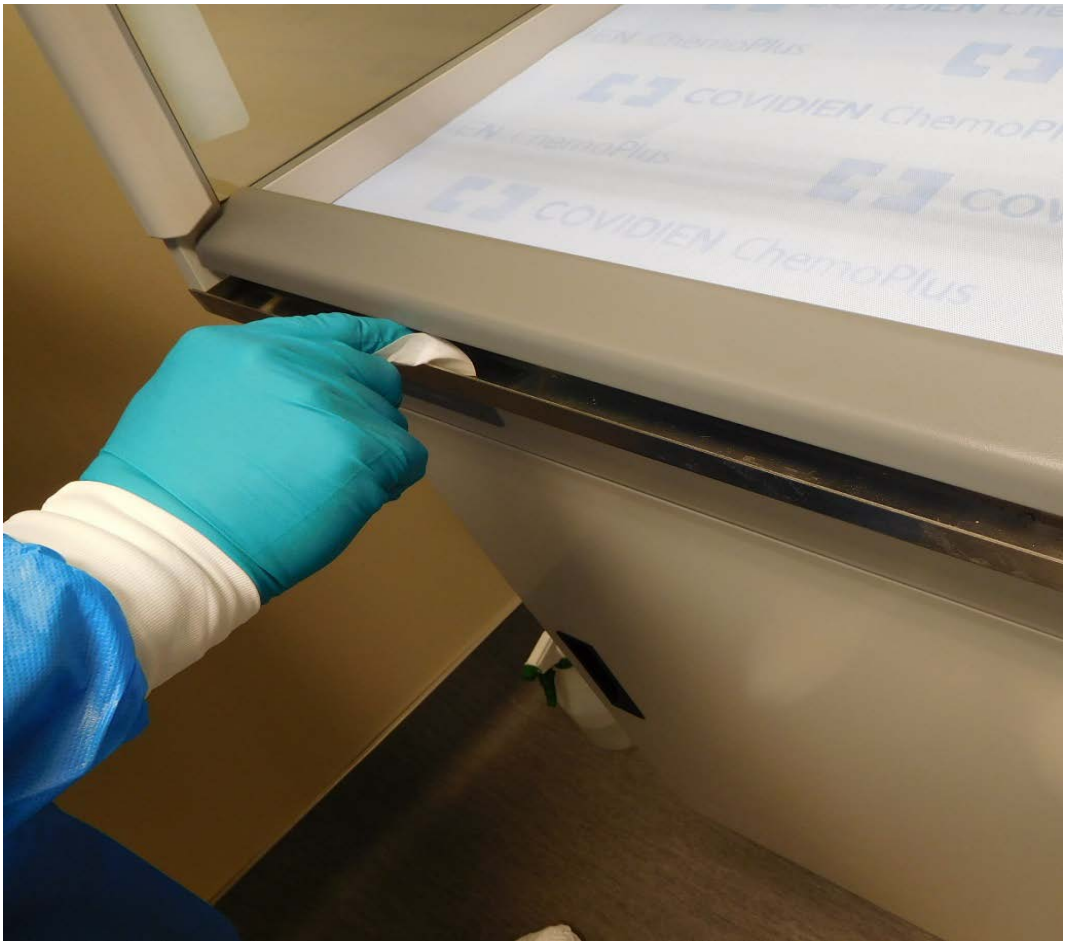

Figure 23. BSC's airfoil (Photo Credit: NIOSH)

