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The relevance of surfaces contamination assessment in occupational hygiene interventions in case of exposure to chemicals

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ABSTRACT: Dermal exposure assessment is still not a priority in the intervention of occupational hygiene when assessing exposure to chemical substances. However, for some substances in specific occupational settings, dermal intake can be the most important exposure route. Skin contamination can occur from contact with contaminated surfaces. Thus, knowing the levels of the substance present on the surfaces of the workplace is an important tool to indirectly measure dermal exposure. This paper aimed to claim attention for the relevance of surfaces contamination assessment in the occupational hygiene interventions. An extensive search was performed to identify scientific papers published after 2010, reporting data of surfaces contamination in the scope of occupational hygiene interventions. Twenty seven papers were considered and, from those, 63% were devoted to antineoplastic drugs occupational exposure assessment. This short review allowed concluding that surfaces contamination assessment is a very useful tool that, besides giving an indirect measure of dermal exposure, can also give relevant information to guide interventions to prevent exposure.

1 INTRODUCTION

Nowadays, dermal exposure assessment is still not a priority in the intervention of occupational hygiene and methods to study exposure by inhalation are much more studied and validated. However, for some chemical substances in specific occupational settings, dermal route can be a very important exposure route.

Skin contamination can occur from the deposition of aerosols, via direct immersion into a chemical substance (liquid or solid), as a result of spills and splashes, through vapour deposition and penetration, or from contact with contaminated surfaces (Fenske, 1993). Considering this, Fenske in 1993 suggested that dermal exposure levels could be assessed from data resulting from: 1) biomonitoring values, 2) levels of contamination on clothing, or 3) levels of deposition on skin or surfaces of the workplace.

Surface contamination assessment, which can be done by wipe sampling or vacuuming of surfaces, may serve as a predictor of dermal exposure to chemicals. Wipe sampling provides information about the mass of the contaminant on a surface. This sampling approach can be used as an indirect method to measure exposure (Fenske, 1993; Schneider et al., 1999), since provide information about contamination on surfaces which may lead to dermal uptake by workers (Connor and Smith, 2016).

The objective of this paper was to claim attention for the relevance of surfaces contamination assessment in the occupational hygiene interventions by conducting a review of studies where surfaces contamination assessment has been performed.

2 MATERIALS AND METHODS

An extensive search was performed to identify scientific papers, available in different scientific databases (PubMed and Web of Science) published after 2010, reporting data of surfaces contamination in the scope of occupational hygiene interventions, particularly related with the assessment of occupational exposure to chemical substances. Only the articles written in English were considered. The search was done using the following key-words in different combinations: surfaces contamination assessment, occupational exposure and exposure assessment.

3 RESULTS AND DISCUSSION

Twenty seven papers were selected and included in a more detailed analysis concerning objectives of the study and the main findings (Table 1). Seventeen papers (63%) were devoted to antineoplastic

Table 1. Papers considered for further analysis (n = 29).

