OPINION ARTICLE

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Risks related to the domestic laundering of filling station attendant uniforms: advances and uncertainties

Riscos relacionados à higienização doméstica dos uniformes de frentistas: avanços e incertezas

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ABSTRACT | Gasoline is the most common transportation fuel in Brazil, with up to 1% of benzene. Benzene is a health-damaging organic solvent that is extensively used worldwide, being classified as a human carcinogen by the International Agency for Research on Cancer (Group 1). Many workers at filling stations are exposed to benzene, present in gasoline. The main routes of exposure and absorption of benzene are inhalation, oral, and dermal routes. The penetration and maintenance of benzene and other chemicals on personal protective equipment and clothing of workers who manipulate these solvents may increase their levels of exposure and offer risks to their family members, since contaminated clothing is laundered at their homes, which goes against legislative framework (Annex 2, Regulatory Standard No. 9). This way, the objective of this work was to discuss the importance of periodic changes and cleaning of filling station attendant uniforms performed by employers as preventive measures against the deterioration of the health of workers and their family members. We performed a narrative review; no systematic criteria were used in the search for national and international studies. After critical reading, we observed a lack of consistent data on this theme. Laundering of uniforms worn by filling station attendants should take place outside the domestic environment in order to protect the health of workers and their family members and avoid possible cross-contamination.

Keywords | gasoline, benzene, filling station, protective clothing, occupational exposure.

RESUMO | A gasolina é o combustível mais utilizado no Brasil para veículos automotores e contém até 1% de benzeno em sua composição. O benzeno é um solvente orgânico amplamente utilizado no mundo e causa danos à saúde, sendo classificado como agente cancerígeno para seres humanos pela Agência Internacional de Pesquisa em Câncer (Grupo 1). A sua presença na gasolina expõe diariamente muitos trabalhadores de postos de revenda de combustíveis. As vias inalatória, oral e dérmica são as principais para exposição e absorção do benzeno. A penetração e permanência do benzeno e outras substâncias químicas nos equipamentos de proteção individual e uniformes dos funcionários que manipulam esses solventes podem aumentar os níveis de exposição desses trabalhadores, além de trazer risco aos seus familiares, uma vez que os uniformes contaminados são levados para serem higienizados em casa, contrariando o marco legislativo (Anexo 2 – Norma Regulamentadora nº 9). Sendo assim, o objetivo do presente trabalho foi discutir a importância da troca periódica dos uniformes e da higienização dos uniformes dos frentistas dos postos de revenda de combustíveis pelos empregadores como medida preventiva ao adoecimento do trabalhador e da sua família. Foi realizada uma revisão narrativa, não tendo sido utilizados critérios sistemáticos para a busca dos artigos científicos nacionais e internacionais. Após a leitura crítica, foi observada falta de dados consistentes sobre o tema. A higienização dos uniformes de frentistas deve ocorrer fora do ambiente doméstico, a fim de proteger a saúde dos trabalhadores e dos seus familiares e evitar possíveis contaminações cruzadas.

Palavras-chave | gasolina; benzeno; posto de combustível; uniformes; exposição ocupacional.

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INTRODUCTION

Fuels present high toxicity levels and can be found in various environments. As these are highly volatile compounds, they could reach the population through environmental contamination and risk workers' health. Regular and premium gasoline, ethanol, diesel fuel, and in some places, natural gas are commercialized in retail filling stations (FS). In addition to selling fuels, other activities such as oil checking and changing, tire repair, and car washing are performed at some FS.[1] Gasoline is the most common transportation fuel in Brazil and comprises a combination of various chemical compounds, including petroleum derivatives such as toluene, xylene isomers, ethylbenzene, and particularly benzene, which can make up to 1% of gasoline by volume.[2]

The World Health Organization (WHO) classifies benzene among the 10 chemicals of major public health concern due to its wide use and high toxicity, highlighting the need for preventive measures against exposure to this chemical agent,[3] since there are no safe levels of exposure to genotoxic and carcinogenic compounds.[4]

The main health hazard associated with benzene exposure is related to its carcinogenic potential, considering its toxicological classification as to this aspect. In 2017, the International Agency for Research on Cancer (IARC) monograph on benzene was reassessed and the compound continued to be classified as a human carcinogen (Group 1 – IARC).[4] This classification was based on the evaluation of experimental studies using laboratory animals and the results of mechanistic information of benzene carcinogenesis, which indicated that it is metabolically activated into electrophilic compounds, induces oxidative stress and oxidative DNA damage, is genotoxic, promoting DNA damage and chromosome alterations, has an immunosuppressant activity, and causes hematotoxicity.[4] The assessment of epidemiological studies related to chronic occupational or environmental exposure to benzene indicated that it causes adult nonlymphocytic leukemia — including acute myeloid leukemia. Positive associations were also found for chronic lymphocytic leukemia, chronic myeloid leukemia, multiple myeloma, lung cancer, and childhood acute myeloid leukemia.[4] In addition to its carcinogenic potential, exposure to benzene causes chronic benzene poisoning, affecting the hematopoietic and neurological systems, and its symptoms vary according to the degree of exposure — acute or chronic — and the absorption route.