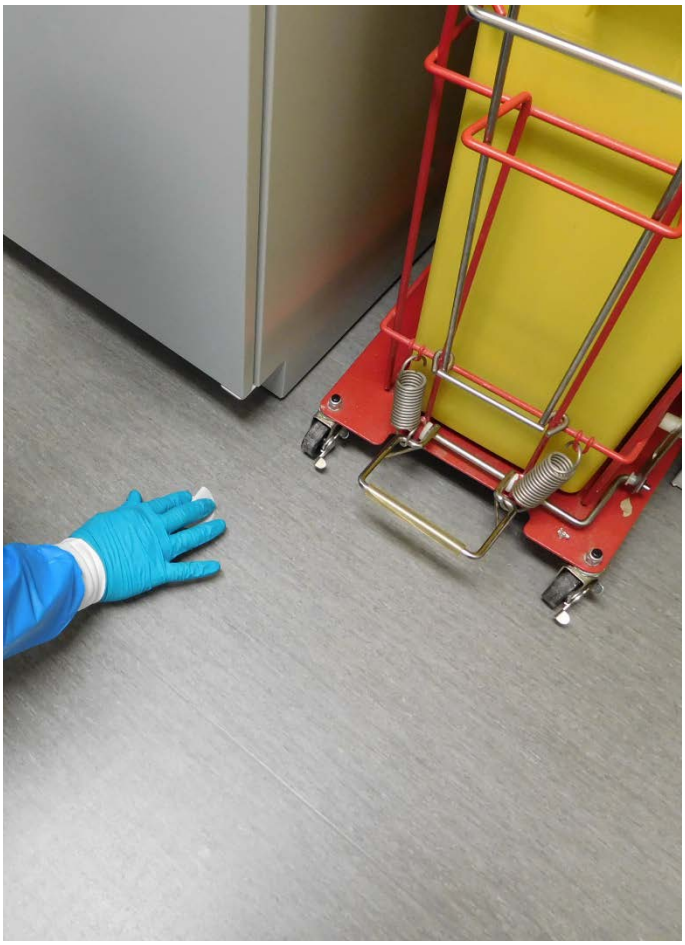

Figure 24. Floor in front of BSC (Photo Credit: NIOSH)

Figure 25. Examination table and floor where patient was administered mustargen/vincristine (Photo Credit: NIOSH)

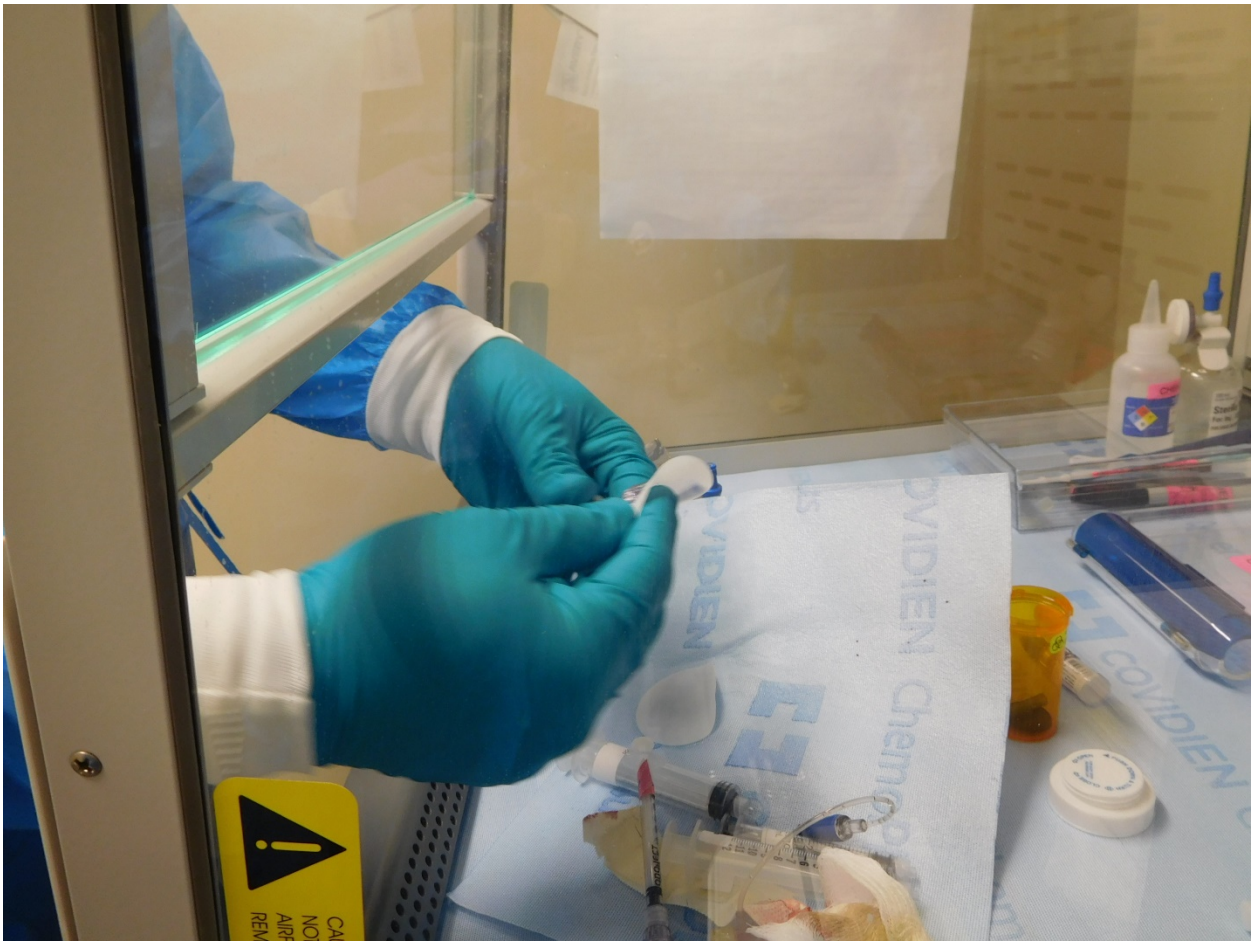

Figure 26. Mustargen syringe. Also shown are properly labeled items that have been in contact with chemotherapy drugs (labels are in pink). (Photo Credit: NIOSH)

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