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Exposures Moved from Work to Home as a Public Health Hazard

Bir Halk Sağlığı Tehlikesi Olarak İşten Eve Taşınan Maruziyetler

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ABSTRACT

There are numerous occupational pollutants originating from a wide variety of industrial areas and working environments. These pollutants can be brought inadvertently from workplace to home in various ways and may negatively affect the health of household. In the literature, this situation was known as para-occupational exposures in the past but today it is referred as take-home exposures. In this review article; transport pathway, the diversity of take-home exposures, the population at risk and occupational security deficits were examined and precautions in reducing the take-home exposures were discussed. At the same time, take-home exposures were considered as an important public health problem and the contribution of social inequalities to the extent of the problem was also evaluated. It is aimed to help researchers to have a comprehensive view of take-home exposures and to support preventive efforts.

Keywords: Take-home, occupational pollutants, exposure, contamination, prevention

ÖZ

Çok çeşitli endüstriyel alanlardan ve çalışma ortamlarından kaynaklanan sayısız mesleki kirletici vardır. Bu kirleticiler çalışanlar tarafından değişik yollarla, farkında olmadan, işten eve taşınabilir ve aile bireylerinin sağlığını olumsuz etkileyebilir. Bu durum literatürde geçmişte iş ile ilgili (para-occupational) maruziyetler, günümüzde ise eve taşınan maruziyetler olarak adlandırılmaktadır. Bu derleme makalesinde eve götürülen mesleki kirleticilerin taşınma yolları ve çeşitliliği, risk altında olan nüfus ve mesleki güvenlik açıkları incelenmiş, eve götürülen maruziyetleri önleme yolları tartışılmıştır. Aynı zamanda eve taşınan maruziyetler önemli bir halk sağlığı sorunu olarak ele alınmış, toplumsal eşitsizliklerin sorunun boyutuna katkısı da değerlendirilmiştir. Araştırmacıların eve taşınan işyeri maruziyetleri hakkında kapsamlı bir görüşe sahip olmalarına ve önleme çabalarına yardımcı olmak hedeflenmiştir.

Anahtar Kelimeler: Eve taşınma, mesleki kirletici, maruziyet, kontaminasyon, korunma

Introduction

An emerging hazard in a workplace becomes environmental when it affects employees, when it crosses the boundaries of the workplace and affects those in the wider community. Employees can carry hazardous materials from work to home without realizing it through their clothing, skin, hair, work tools and vehicles. In this case, employees can become "tools" by which occupational hazards are brought into the home environment (1). As a result, various adverse health effects attributed to occupational pollutants may develop in household members by their exposure to hazardous substances (2,3). The importance of these exposures carried to the home has actually been known for a long time, as they are also called "work-related (para-occupational) exposures" (4). For example; Oliver (5) reported in 1914 that the spouses of paint workers who wash their work clothes had lead poisoning. The conceptualization of take-home exposures has emerged over time with the reporting of specific cases such as childhood lead poisoning by the Centers for Disease Control and Prevention.

Evidence from scientific literature shows that a wide variety of occupational chemicals such as pesticides, asbestos, lead, beryllium, halogenated aromatic hydrocarbons can be transported from the workplace to the home environment. Apart from chemical factors, occupational exposures such as various psychosocial stressors and work traumas can also disrupt family and society relations by affecting the behavior of employees (1). However, these behavioral changes were not widely accepted as take-home exposures. At the same time, various allergens (such as cereal dust, animal proteins), radiation and infectious

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agents (such as coxiella, methicillin-resistant *Staphylococcus aureus* (MRSA), scabies) are also take-home exposures that negatively affect family health.