The 3 main routes of exposure and absorption of benzene are inhalation, oral, and dermal routes. Inhalation promotes the absorption of atmospheric vapors containing benzene through the large surface area of the respiratory system.[4,5] Oral exposure, in general, is related to the accidental ingestion of this solvent caused by the habit of eating and drinking in the workplace, in addition to inadequate practices by FS attendants such as "siphoning" gasoline.[5] The aspiration of small amounts of liquid benzene can cause pulmonary edema and lung tissue hemorrhage.

Considering dermal exposure, benzene in gasoline is irritating to the eyes, nose, skin, and throat, and once absorbed it reaches the bloodstream, potentially causing headaches, dizziness, tremor, sleepiness, nausea, tachycardia, shortness of breath, seizures, loss of conscience, coma, and death. Absorption can be faster in case of injured skin or when benzene is in a solution such as gasoline or as a contaminant of other solvents. Moreover, the degreasing property of benzene can cause primary irritation due to repeated or prolonged contact with the skin.[6] The dermal route has gained significance as an important factor to be considered in occupational health.[7] As the epithelial tissue is the largest organ of our body and has a metabolic ability, it could both increase systemic absorption during the exposure to chemical compounds and actively participate in a series of immunological events. In addition to triggering problems such as dermatitis (one of the main occupational diseases regarding chemical agents), these alterations can contribute with a series of adverse events to other organs.[7]

Regarding volatile organic compounds, the lipophilicity and physicochemical characteristics of these agents contribute to the fact that the dermal

route is the main absorption route when compared to exposure by inhalation.[6] According to Adami et al.,[8] benzene has a higher permeability coefficient when compared with toluene and xylene, which may be explained by the fact that benzene has a lower boiling point and higher solubility in water, increasing the risks of absorption through the skin even after a short exposure.

The concern about the percutaneous absorption of benzene and the consequent contamination of FS workers has led to the inclusion of item 11 (Uniforms) on Annex 2 (Occupational exposure to benzene at FS) of Regulatory Standard No. 9 (NR-9),[9] which recommends periodic changes of contaminated uniforms as a measure for reducing dermal absorption of benzene and weekly laundering of uniforms by employers to reduce the risk to workers and avoid cross-contamination.

Therefore, considering the risks to health due to the aforementioned environmental and occupational exposures to benzene and the lack of compliance with measures established by Annex 2 of NR-9, this work aimed to discuss the importance of periodic uniform changes and uniform cleaning performed by the employer as preventive measures against the deterioration of the health of workers and their families.

METHODS

We performed a narrative review with a broader criterium of methodological approach, bringing together theoretical and empirical data from the literature, including definitions of concepts, and presenting theories and evidence that contributed to problematize the theme of interest. The inclusion criteria defined for selecting studies were: studies published in Portuguese or English, available in full, and belonging to the theme of the narrative review. Due to the lack of published studies, we considered all relevant publications regardless of the date of publication.

For collecting studies, we searched the following databases: Latin American and Caribbean Health Sciences Literature (LILACS) and Medical Literature Analysis and Retrieval System Online (MEDLINE), via PubMed. We also searched the Brazilian Association of Technical Standards (ABNT), International Organization for Standardization (ISO), and American Conference of Governmental Industrial Hygienists (ACGIH), as well as Brazilian legislations and directives on this theme. The search was performed using the following terms from the Medical Subject Headings (MeSH) thesaurus: gasoline; benzene; fuel stations; protective clothing; occupational exposure; and volatile organic compounds.

