Mount Sinai *Selikoff Centers for Occupational Health*

Bellevue/NYU Occupational & Environmental Medicine Clinic

Quaternary Ammonium Compounds in Cleaning Products:

Health & Safety Information for Health Professionals

This information sheet reviews the recognition, assessment, and treatment of possible adverse health effects of products containing alkyl dimethyl benzyl ammonium chlorides and several other quaternary ammonium compounds (QACs or "quats") used in cleaning and disinfection. It is intended for health professionals who may see individuals or groups with exposure to these materials and also covers the identification and prevention of exposure to QACs commonly found in commercial products.

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Introduction

In recent years, there has been a rise in publications linking asthma to the use of cleaning products [1]. One particular ingredient that has received more attention recently as a cause of asthma is the class of chemicals known as quaternary ammonium compounds (QACs). Alkyl dimethyl benzyl ammonium chlorides (BACs) are one type of QACs that has been implicated in causing adverse health effects.

Cleaning products that contain QACs and other disinfectants are commonly used in homes, workplaces, and public spaces. Disinfectants have an important role in preventing the spread of serious infectious diseases. Health care facilities, day care centers, and restaurants may be centers for transmission of bacterial and viral illnesses where use of disinfectants is important. On the other hand, use of these disinfectants is not recommended in places such as homes and offices when there is no elevated risk of infection, or where plain detergents would be effective in removing infectious organisms.

For most people, the QACs in cleaning and disinfectant products cause no problems. However, exposure to QACs does have the potential to cause serious and preventable health effects. These may include:

- contact dermatitis [2, 3]
- triggering of asthma symptoms in people who already have asthma or new onset of asthma in people with no prior asthma [4]
- eye and mucous membrane injuries from splashes or contact with mists [5], and
- oral and gastrointestinal injuries from swallowing solutions containing QACs [5].

The role of QACs in many other disorders such as cancers, reproductive problems, and endocrine changes has not been adequately studied, so guidance specific to those disorders cannot be provided.

Exposure to QACs

Use of QACs

QACs are disinfectants used alone or added to cleaning products. Manufacturers have added them to dishwashing liquids, hand soaps, window cleaners, "all-purpose" cleaners, floor products, baby-care products, disinfectant sprays and wipes, air fresheners, and other cleaning products that advertise anti-microbial activity.

QACs are used extensively in health care settings to clean noncritical patient care items (non-sterile medical equipment that may come into contact with intact skin but not mucous membranes) and environmental surfaces. Other industries in which they are approved and widely used for their anti-microbial properties include food service and hydraulic fracturing [6,7]. QACs are also used in cleaning homes and offices. In routine cleaning, where surface contamination with pathogenic bacteria and viruses does not present a hazard, QACs and other disinfectants are usually not necessary or recommended.

QAC Properties

QACs are solids that are dissolved in liquid solutions. They do not evaporate into the air. When solutions of QACs dry they leave behind a solid residue. QACs can get in the air if they are sprayed or if mixing of solutions results in foaming or splashing. In theory, surface residue could become another source of airborne QACs if disturbed or attached to dust, but this has not yet been studied. QACs persist in the environment, both on cleaned surfaces and in waste water, both of which could possibly result in skin exposure [8].

Many QACs have the chemical structure $N\text{-}R_1R_2R_3R_4{}^+X^-$ where N is nitrogen, the 4 "R" positions are alkyl groups (methyl, ethyl and longer alkyl chains with up to 18 carbons) or an aryl group (such as benzyl) that may be connected to each other, and X- is an anion, usually chloride. Other anions include bromide and saccharinate. Commercial products are often mixtures of QACs with different length carbon chains.

Identification of QACs

There are many different QACs found in disinfectants or cleaning products. The most commonly used QAC disinfectants are the benzalkonium chlorides, also known as alkyl dimethyl benzyl ammonium chlorides (Figure 1). Abbreviations for benzalkonium chloride include BAC, BZK, BKC, and ADBAC.