Population at Risk and Structural Sensitivities

The population at risk for the take-home exposures is the household members affected by the employee carrying the pollutants from work to home (Table 1). This also includes homes that function as workplaces (such as farms). Factors such as age, health status, behavior, and education may contribute to varying sensitivity to adverse health effects that occur among the household members (6). Young children with small bodily structures who are in a period of rapid development can be more affected by occupational pollutants carried home by their parents. In addition, their risk of exposure is higher, usually because they spend more time on the ground, they have more hand-to-mouth activities, and their gastrointestinal absorption of pollutants is more than adults (7,8). The susceptibility of the elderly to toxic substances may change, or significant body loads of toxic substances may have accumulated in the elderly before the contaminants carried to the home (9). Women may be particularly at risk because of their tendency to do more housework, including laundry and cleaning. For example; wives of workers exposed to beryllium were exposed to beryllium at home as a result of shaking their husbands' clothes contaminated with gray-black beryllium soot before washing (10). This behavior suggests that both workers and their spouses are unaware of the risk of beryllium contamination taken home.

Transport of Occupational Pollutants

Low occupational hygiene awareness of employees and their family members and the lack of personal protective equipment use of employees play an important role in the transportation of occupational pollutants. However, the risk may persist when employees are aware of workplace hygiene but do not know their right to access protective measures, and feel that their demands for safer conditions or better training will not be met (11).

Jones and Burstyn (1) mentioned external contamination as one of the steps in which occupational pollutants are brought home by developing a conceptual model (Figure 1). Employees can carry occupational contaminants on their skin, clothes (especially shoes), vehicles, work tools and other objects. Many studies have shown that pollutants are released directly into the home environment in these ways. Pollutants from the workplace can be in chemical, physical or biological form and affect workers and their families through dermal, inhalation or oral exposure. A comprehensive mathematical explanation of the distribution and accumulation of external contamination at home was provided by Zirschky (12).

Table 1. Structural vulnerabilities of the population at risk and other influential social-ecological elements

Household members	Age
	Gender
	Health condition
	Behavior
	Education
	Occupation
	Geographical features of the living area
	Industrial features of the living area
	Legal regulations/legislations

After the external contamination of the employee, exposure of household members at home can be direct or indirect. Direct exposure includes direct contact between contaminated objects and household members. For example; by hugging their child, an employee can transfer occupational contaminants to the child's body or clothing. In indirect exposure, contamination is mediated by the home environment (such as carpets), and situations such as washing contaminated and uncontaminated clothes together can lead to cross contamination between clothes (13).

1. Employee's Skin

The skin of the workers is thought to play an important role in the transmission of occupational pollutants. Many studies report contamination in workers' hands, forearms, forehead, and feet (14). Skin contamination often occurs among those who do not adhere to hygiene practices such as hand washing and showering before leaving their workplace or who do not shower immediately upon arrival. For example, in facilities with appropriate infrastructure, workers washing their hands and showering at the end of the shift led to low skin lead levels at the end of the shift (15). Pollutants carried on the skin of the workers can be transferred to the vehicles (10) and the home floor (16).

2. Contaminated Hair

Although there is little evidence to support the hypothesis that occupational pollutants are carried home by hair, measurements of potentially transported allergens in workers' homes in this way have

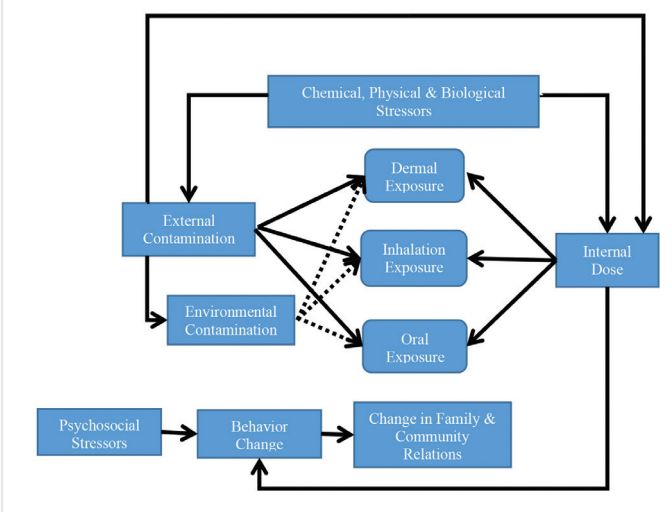

Figure 1. Chemical, physical, biological and psychosocial workplace exposures are carried home by employees through 3 ways (external contamination, internal dose and behavioral change in the worker). Workplace exposures can affect workers and their families through dermal, inhalation, and oral exposure. Dashed arrows represent the impact of environmental pollution on household members from employee's workplace exposure

been reported (17,18). The study by Krop et al. (17) shows that hair can be a source of animal allergen transport to an environment that does not contain allergens.