WORKERS OF FS AND ANNEX 2 OF NR-9

FS are defined as establishments that perform the retail resale of petroleum-based liquid fuels, ethanol, and other transportation fuels and have measuring equipment and storage systems.[2] Brazil currently has 41,984 liquid fuel retail resale stations,[10] which operate within risk conditions and expose workers to chemical compounds in fuels such as benzene. Studies demonstrate that the atmospheric concentration of benzene at FS in Brazil is above 5 pg m^{-3}, which is the value established by Directive 2000/69 of the European Union[11]. A study performed with FS in Rio de Janeiro, Brazil, indicated that benzene, toluene, ethylbenzene, and xylene air concentrations at FS were noticeably higher than the mean values in places with a high traffic flow.[12] Costa[13] observed that FS workers, during a fueling procedure, are exposed to air concentrations of benzene that varied from 40 to 700 parts per billion (ppb), that is, from 0.04 to 0.7 ppm. This value is within the technological reference value (TRV) of 1 ppm established for chemical and petrochemical industries that "produce, transport, store, use, or manipulate benzene in its liquid mixtures containing 1% or more by volume" (Annex 13 of NR-15)[14]. However, activities performed by FS, such as "the storage, transportation, distribution, sale, and use of petroleum-based fuels," were not included in Annex 13 of NR-15[14], thus these businesses do not have a pre-

established TRV. Still, it is important to note that even though the TRV is used as reference by programs for the continuous improvement of workplace conditions, compliance with this parameter does not exclude the risk to workers' health. Therefore, the biological monitoring of FS workers through biological exposure indicators (trans, trans-muconic acid [ttMA] and S-phenylmercapturic acid [S-PMA]) is extremely relevant, as indicated by Directive SIT/DSST No. 34,[15] and allows a more accurate approach by occupational health of this vulnerable group of workers.

Although this is an extremely important theme, few studies are available on the literature on the occupational exposure to benzene at FS since this occupation is almost extinct in other countries, where auto-service pumps are operated by customers. In Brazil, however, the FS attendant occupation is secured by Law No. 9956/2000,[16] which prohibits customers from pumping their own fuel and defines a scenario of occupational exposure of FS workers to benzene.

Regarding the occupational exposure to benzene, the International Labour Organization (ILO), through Recommendation No. 144 of 1971[17]— "On the protection against the risks of benzene intoxication" —, approved many proposals regarding worker protection, including: a) workers who may have skin contact with liquid benzene or liquid products containing benzene should be provided with adequate means of personal protection against the risk of absorbing benzene through the skin; b) should be required to wear personal protective equipment (PPE) and appropriate work clothing/uniforms; c) should store their work clothing separately from their ordinary clothes and in an appropriate facility; d) work clothing should be supplied, cleaned, and regularly maintained by the employer.[17]

However, in Brazil, until recently there were no legal recommendations as to the use of PPE and periodic changing and cleaning of FS attendant uniforms, since this group of workers was not included in the 1995 Agreement and Legislation on Benzene[18] and no specific recommendation was made regarding the risk activities these workers perform at FS. Nevertheless, Annex 2 of NR-9 (Directive MTPS 1109/2016)[9] was published in 2016; it contemplated the occupational exposure to benzene at FS and established minimal occupational health and safety requisites for activities with occupational exposure to benzene at these sites.

The incorporation of FS to the legal and regulatory framework related to benzene exposure (Annex 2 of NR-9) was the product of extensive work performed by the National Permanent Commission on Benzene (CNPBz), a tripartite body for the discussion, negotiation, and following of the Benzene Agreement. According to Mendes et al.,[19] this is a present-day discussion that approaches different positions on the need for applying these laws to this production branch, which represents an important step in the advancement of the current legislation towards an expansion of preventive actions against benzene exposure for FS workers.[20]

PERSONAL PROTECTIVE MEASURES AND THE SUPPLY AND CLEANING OF FS ATTENDANT UNIFORMS

Personal protective measures, when adopted during the work process, contribute in a definitive manner to prevent intoxication, minimizing worker exposure. In Brazil, according to NR-6, PPE is understood as "all equipment comprising many items that have been associated by the manufacturer with one or more risks that may simultaneously occur," thus contributing to promoting occupational safety and health[21].

The success of PPE in protecting workers is linked to factors such as its availability, continuous use during work activities, adequate usage, and periodic changes. Ideally for workers to comply with its use, PPE should be comfortable, not restricting movement; stay cool (in case of occupations exposed to heat); and be adequately cleaned. However, a concept that is widely used in occupational health and safety is that protective clothing and PPE should be used only as last resources, since a failure in these items would result in the mandatory exposure of workers.[22] On the other hand, PPE provides immediate protection when other control measures are implemented.