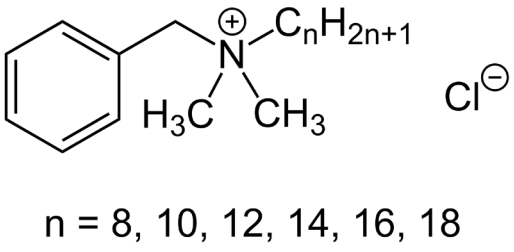

Figure 1. Chemical structure of benzalkonium chlorides

The concentration of benzalkonium chloride in disinfectants and cleaning supplies is usually between 0.01 and 1%, but can be as high as 5% [9]. Concentrated solutions used for mixing can contain 25% or more. Other QACs found in cleaning supplies and disinfectants have similar concentrations.

Cleaning supplies claiming antimicrobial activity and containing QACs must list the QACs on the label and be registered with the Environmental Protection Agency [10].

The label does not specify that a substance is a QAC; rather it lists specific ingredients which often end in "ammonium chloride." A typical label entry for a benzalkonium chloride, for example, would be:

Alkyl (40% C12, 50% C14, 10% C16) dimethyl benzyl ammonium chloride

QACs might not be listed on Safety Data Sheets because they are often less than 1% of the cleaning product and are not required to be listed.

The NIH Household Products Database can be searched to determine if a household cleaning product contains QACs. Products can be searched by product name or by ingredients (such as quaternary ammonium compounds, quaternium, ammonium chloride, and ammonium saccharinate).

This database is located at **http://householdproducts.nlm.nih.gov**

The Pesticide Action Network (PAN) Pesticide Database has pesticide information from the U.S. EPA Pesticide Product Information System and the Purdue University National Pesticide Information Retrieval System. This database is located at **www.pesticideinfo.org**

Environmental Monitoring

Literature on exposure levels to workers or the public is scarce and there are no standard methods for environmental monitoring. The National Institute for Occupational Safety and Health (NIOSH) is currently developing standardized analytical methods for air, dust, and surface sampling.

Potential Adverse Health Effects: Recognition, Diagnosis, and Treatment

Medical Assistance

If illness or injury due to exposure to a QAC-containing product is suspected in a workplace, the worker involved should be referred to a physician. In an emergency situation, if no physician is immediately available, the nearest Poison Control Center should be consulted immediately. The U.S. nationwide Poison Control Center emergency number is 1.800.222.1222.

Health care and health and safety professionals who encounter people with non-emergency exposures and illnesses can get further assistance from their local occupational medicine clinic. To find a list of many of the occupational medicine clinics in New York State, go to **https://www.health.ny.gov/environmental/workplace/clinic.htm** A list of occupational health clinics in North America is available at: **www.aoec.org.**

Treating physicians should ask patients with medical complaints potentially related to their use of QACs to record the names and manufacturers of products that they suspect may be causing their symptoms. In some cases asking them to photograph product labels with a phone or digital device can be helpful in identifying the products.

Contact Dermatitis

Three types of QACs used as antimicrobials have been reported to cause irritant and/or allergic contact dermatitis [2, 3, 11, 12, 13]. These QACs are the benzalkonium chlorides, didecyl dimethyl ammonium chloride (DDAC), and N,N-didecyl-N-methyl-poly(oxyethyl) ammonium propionate. Other QACs used as preservatives, hand lotions, and cosmetics, including quaternium-15, polyquaternium-9, and cetyl pyridinium chloride, have been reported to cause allergic contact dermatitis [14, 15].

Accidental spillage of liquid cleaning products containing QACs onto skin and clothes is common [11]. QACs have been reported to cause irritant contact dermatitis through direct injury to the outer skin layers in exposed individuals. Contact with concentrated solutions of QACs may be

especially hazardous. Patients with leg ulcers, eczema, or skin infections are particularly susceptible to irritant dermatitis from direct contact with broken skin [12]. Systemic absorption through unbroken skin is low [11].

QACs can also cause allergic contact dermatitis. Quaternium-15, a QAC that is used as a preservative in hand moisturizers, was found to be the most frequent allergen in one North American study of hand allergic contact dermatitis, causing a clinically positive reaction in 16.5% of subjects [2]. Similarly, in a Swiss study, 5.5% of people with contact dermatitis were found to be sensitized to BAC [3].

Contact dermatitis can present in mild forms, such as skin dryness with reddening, chapping, and scaling. It can also occur in more severe forms, as eczema-like dermatitis with swelling, blisters, or fissures, or even as severe chemical burns with necrosis. Symptoms can include itching, burning, stinging and pain. Typically the dermatitis is limited to areas of direct contact.