3. Contaminated Clothing and Shoes

Studies in the literature have shown evidence based on indirect and direct measurements that pollutants can be transported home through contaminated clothing and shoes. Significant levels of pollution have been found in locker rooms where clothes contaminated with occupational pollutants are changed. Based on these findings, contaminated clothing was thought to be a potential source of contamination in workers' homes. Another evidence showing that clothing is a potential source of contamination is the detection of high pollutant levels in children whose parents wear contaminated clothing at home (19). In their study, Lu et al. (20) reported that the rate of pesticides taken home by means of boots was high in the swab samples taken from parents' work boots.

4. Items Moved Home from Work

Employees can take work tools and equipment with them, carry them in their vehicles, or take them from work to home for their own use (6). For example; it is possible for agricultural workers to get pesticides from the workplace to use in their homes.

5. Contaminated Vehicles

Tools can mediate the home transport of occupational pollutants, both as a "reservoir" and as a "vector". They also serve as a microenvironment where pollutants can contaminate all family members (2). A significant relationship has been found between home and vehicle concentrations of occupational pollutants and urine metabolite levels in workers and their children (21).

6. Workplace Visit of Family Members

Workplace visits by family members may also result in occupational contaminants being moved home, although this is different from exposures carried home by parents. For example; immunoglobulin E antibodies specific to laboratory animal allergens were detected in children who developed a cough and rhinitis clinic after they visited the workplace of their parents working in an animal laboratory (22).

7. Professional Preferences and Hobbies

It is an issue that should be taken into account that the parenting profession is also maintained by children. Children exposed to pollutants through the parent's occupation may increase their risk of sensitization if they continue the same profession in their adulthood. Another factor to consider is the exposures associated with hobbies. It is useful and necessary to detail the anamnesis to include these areas as well as the occupation questions.

Main Take-home Exposures and Health Effects

Current information on take-home exposures and health effects is not sufficient. It is almost impossible to predict which occupational exposure factors may pose a threat to employees and their families in the future. In evidence from scientific literature; lead, beryllium, pesticides, and asbestos are prominent examples of take-home exposures. Workplace pollutants can be in chemical, physical or biological form and can contaminate workers and their families through dermal, inhalation, or oral exposure.

Hazardous pollutants can enter the employee's body in various ways and affect household members in various ways through contact (respiratory secretions, blood, urine, etc.) or the body fluids they are fed (such as breast milk). This situation has been called the internal dose of the pollutant (1). For example; workers who have occupational exposure to products containing polybrominated diphenyl ether (PBDE) used as flame retardants have higher serum PBDE levels than the general population (23). PBDE's breast milk levels are proportional to serum levels, and breastfed babies of workers may be exposed to PBDE in this way (24). In addition; occupational exposures of female workers may result in intrauterine exposure of a developing fetus through the placenta. It can cause genotoxicity and decreased fertility by affecting the germ cells of male and female workers.

1. Chronic Beryllium Disease (Berylliosis)

In the literature, there are case series and cohort studies reported in the families of the employees regarding this potentially fatal granulomatous lung disease (25,26). It is found in the families of employees who are exposed to beryllium in the workplaces involved in the production of fluorescent lights, beryllium and gyroscopes, and in the nuclear and aviation industries.

2. Asbestos and Its Effects

In studies evaluating the health effects of asbestos on families of asbestos workers, diseases such as asbestosis, mesothelioma, pleural plaques and cancer have been reported. Twenty percent of mesothelioma cases were attributed to take-home exposures (27), and it was reported that a large number of asbestos fibers were found in the lungs of family members of exposed workers (28). An increased risk of mesothelioma was found in a large cohort study conducted among the spouses of asbestos workers in Italy, but no relation with lung cancer was found (29).