Regarding the use of PPE, Annex 2 of NR-9 states that recommendations by NR-6, of Normative Ruling No. 1 (11/04/1994) should be applied to FS; full-face respiratory protection with an organic vapor filter and a protection factor of 100 or more, as well as skin protection, should be worn by workers who perform critical activities. Workers who perform vehicle fueling, due to characteristics inherent to this activity, are not required to wear respiratory protection.[9,21]

In a study performed with 221 FS attendants in a municipality of the state of Rio Grande do Sul, workers were interviewed on the use of PPE. The authors reported that, although workers mentioned the use of various pieces of PPE, only boots (91.4%), aprons (40.3%), and uniforms comprising pants, shirts, jackets, and caps (8.5%) were worn in practice. Out of 22 FS, the authors verified that uniforms were worn in 20 cases (90.1%), but even in these environments not all workers (only 3.2%) properly wore all items.[23] It is important to educate workers on the importance of protecting themselves and explain the difference between PPE and uniforms, so that they can participate with self-care measures.

Regarding uniforms, it is important to note that these should not be confused with PPE or with ordinary clothing worn at work, since when there is a risk of exposure to chemical agents, uniforms should be manufactured using specific resistant materials and according to requirement levels for them to provide greater protection to workers. Moreover, the material should be resistant and light, allowing flexibility during the execution of various activities and providing comfort and safety; uniforms should be changed whenever necessary and cleaned by the employer in case of contamination risks.[24]

According to item 11.2 of Annex 2 of NR-9,[9] FS workers with activities that entail occupational exposure to benzene should receive risk-appropriate work uniforms and shoes from the employer at no cost, and cleaning should be performed by the employer at least weekly (item 11.3). These actions help reduce the risk of occupational cutaneous exposure and prevent the contamination of other environments such as the worker's home.[9]

Another important determination by ILO stated in the NR is the fact that

> In addition to a uniform for every worker with occupational exposure to benzene, the employer should have an extra set of uniforms available for at least one-third of the workforce exposed to liquid benzene-containing fuels.[9]

This measure encourages uniform changing in case they become contaminated with fuels during the work activity, consequently reducing exposure to benzene. Extra uniforms should follow the same cleaning rules of the items regularly worn by FS attendants.

However, in practice, some items of Annex 2 of NR-9[9] are not observed by FS. Conceição et al.,[1] aiming to verify the compliance to requirements by Directive No. 1109/2016, developed a project for inspecting FS within the Regional Superintendency of Labor of the state of Bahia with the participation of half of the FS in the state and 70% of the workers. Regarding the diagnosis of work conditions and irregularities, we can cite inadequacies in fueling lanes, the use of flannel cloths, absent or insufficient collective protective measures, the absence of electronic measurement in the tanks and uniform cleaning by the companies, and the lack of periodic health checks that included exposure and effect markers referring to the risks faced at these workplaces, which reinforced findings published by Moroyama et al.[25]

It is worth noting that preventive actions are those presented as more relevant in protecting the health of workers exposed to benzene (Directive No. 776).[26] Therefore, the work environment and conditions should always ensure the least possible occupational exposure.

CONTAMINATION OF THE FS WORKERS' UNIFORMS

Gasoline and other volatile organic compound vapors significantly increase the rates of permeation and evaporation of fuel compounds, resulting in an increased exposure via inhalation and dermal routes

for workers and the whole population.[24] Permeation characteristics of solvent mixtures differ from those of pure substances. According to various studies on the permeability of solvents through protective gloves, one component of a mixture can promote the permeation of other compounds through the glove at a much faster rate than what was expected for their pure forms[27] — this phenomenon is known as the co-solvent effect. Although the permeation rates of some chemical products are known, information is scarce when considering complex mixtures such as gasoline and other fuels, especially regarding the behavior of solvents on fabric.[28]

The volatility of an organic compound directly influences its permeation into the fabric. As volatility increases, gas/particle partitioning also increases, that is, compounds are more easily dispersed when in vapor phase, reducing the delay in transportation through the fabric, which means the substance penetrates clothes faster.[28] Less volatile compounds associate with particulates and, for this reason, have a low mobility when deposited in areas close to their emission.[29] Other important factors are the composition and chemical resistance of clothing items. More resistant fabrics offer higher protection to the individual facing solvent exposure.