Diagnosis of contact dermatitis is based on history, clinical appearance, and in many cases, patch testing to identify specific allergens. In addition, the diagnosis of contact dermatitis depends on considering other causes and conditions, including other contact allergens and irritants, and similar-appearing skin conditions including eczema, psoriasis, scabies, and fungal infection. Optimal treatment may depend on differentiation of allergic contact dermatitis from irritant contact dermatitis.

Allergic contact dermatitis often requires complete elimination of exposure to the sensitizing agent. Less extreme means of exposure control may be adequate for irritant contact dermatitis. Evaluation and treatment may be best done in partnership with a dermatologist with experience in contact dermatitis. Guidelines on diagnosis and management of contact dermatitis have recently been summarized [16].

Work-Related Asthma

Work-related asthma includes occupational asthma and work-exacerbated asthma. Occupational asthma is defined as a disease characterized by variable airflow limitation and/or hyperresponsiveness and/or inflammation due to causes and conditions attributable to a particular occupational environment and not to stimuli encountered outside the workplace [17]. Work-exacerbated asthma is defined as pre-existing or concurrent asthma that is worsened by workplace conditions [18].

Workplace exposure to some types of QACs can potentially cause occupational asthma and/or work-exacerbated asthma. Evidence supporting QACs as causes of work-related asthma includes surveillance studies [19, 20, 21, 22, 23], case reports [24, 25], case series [22, 26, 27], and a cross-sectional study [28]. Not all studies have identified the specific QACs that are associated with work-related asthma symptoms, although many different QACs have irritant properties and could trigger symptoms of existing asthma. See Appendix 1 for more details on these studies.

Two types of QACs used as microbicides have been reported to cause respiratory sensitization and occupational asthma. These are the BACs [24, 25, 26, 27] and didecyl dimethyl ammonium chloride (DDAC) [27]. A list of QACs, mostly BACs, meeting the Association of Occupational and Environmental Clinics (AOEC) criteria for asthmagens [29] can be found using the AOEC exposure code 322.32 on the AOEC website: **(http://www.aoecdata.org/ExpCodeLookup.aspx).**

The AOEC has classified these asthmagens as respiratory sensitizers (denoted by Rs on the website), and it would be prudent to consider each of them as capable of causing occupational asthma.

Respiratory irritants in single or multiple very high-dose exposures can also cause a form of occupational asthma called Reactive Airways Dysfunction Syndrome (RADS) as a result of inhalation injury. However, as of yet there are no reports of RADS due to QAC inhalation [19].

It is often difficult to identify whether the QAC component is the primary chemical associated with respiratory or skin disorders because cleaning and disinfecting products typically contain other ingredients, such as fragrances and other disinfectants, that can cause or trigger these symptoms [19, 24]. In addition, multiple QACs are often present in one cleaning product [24].

Diagnosis and treatment of work-related asthma: A person exposed to QACs who has cough, shortness of breath, chest tightness or wheezing should be evaluated for asthma. Respiratory symptoms are often worse on work days and better on days away from work in early stages of work-related asthma [17, 30, 31]. Predictive value positive of the history of work-related asthma symptoms is not high enough to confirm a diagnosis of work-related asthma without further detailed clinical evaluation [17]. Similarly, predictive value negative of the clinical history alone is also low and absence of the history of work-related asthma symptoms is not enough to confidently rule out work-related asthma without further clinical evaluation [17].

Treatment of occupational asthma due to respiratory sensitization generally requires complete cessation of the exposure and often permanent job change. This can be very difficult for the patient; therefore, the diagnostic evaluation needs to be thorough and based on objective evidence, if possible.

This evaluation should be done by an occupational physician, pulmonologist, or allergist experienced in evaluation and care of patients with work-related asthma. It generally includes a thorough environmental and occupational history, a full set of pulmonary function tests, and immunologic testing for any likely causal agents, if validated tests are available. If pulmonary function tests are normal, often methacholine challenge testing for nonspecific bronchial hyperresponsiveness is indicated. See Appendix 2 for more details on diagnosis and management of work-related asthma. If the patient has a history of asthma, medical records of any diagnostic evaluations by other physicians should be obtained.