Reference	Substance/group of substances analized	Objective of the study	Main conclusions
Siderov et al., 2010	Antineoplastic drugs	Determine the impact of a CSTD on cytotoxic surface contamination.	When used inside a CDSC, the CSTD further reduces surface contamination, in some instances to undetectable levels.
Sottani et al., 2010	Antineoplastic drugs	Analyze trends of surfaces contamination.	A strong reduction of contamination was observed since 2003, when recommended safe handling procedures started to be followed by workers.
Moretti et al., 2010	Antineoplastic drugs	Study protocol: Assess occupational exposure in nurses involved in preparation and administration of drugs.	Findings will be used to prevent exposure.
Villarini et al., 2011	Antineoplastic drugs	Evaluate work environment contamination: preparation and administration of drugs.	Highest contamination found in preparation. Procedures adopted are not sufficient to prevent exposure. Important to use protective equipment and implement correct work practices.
Konate et al. 2011	Antineoplastic drugs	Assess platinum contamination in the operating room and exposure of health workers.	Contamination on surfaces and nearby area was found. Based on the level of floor contamination, there is a high risk of exposure for cleaning and maintenance staff.
Hedmer and Wohlfart, 2012	Antineoplastic drugs	Propose hygienic guidance values for surface monitoring of CP and IFO.	Surface monitoring combined with hygienic guidance values is a useful tool for health care workers to regularly benchmark their own surface loads.
Naito et al., 2012	Antineoplastic drugs	Examine platinum contamination on the exterior surface of vials containing cisplatin or carboplatin.	External contamination was confirmed in all cisplatin and carboplatin vials tested.
Chu et al., 2012	Antineoplastic drugs	Determine if antineoplastic drug contamination of surfaces exists despite being cleaned.	Results suggest that drug contamination is common in hospital pharmacies and that current cleaning practices may not be effective in removing residual drug from the surfaces.
Hon et al., 2013	Antineoplastic drugs	Describe the contamination of frequently contacted surfaces and identify factors that may be associated with surface contamination.	Frequently contacted surfaces at every stage of the hospital medication system had measureable levels of antineoplastic drug contamination. Drug preparation stage had the highest average contamination.
Odraska et al., 2013	Antineoplastic drugs	Compare the surface contamination level of the conventional preparation room and outpatient clinic before and after the implementation of measures.	Measures implemented in the outpatient clinic were shown to reduce workplace contamination effectively. However, measures implemented in the preparation room, where relatively strict regulations had already been adopted before the study, were less effective.
Luo et al., 2013	DDTs and dicofol	Evaluate the potential contamination of dicofol manufacturing equipment.	The surfaces were contaminated with DDT and dicofol.
Kopp et al., 2013	Antineoplastic drugs	Evaluate working practices and safety measures during drug administration and to assess workplace contamination in outpatient oncology health care.	Workplace contamination with antineoplastic drugs is still present. As patients have to be considered as potential source of contamination. The study revealed that it is possible to administer a large number of preparations without causing high workplace contamination.
Gribovich et al., 2013	Arsenic	Assess potential arsenic contamination of work surfaces in an anthropology department in a museum.	Workplace observations and wipe sampling data enabled the development of recommendations to help to further reduce potential occupational exposure to arsenic.
Viegas et al., 2014	Antineoplastic drugs	Characterize occupational exposure to antineoplastic drugs in pharmacy and administration units.	Workplace contamination with antineoplastic drugs was observed. Specific measures should be taken, particularly those related with the promotion of good practices and safety procedures.
Shepard and Brenner, 2014	Nanoparticles	Identify potential exposure scenarios and evaluate the presence of these materials on surfaces.	Nanoparticles were identified in surface samples from work areas where engineered nanoparticles were used or handled. Precautionary measures should be applied.
Fleury-Souverain et al., 2014	Antineoplastic drugs	Evaluate the contamination of surfaces during preparation of injectable chemotherapies in hospital pharmacies.	Most of the hospital pharmacies had some contamination of surfaces by different cytotoxic agents. Higher levels of contamination were mainly detected inside biosafety cabinets, but contamination was also found in logistical and storage areas.
Ceballos et al., 2015	Pesticides	Assess occupational exposures to sea lamprey pesticides.	Found surfaces and worker's skin contaminated with pesticides. Recommended minimizing exposures by implementing engineering controls and use of personal protective equipment.
Hedmer et al., 2015	Nanomaterials	Know the presence of carbon-based nanomaterials in surfaces at a small-scale producer.	Nanomaterials were identified in all parts of the workplace, thus, increasing the risk for secondary inhalation and dermal exposure of the workers.
Anastasi et al., 2015	Antineoplastic drugs	Evaluate two cleaning solutions for the chemical decontamination of the surfaces.	Higher contamination levels were distributed on areas frequently touched by the pharmacy technicians. Both cleaning solutions were able to reduce contamination.
Vyas et al., 2016	Antineoplastic drugs	Investigate the surface contamination from the preparation of five anticancer drug infusions with two different types of equipment.	It was possible to conclude the equipment that implicates less contamination.
Ceballos et al., 2016	Metals	Characterize employee exposure to metals and recommend control strategies to reduce exposur.	Found metals on non-production surfaces. Provided recommendations for improving local exhaust ventilation, using respirators until exposures are controlled, and reducing the migration of contaminants from production to non-production areas.
Schenk et al., 2016	Antineoplastic drugs	Evaluate surface contamination by platinum drugs in the environment of patients in ICUs and wards treated by hyperthermic intraperitoneal chemotherapy.	High platinum-drug concentrations in urine and drainage liquids are the main source of contamination. Therefore, safe handling of these liquids is the best way to avoid cross-contamination on surfaces in wards and ICUs.
Poupeau et al., 2016	Antineoplastic drugs	To monitor environmental contamination in pharmacy and patient care areas in Canadian hospitals.	In comparison with other multicenter studies that were conducted in Canada, the concentration of antineoplastic drugs measured on surfaces is decreasing.
Paik et al., 2017	Beryllium	Assessment of current conditions in the facility and a create baseline for future impacts.	All the data have shown that beryllium has been effectively managed to prevent exposures to workers during routine and non-routine work.
Beaucham et al., 2017	Metals (lead)	Discuss wipe sampling for measuring lead on surfaces in three facilities.	Wiping sampling demonstrated lead in non-production surfaces in all three workplaces and that the potential that employees were taking lead home to their families existed.
Beattie et al., 2017	Metals (Cr)	Investigate whether repeat biological monitoring over time could drive sustainable improvements in exposure control in the industry.	This study has shown that exposures to chromium VI and nickel in the electroplating industry occur via a combination of inhalation, dermal and ingestion routes. Surface contamination found in areas such as canteens highlights the potential for transferal from work areas, and the importance of a regular cleaning regime.
Brouwer et al., 2017	4,4'- methylene dianiline (MDA)	Evaluate two different techniques for assessing dermal exposure to MDA.	Results indicated a general contamination of the workplace and equipment.

