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The effects of cleaning chemicals on indoor air quality and means to reduce harmful exposure in educational buildings

Background: Cleaning activities commonly conducted in educational buildings are intended to promote hygiene and comfortable learning environments. However, using cleaning products can result in exposure to both primary and secondary indoor air pollutants. This exposure arises from the emission of various substances and their interactions with other compounds present in indoor environments, for example ozone. Many components found in cleaning products, such as fragrances, detergents, surfactants, solvents, pH stabilizers, and bases including glycol ethers, hydrocarbons, and carbonyl compounds, are deemed hazardous by the European Union.
Objective: The aim of this study was to summarize the effects of commonly used surface cleaning and disinfecting products on indoor air quality and the means to reduce the exposure in educational buildings.
Methods: The literature review was performed using Google Scholar, and PubMed. Altogether 10 search terms (cleaning agent, cleaning product, school, university, kindergarten, indoor air, indoor environment, exposure, chemical emissions, particles) and their combinations were used to identify scientific journal publications. The search included original peer-reviewed scientific journal articles, literature reviews, conference publications, theses and final reports published between 2014 and 2024. The search was then extended to the reference lists of relevant articles. From the publications identified in the initial search, we finally included 23¬¬¬¬¬ publications in the review.

Results: The literature review revealed that common cleaning and disinfecting products used in educational buildings can emit numerous volatile organic compounds including formaldehyde and terpenes like limonene and α-pinene. The application of cleaning products like waxes and polishes can also lead to increased concentrations of benzene, ethylbenzene, m/p-xylene, tetrachloroethylene, and styrene (Gabriel et al., 2021). Exposure to high levels of terpenes can occur even when products contain essential oils, and these compounds can react with oxidants like ozone to form secondary pollutants (Angulo Milhem et al., 2020). Deep cleaning methods such as steam cleaning can prompt the release of chemicals from carpets, which accumulate in indoor air, particularly if ventilation during and after cleaning is inadequate (Wakayama et al., 2019). Wet mopping, although reducing particle resuspension, can lead to higher VOC levels when cleaning products are used, as well as increase levels of viable bacteria in indoor spaces (Smedje and Norbäck, 2001; Wei et al., 2016). Using a detergent with limonene was shown to increase ultra-fine particle concentrations significantly (Morawska et al., 2009; Salonen et al., 2024). Monitoring of daily patterns of particulate matter in school classrooms has revealed the significant impact of cleaning activities, occupancy, and dust resuspension on increased particle concentrations (Faria et al., 2020).
To lower chemical exposure, it is advisable to enhance cleaning routines, switch to low-emitting cleaning products, alter cleaning techniques, and improve ventilation during and after cleaning. Major cleaning activities should preferably be conducted after school hours. Furthermore, it is highly recommended to avoid using air fresheners or fragranced cleaning products in educational buildings.
Conclusions: The use of cleaning agents can lead to harmful exposure to chemical and particulate pollutants. It is essential to implement measures to minimize this exposure, particularly in educational settings with young children. Further studies should focus on analyzing the chemical composition of cleaning products and assessing exposure levels with targeted measurements rather than with questionnaire. Research is needed to examine the long-term health effects of these chemicals, compare potentially environmentally hazardous products with eco-friendly alternatives (such as citric acid, Na2CO3, NaHCO3, essential oils, and natural tensides), and evaluate the effectiveness of different ventilation strategies. Recognition of optimal cleaning techniques to substantially reduce chemical exposure is significant. Furthermore, studies exploring the interactions between cleaning product chemicals and other indoor pollutants are called for. Simultaneously, an exploration

of new cleaning technologies, combined with a critical assessment of related regulations, is indispensably important for healthy learning atmospheres.

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