Prompt evaluation is important as work-related asthma can sometimes be completely reversible if exposures can be identified and stopped early. However, if exposure continues, work-related asthma may later progress into more persistent chronic asthma with frequent exacerbation. Once this occurs, the asthma may not be completely reversible even after the patient is removed from the workplace exposures that were the initial cause.

Eye and Mucous Membrane Injuries

Direct contact with QACs splashed into the eye or mucous membrane can cause injuries, ranging from short-term irritation to long-term or permanent damage to the cornea. For example, BACs are known eye irritants [5]. At low concentrations (0.1%), they can cause mild discomfort. At concentrations above 10%, there can be ocular inflammation, corneal damage, and ocular toxicity [11].

Immediate flushing with copious amounts of tepid water is indicated for all splashes to the eye. If only one eye is affected, be sure to flush the affected eye away from the unaffected eye. Individuals with direct eye contact with QACs should be evaluated by a physician as soon as possible after the exposure.

Ingestion Injuries

Ingestion of dilute solutions of QACs is unlikely to be serious, but ingestion of concentrated solutions can cause caustic burns of lips, tongue, mouth, throat, esophagus and stomach, and, in rare instances, may be fatal [5,11]. As disinfectant cleaning products can have multiple ingredients that may be toxic by ingestion, the Poison Control Center (1-800-222-1222) should be immediately consulted in cases of acute ingestion.

Eliminating or Reducing Exposure

Employers and workers can reduce or eliminate exposure by:

- using disinfectants only when necessary;
- choosing safer substitutes; or
- employing safe work practices when QACs are called for.

More details on these recommendations can be found in Appendix 3.

Resources for your Patients

Health and safety information for individuals who may be working with QACs can be found in an information sheet titled "Quaternary Ammonium Compounds in Cleaning Products:Health & Safety Information for Cleaners and Supervisors" available at: http://www.mountsinai.org/patient-care/service-areas/occupational-health/resources

Resources

Rutala, W.A., Weber, D.J. et al. 2008. Guideline for Disinfection and Sterilization in Healthcare Facilities. Centers for Disease Control. Available at: http://www.cdc.gov/hicpac/pdf/guidelines/Disinfection_Nov_2008.pdf

Centers for Disease Control. 2012. Work-related asthma: Most frequently reported agents associated with work-related asthma cases by asthma classification, 1993–2006. Available at: http://www2a.cdc.gov/drds/WorldReportData/FigureTableDetails.asp?FigureTableID=2611&GroupRefNumber=T09-05A

Burge, S. and Hoyle, J. 2012. Current topics in occupational asthma. Expert Review of Respiratory Medicine, December 2012, 6 (6): 615-627, DOI 10.1586/ers.12.65
International Programme on Chemical Safety. 1998. Quaternary Ammonium. Available at: http://www.inchem.org/documents/pims/chemical/pimg022.htm

Rosenman, K. 2008. Disinfectants and Asthma. Available at: http://www.oem.msu.edu/userfiles/file/News/v20n1.pdf

California Dept. of Public Health. 2012. Fact sheet on Cleaning Products and Work-Related Asthma. Available at: http://www.cdph.ca.gov/programs/ohsep/documents/wra-cleaningprod.pdf

Hazardous Substances Data Bank. 2010. Benzalkonium Chloride Compounds. Available at: http://toxnet.nlm.nih.gov/cgi-bin/sis/search2/r?dbs+hsdb:@term+@DOCNO+234

Workplace Safety & Prevention Services, Occupational Health Clinics for Ontario Workers, Inc. 2010. Work-Related Asthma: Preventing Work-related Asthma in the Cleaning Industry. Available at: http://www.wsps.ca/WSPS/media/Site/Resources/Downloads/fd_WRA_Cleaning_BK_F_1.pdf?ext=.pdf

U.S. Environmental Protection Agency. 2009. EPA Registered Hard Surface Disinfectants Comparison Chart. Available at: http://education.nh.gov/instruction/school_health/documents/disinfectants.pdf

U.S. Environmental Protection Agency. Design for the Environment. Available at: http://www2.epa.gov/saferchoice/design-environment-dfe-workplace-best-practices

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Appendix 1. Epidemiology of QAC-Related Asthma

With funding assistance from the National Institute for Occupational Safety and Health, the Centers for Disease Control and Prevention (CDC) monitors work -related asthma (WRA) cases in California, Massachusetts, Michigan, and New Jersey [20]. These four states have mandatory asthma reporting systems.