drugs occupational exposure assessment. The others papers were dedicated to occupational exposure assessment to other substances, such as metals (chromium and lead), beryllium, arsenic, nanomaterials, 4,4'- methylene di-aniline (MDA) and pesticides. However only after 2013 it was observed other substances being considered for this approach, besides antineoplastic drugs.

The assessment of the contamination present on work surfaces is commonly reported in the case of antineoplastic occupational exposure assessment, since skin absorption is a more important route of exposure than inhalation, and also because these drugs are non-volatile and remains on work surfaces for long periods of time (European Parliament, 2016). These characteristics are common to almost all the substances reported on the selected studies but in some cases the deposition on surfaces means that exposure by inhalation can also occur, since resuspension of the substances from the surfaces can happen. This is a reality particularly in the case of nanomaterials (Hedmer et al., 2015).

Considering the main conclusions in each study analysed (Table 1), it is possible to realize that, more than an indirect measure of exposure, the surfaces contamination assessment allows understanding if the workplace contamination can promote exposure by dermal absorption since the information obtained provides an indication of the potential for dermal exposure (Sottani et al., 2010; Villarini et al., 2011). This is particular relevant if the criteria to choose the surfaces to sample were based on tasks observation to identify the surfaces that workers handle or touch more frequently (Hon et al., 2013; Viegas et al., 2014).

The information obtained can also help to investigate mechanisms of release and spread and thus help to identify possible sources and routes of exposure (Naito et al., 2012; Hon et al., 2013; Kopp et al., 2013; Schenk et al., 2016). Several studies also use the information obtained to recognize surface contamination concentrations and trends (Sottani et al., 2010; Villarini et al., 2011; Konate et al. 2011; Naito et al., 2012; Anastasi et al., 2015). The information allows for instance to identify what are the areas with higher contamination and with more surfaces contaminated (Viegas et al., 2014; Fleury-Souverain et al., 2014). Those areas are the ones where the risk management measures should be applied first.

Frequently, the information was also used to identify the most relevant risk management measures and to evaluate effectiveness of those measures. This was one of the main objectives in several studies (Sottani et al., 2010; Siderov et al., 2010; Chu et al., 2012; Odraska et al., 2013; Viegas et al., 2014; Ceballos et al., 2016; Beaucham et al., 2017).

The need of cleaning and the assessment of the effectiveness of the cleaning process were also reported in numerous studies since the results obtained allowed having a detailed picture of the surfaces contamination and to understand where the cleaning process is failing (Chu et al., 2012; Anastasi et al., 2015; Beattie et al., 2017; Brouwer et al., 2017).

4 CONCLUSION

This short review allowed to demonstrated that surfaces contamination assessment is a very useful tool that, besides giving an indirect measure of exposure by the dermal route, can also give relevant information to guide interventions to prevent exposure by dermal route, inhalation route and, even, digestive route that can occur due to contaminated hands after touching a contaminated surface. Occupational hygienists should keep in mind this tool as a complementary resource to a more accurate exposure assessment and to identify the most suitable risk management measures to apply. This will also guarantee more data available related with dermal and surface contamination in different settings promoting that the dermal exposure assessment models that are being developed are more robust and reliable.

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