Since gasoline is volatile, any FR attendant uniform after a common workday is potentially contaminated. This way, although uniforms function as a barrier, fuels may penetrate the materials used for manufacturing them. A study performed by Chin & Batterman[30] investigated the permeation of biofuels and petroleum-based fuels, including gasoline and diesel fuel, through fabrics used in chemical protective clothing. Permeation tests were performed for 4 types of fuel (regular gasoline, ethanol + gasoline, diesel fuel, and biodiesel) through 3 types of gloves commonly used as chemical protective equipment and 3 types of gloves used in laboratory environments. Among all analyzed samples, gasoline presented the highest rate of permeation through the tested materials.[30]

When it comes to the dermal absorption of solvents through contaminated uniforms, Morrison et al.[31] performed a study with workers exposed to solvents and observed that levels of metabolites of semi-volatile organic compounds excreted in urine were higher in individuals who wore uncleaned clothing (with no previous laundering) than in those who wore clean clothing. Solvent absorption was also higher in workers who wore dirty uniforms than in those who did not wear protective clothing, that is, who had completely exposed skin.[31] This confirms that clean clothing acts as a barrier and delays the transportation of these compounds from the air to the skin, while previously contaminated clothing potentializes the exposure of individuals to these components probably through the promotion of direct contact between these substances and the skin for a long period.

In line with these results, Colman & Coleman[32] performed a study with workers of coker units for verifying the possible causes of an increased contamination of workers with benzene and the use of dirty uniforms. Workers at coker units are frequently subjected to individual assessments of airborne benzene exposure, but in this case, the individual measurement of benzene in workers of the same shift was performed through a benzene metabolite, S-PMA, in urine. The biological monitoring of urinary benzene in these workers indicated that, for every 10 assessed workers, 2 had a significant increase in S-PMA in urine. However, personal samples indicated that there were no excessive levels of benzene in the air. The authors thus concluded that skin absorption happened through contaminated uniforms, verifying that uniform changes every 4 shifts reduced the levels of benzene introduction to less than 1 ppm of the inhaled dose for all employees. They observed that percutaneous benzene absorption in coker unit workers through protective clothing may be significant, thus uniforms should be changed regularly and frequently.[32]

Accordingly, we highlight that the penetration and permanence of these solvents in workers' PPE and uniforms increase the levels of occupational exposure to which these individuals are susceptible. Moreover, the irresponsible transfer of contaminated uniforms to other areas beyond the workplace promotes the contact of other unprotected persons with these contaminants,

possibly resulting in exposure occurrences outside the workplace, which are named cross-contamination.[33]

Cross-contamination may occur when workers spread contaminants (such as chemical compounds) from work to their homes through dirty clothes, shoes, or skin contact. Contaminants may be mechanically transferred to items or places touched, walked on, or sat on by workers. Therefore, personal hygiene, showering, and changing clothes and shoes worn at the workplace, in addition to the laundering of uniforms by the employer, may help avoid cross-contamination in the worker's home and the consequent contamination of his or her family, which may include children and pregnant women.[7]

This study comprehended benzene toxicity and some singularities related to FS workers, specifically approaching the importance of periodic uniform changes and cleaning performed by the employer, according to current legislation,[15] in order to reduce benzene exposure. During fueling procedures at FS, the use of protective clothing is the only barrier between the attendant and dermal exposure to gasoline. The penetration and permanence of volatile organic compounds such as benzene on FS attendant uniforms, associated with the active participation of epithelial tissue in absorption, metabolization, and distribution processes, may increase adverse effects to the health of these workers.

This way, in activities that involve health risks due to dermal contact with chemical agents, uniforms should be periodically changed and supplied, cleaned, and decontaminated by the employer, according to the current legislation.[15] Decontamination consists of physically removing contaminants or shifting their chemical nature into innocuous substances through chemical neutralization. More prejudicial contaminants demand more extensive and complex decontamination processes.[33] It is thus extremely important that the cleaning of FS attendant uniforms be performed by employers at appropriate sites, far from the workers' homes; this should avoid cross-contamination, that is, the transfer of carcinogenic chemical substances to the worker's home and consequent contamination of the domestic environment and family.[9]

There is a significant gap in information regarding the use of uniforms and its participation as a risk factor in the occupational exposure of workers to chemical agents. Since this is an area of great interest for public health, especially occupational health, we consider that the development of more studies directed towards this theme is essential. However, it is important to note that, in case of insufficient information, the precautionary principle is the most important protective measure for minimizing the exposure of workers and their family members to carcinogenic chemical agents. This way, since not all Brazilian FS follow the recommendations of Annex 2 of NR-9, especially item 11.3, an increase in surveillance and the requirement of uniform cleaning performed by employers are mandatory to reduce benzene exposure and improve the quality of life, health, and safety of workers and their families.

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