Surveillance from 1993–2006 yielded 962 cases of WRA due to cleaning supplies (14.2% of total) [21]. Of these, 22 cases of WRA (2.3%) were attributed to QACs. These included 16 cases of new onset asthma and six of work-exacerbated asthma. Sodium hypochlorite bleach and ammonia accounted for the largest number of cases of WRA, 157 and 54 cases respectively. Many more WRA cases (481 or half the total) were noted to arise from unspecified cleaning agents, which may indicate a greater incidence of QAC-related asthma than those cases specifically attributed to these agents.

Several case reports and case series have documented new onset occupational asthma with respiratory sensitization to BACs present in cleaning products [24, 25, 26, 27]. The largest, conducted in Belgium, identified 17 subjects with positive specific inhalation challenges for cleaning disinfection products out of a total of 44 participants with cleaning-related asthma symptoms [27]. Of these 17 subjects, 10 involved products containing QACs, mainly BACs and didecyl dimethyl ammonium chloride.

Several epidemiologic studies have reported associations of QACs with asthma, but without objective confirmation of relation to specific QACs. A 1993–1997 study of 300 WRA cases due to cleaning agents reported the main occupations of the WRA cases were janitors and cleaners (22%), nurses and nurses' aides (20%), and clerical staff (13%) [22]. The study indicated that cases had most likely been exposed to cleaning products in a medical setting (39%), school (13%) or hotel (6%).

A 2001–2009 study of WRA cases collected from the French National Network of Occupational Health Surveillance and Prevention concluded that QACs were the only substances associated with a significant increase in the number of WRA cases during this period (P=.003) [23].

A 2013 French study of 543 health care workers found that nursing professionals had a higher prevalence physician-diagnosed asthma than did administrative staff [28]. The prevalence of asthma was associated with tasks involving dilution of QAC disinfection products by manual mixing. Results of this cross-sectional study are difficult to interpret however, because the study did not account for likely bias caused by inclusion in the QAC-exposed group of participants who had asthma symptoms caused by past use of chlorine bleach and other irritant disinfectants.

In summary, the case reports and case series using specific bronchial challenge testing provide strong clinical evidence that BACs can cause respiratory sensitization and occupational asthma. The epidemiologic studies confirm this and suggest that occupational asthma due to BACs occurs often enough that it warrants the attention of clinicians seeing patients with asthma-like symptoms and exposure to BACs. Didecyl dimethyl ammonium chloride and possibly other QACs may also cause occupational asthma, but evidence is limited. Although clear epidemiologic evidence is not available, it seems prudent to consider all QACs that are used as microbicides as possible triggers of existing asthma, but only in patients who report work-related worsening of their asthma symptoms.

Appendix 2. Diagnosis and Treatment of Work-Related Asthma

Clinical evaluation and management of persons with possible work-related asthma have been summarized recently [30] and described in great detail [17, 18]. If work-related asthma is suspected based on symptoms, workplace exposures to substances, or conditions that could potentially cause or exacerbate asthma, the patient should be carefully evaluated for work-related asthma.

In particular, if sensitizer-induced occupational asthma is diagnosed, effective treatment most often requires complete cessation of exposure [17]. This often means a change of job or career, which may have severe social, psychological, and financial consequences for the patient. At a minimum it requires a major change in their workplace environment, which can also lead to difficulties on the job for the patient. For these reasons, the evaluation of work-related asthma should be thorough and, if possible, based on objective evidence of work-related changes in airflow obstruction [30].

This evaluation should include:

- Doing, or obtaining prior results of, objective testing to confirm or rule out asthma
- A careful history to assess a possible work-related time pattern of asthma symptoms.
- If possible, objective assessment of possible work-related reversible airway obstruction.
- Identification of the workplace conditions that caused and/or exacerbated the asthma symptoms, and
- Efforts to distinguish the different types of work-related asthma.