3. Lead and Its Effects

It is evidence-based information that lead poisoning causes a variety of problems in children, ranging from behavioral disorders to brain damage. High blood lead levels may adversely affect the reproductive system in women and men, and cause irreversible neurological damage in pregnant women by affecting the fetus (30). In a meta-analysis study conducted in the United States of America (USA), it has been suggested that the risk of detecting high blood lead levels is higher in the children of workers exposed to lead (31). According to this meta-analysis, it is predicted that 723,500 employees in the USA work in industries that have the potential to take lead home, and two-thirds of them have a significant risk of taking home. In the study conducted by Whelan et al. (8), it was found that children of construction workers who were exposed to lead were six times more likely to have high blood lead levels compared to the children of those who were not exposed, and also their homes had higher lead dust levels.

4. Pesticide and Its Effects

Home transport of pesticides (main organophosphates) by agricultural workers has been well documented in the literature since the mid-1990s. The agricultural jobs of the parents were found to be significantly associated with taking home pesticides (32). Studies have consistently found high levels of organophosphate (33) in the homes of agricultural workers and high levels of metabolites (20) in the urine of their children. In the studies conducted, high organophosphate levels (33) and high metabolite levels in the urine of their children (20) were found in the homes of agricultural workers. Agricultural based take-home pesticide exposure is a major health problem among children in rural communities.

5. Arsenic and Its Effects

Agricultural use of pesticides and herbicides containing arsenic can pollute the home environment. Klemmer et al. (34) concluded that arsenic could be carried home through work clothes. In a study, extremely high levels of arsenic dust were found in the homes of families working in the wood processing field in Hawaii (4). It has also been emphasized that arsenic coming from the workplace may cause cancer development in children. Four cases of hepatic angiosarcoma, a rare tumor in children, have been reported in the literature. One of the cases was associated with arsenic exposure moved home from work (35).

6. Mercury and Its Effects

Toxic mercury exposure is a health problem that is becoming common worldwide. Recent studies show that mercury exposure may be mediated by the occupational and home environment with an increasing ratio, as well as from the general environment. Children are particularly vulnerable to mercury poisoning, as it can lead to pulmonary and nephrotic damage as well as a developing central nervous system disorder. In a study, children of employees who work in a facility producing mercury thermometers were found to have higher urine mercury levels in the study group compared to the control group. At the same time, higher levels of mercury in air were measured in the homes of workers who work in facilities producing thermometers (36). This study showed that toxic mercury can be carried home through shoes or clothing.

7. Polycyclic Compounds and Their Effects

One of the leading reports of a disease in family members attributed to workplace pollutants was published in 1943. This disease was associated with Halowax, a mixture of pentachloronaphthalene, hexachloronaphthalene and chlorinated biphenyl, used for insulation of electrical cables. Acneiform lesions (chloracne) called "Halowax Acne" developed in 52 isolation workers exposed to Halowax. Workers' spouses also had similar acneiform lesions, most likely due to contact exposure with contaminated workwear (37). Similar clinical pictures occurring in workers and their families at similar production sites where polycyclic compounds are used have been reported in the literature.

8. Synthetic Estrogens

There are few studies in the literature on exposure to synthetic estrogens that are brought home as occupational pollutants. Gynecomastia has been reported in the sons of several employees of a chemical plant producing synthetic animal estrogen called zeranol in the Indianapolis city of the USA. In the later examination, zeranol was found in the work clothes of the workers (38).

9. Radioactive Contamination

Radioactive agents as occupational pollutants transported to the home have been less studied and there is insufficient data in the relevant literature. In a study, samples taken from the hair of employees working in the nuclear energy, pharmaceutical and biotechnology industries using C14 radionuclide, were evaluated in terms of contamination with the help of accelerator mass spectrometry. C14 contamination was detected in the analyzes, but it could not be clearly distinguished whether there was an occupational contamination (39). Another case example was reported as an industrial accident due to careless handling of a source of Cs-137, a radionuclide, by the worker. Contamination was found in the urine sample of the spouse of the employee who was exposed to radionuclide body load of the employee (40).

10. Infectious Agents

Hospital and laboratory workers and agricultural workers can transmit infectious pollutants such as scabies, *Coxiella Burnetti* (Q fever agent) and MRSA to household members through their skin and clothing. Workers can mediate the home transport of these pollutants, both as a "reservoir" and as a "vector". In studies conducted, MRSA contamination was found in samples taken from the homes and in the family members of healthcare workers who are MRSA carriers (41). In another study, it was determined that the spouse of a goat farm worker who was diagnosed with Q fever was also diagnosed with the same disease months later, and it was thought that the contamination occurred as a result of washing the contaminated work clothes (42).

11. Nanomaterials

If at least one dimension of the material is between 1 and 100 nm, that material is called a nanomaterial. All over the world, interest in this sector is increasing day by day. Nanomaterials are widely used in many sectors due to their superior properties, so the number of employees exposed to these materials is also increasing. The precautions to be taken during the use, transportation and most importantly the production of these materials (43), which are newly emerging with a wide variety of harmful effects on human health and which are also proven to have asbestos-like properties, are of great importance. Nanoparticles can be dispersed in the working environment by means of air, water and clothing. Therefore, it has become necessary to clean workwear in a specialized facility in order not to transport nanoparticles (especially carbon nanotubes) and limit the risk of contamination of workers' homes (44). Despite the existence of various studies and studies in the literature, the effect of nanotoxicity on human health is not yet fully understood (45). Studies to investigate the health effects of nanomaterials, which have the potential to be moved home as an occupational pollutant, on employees and their families should be developed and continued.

Take-home Exposures as a Public Health Problem

Occupational exposures-related diseases are increasingly recognized as an important public health problem and awareness of the issue is

increasing. The proven existence of take-home exposures has required some countries to make regulations in their labor legislation. In the USA, the "Law for the Protection of Working Families" was passed in 1992. This law necessitates to investigate the risks arising from dangerous substances that are moved to the house and affect household members. The National Institute for Occupational Safety and Health (NIOSH) mentioned about the exposure associated with the contamination of employees' homes with hazardous chemicals transported from the workplace in 1995 and its adverse health effects (3). Effective measures against occupational pollutants carried home by NIOSH are described. But today, as in diagnosis of many occupational diseases; diagnosis of take-home exposure by occupational pollutants that affect family members is also missed.

This problem continues to grow in sectors where prevention is insufficient and in countries where legal regulations are not implemented adequately. In addition, workers with take-home exposure contamination often work in hazardous, temporary or seasonal jobs (8). In most cases, families of immigrant labor work in sectors such as agriculture and construction in high-income countries are mostly affected (46). Syrian refugees working in Turkey have also been found to work in dangerous and temporary locations where there is a risk of moving occupational pollutants home (47). Given this, it can be said that the most affected groups are less likely to benefit from existing standards in occupational health policies and practices. Low socioeconomic status can lead to limited access to health care for workers and their families exposed to toxic workplace pollutants, and when this is combined with poor health care and unhealthy diet, it increases the risk of adverse health effects (6). The exposure is greater in sectors that consist of large numbers of small businesses, such as the service, construction and agriculture sectors, or that carry out high-risk tasks by outsourcing. At the same time, low political power of employee organizations may cause managers to feel little pressure to change policies to improve job security and may play a role in the continuation of the problem.

Prevention and Protection of Take-home Exposures

It is emphasized that a three-layer approach that includes prevention efforts at the workplace, at home and at the community level together is required to prevent exposures taken to the home in a comprehensive way (48). It also requires well-functioning control strategies and workplace hygiene standards that can be supported through public policies (32,49). It is aimed to identify and reduce workplace pollutants that may be responsible for primary protection, which is the most effective and proactive approach. However, these efforts need to be complemented by secondary and tertiary protection measures. Current legal regulations may enable the accumulation of chronic exposure pests and home transport even in full compliance with primary protection measures. Therefore, secondary and tertiary protection measures are also required. At the same time, the presence of occupational pollutants that are not yet known and may pose a threat in the future supports this requirement.

Primary protection includes reducing the use of the most problematic chemicals, better safety protocols and training, mandatory regulatory adaptations, and participation of worker organizations in safety control strategies. It is aimed to determine the effects of occupational pollutants identified in secondary protection at an early stage. Secondary protection includes biological monitoring of home chemicals in children, workplace and home controls including education, and assessing the health of employees, families and communities. Educational intervention programs involving employers, employees, children, teachers, parents, physicians and other health professionals should be developed for prevention. For example; hygienists can visit the workplaces and take the necessary measurements to show whether existing decontamination procedures are effective in preventing contaminants from being carried home. In addition, clinicians should be aware of occupational contaminants transported to the home, and the medical history should include questions about the profession of the parents or spouse (2). It is aimed to alleviate the related health problems in tertiary prevention. Tertiary protection includes community-based programs, improved access to health care for all family members and government programs.

The main recommendations for preventing and controlling workplace pollutants from being taken home can be listed as following: (i) reducing exposure in the workplace by observing safety practices, (ii) regular wet cleaning of floors and work surfaces, avoiding dry dusting and brushing, (iii) using appropriate and effective washing methods to ensure decontamination from the skin, (iv) to take a shower before leaving the workplace, (v) to take a shower immediately upon arrival if it cannot be done at the workplace, (vi) to change work clothes and work shoes before going home, (vii) leaving the contaminated clothing and shoes at workplace to be properly cleaned by the employer (viiii) disposal of the disposable coveralls and shoe covers properly, (ix) keeping street clothes or shoes in separate areas in the workplace to prevent contamination, (x) washing the contaminated clothing separately from family laundry if it is necessary to wash at home, (xi) prohibition of bringing contaminated work items home (xii) separation of work areas from living areas (for those who work in their homes), (xiii) separation of work vehicles from personal vehicles, (xiv) regular cleaning of vehicles used for work, (xv) preventing family members from visiting workplaces and informing family members about this (xvi) proper storage and disposal of hazardous materials for those who work in their homes.

Conclusion

There are numerous occupational contaminants originating from a wide variety of industrial areas and working environments. These pollutants can be carried from work to home by employees without realizing it through their clothing, skin, hair, work tools and vehicles. Apart from chemical, biological, radioactive occupational pollutants, various psychosocial stressors should also be considered as an exposure factor that can affect the behavior of employees and disrupt family and social relations, and this should be taken into account when applying appropriate intervention methods. As a result of all these, other than occupational diseases or injuries that may occur in the employee, various adverse health effects attributed to occupational pollutants may also develop in employee's family members. In addition to individual sensitivities that can change within the family, it has been observed that socio-cultural and socioeconomic differences in the society can also change the exposure rates of employees and their

families from occupational pollutants. For these reasons, take-home exposures are a major problem not only for occupational health but also for public health. In this review article, transportation ways and variety of pollutants taken home, population at risk and occupational vulnerabilities are examined, and measures to prevent take-home exposures are discussed. It was aimed to help researchers to have a comprehensive view of take-home exposures.

The proven existence of take-home exposures and their adverse health effects made it mandatory to make regulations in the labor legislation. Prevention of exposures in the workplace by considering safety practices is the most important step in the primary prevention strategy. However, in the literature, it has been found that current information about exposures taken to home and their adverse health effects is not sufficient, and more studies are required to be conducted. It is clear that it is almost impossible to predict which occupational exposure factor may pose a future threat to employees and their families. For this reason, it should be taken into consideration that besides primary prevention, which is the most effective and proactive approach, secondary and tertiary prevention may have defining features for new diseases in addition to their complementary features. In fact, a well-functioning control strategies and ensuring compliance with the determined workplace hygiene standards supported by healthy public policies after awareness of take-home exposures can be very effective in preventing this important public health problem.

The first of the action principles proposed in the first part of the "Closing the gap in a generation, 2008" report by the World Health Organization Commission on Social Determinants of Health is "Improve the daily living conditions in environments where people are born, grow up, live, work and age". Exposures carried from work to home should be addressed within the integrity and interaction of the work environment, sheltering-housing conditions and settlement, and not only in physical terms, but also in social and sociocultural scope.

Ethics

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