Objective testing for asthma generally includes full pulmonary function tests including lung volumes, expiratory flows, and results of bronchodilator administration.

Since airway obstruction in asthma is variable, normal pulmonary function tests do not rule out occupational asthma, especially when done while the patient is asymptomatic or has been away from the provoking materials. In these cases, a methacholine challenge or other test for bronchial hyper-responsiveness should be done to help confirm or rule out asthma. In some cases even these tests can normalize within days or weeks after cessation of the inciting workplace exposure, so a negative methacholine challenge test in a person who is no longer working does not by itself rule out occupational asthma [17]. Inhalation challenge testing for specific sensitizing agents is commonly done in Canada and some European countries but is not available in clinical settings in the United States.

Once asthma is confirmed, recording of serial peak flow measurements at least 4 times a day both at work and away from work for several weeks if possible may provide important objective evidence for a workplace source. If an occupational physician or pulmonologist experienced in interpreting these peak flow data is not available, statistical methods for evaluation of serial peak flow measurements are reviewed in the Vandenplas et al. chapter in Reference 17. Immunologic tests for workplace allergens may be performed if there are validated tests for those allergens as well as for other causes of allergies and asthma. Validated immunologic tests for QAC allergies are not commercially available, however some other potential causes like latex or glutaraldehyde may need to be ruled out or confirmed with available immunologic tests.

Identification of environmental asthma triggers in the workplace and outside the workplace can be aided by a prospective diary kept by the patient that includes all the peak flow measurements with date, time, and whether it was a work day or not, plus notations of day and time of all uses of short-acting rescue bronchodilator medication and suspected asthma trigger exposures. There will likely be multiple potential triggers in addition to use of the QAC-containing products.

If a two-day weekend is not sufficient time for asthma symptoms to abate away from workplace trigger exposures, it may be diagnostically helpful to place the patient on a formal medical leave from work for several additional days or even a week or two, while continuing the prospective diary monitoring serial peak flows, medications, and exposures. It is sometimes helpful to do a carefully monitored diagnostic trial of cessation of exposure when a higher level of diagnostic certainty is needed, for example before recommending a job or career change [30].

Pharmacologic treatment of occupational asthma is based on guidelines similar to those used for the management of non-occupational asthma such as the National Asthma Education and Prevention Program: Expert panel report III [32] or the Global Strategy for Asthma Management and Prevention [33].

Patients with sensitizer-induced occupational asthma have a better prognosis with complete cessation than with reduction of the sensitizing exposure [30]. Patients with workplace exacerbation of asthma symptoms sometimes improve with reduction of the irritant exposures. Ongoing peak flow monitoring for several weeks or months after return to the safer work environment is very important to ensure that the patient is actually improving. If improvement cannot be documented, the work environment should be reassessed and modified further or complete removal from that workplace should be considered. The patient also should be counseled to avoid exposure to materials and processes that contain known sensitizers or irritants that may trigger symptoms or otherwise worsen their occupational asthma [34]. In many cases these agents, including disinfectant products, may also be present outside of the workplace, in hospitals, health and social service centers, schools, homes, and other buildings.

Appendix 3. Working Safely with QACs

1. Use Safer Products

   - Disinfectants should not be used unless necessary. Unnecessary use exposes people and the environment to the potential health effects of QACs and may also promote development of bacterial resistance to both biocides and antibiotics [35, 36, 37, 38].
   - Infection control experts or local health departments should be consulted regarding an individual institution's need for disinfection and choice of disinfectants for specific situations. The risk-benefit decisions require consideration of multiple factors including likely pathogens of concern, antimicrobial effectiveness and goals, as well as potential toxicity of the disinfectants used [36, 39, 40, 41].
   - Organizations that rate cleaning products based on their effects on the environment and human health include Green Seal (**http://www.greenseal.org/**), UL Ecologo **(http://industries.ul.com/environment/certificationvalidation-marks/ecologo-product-certification),** and EPA's Design for the Environment **(http://www2.epa.gov/safer-choice/design-environment-alternatives-assessments).**
   - It is important to note that products that are environmentally safe are not necessarily healthy for humans and/or may not have the necessary antimicrobial efficacy.
   - To date, cleaning products containing hydrogen peroxide as the main disinfectant may be considered as equally or more effective disinfectant alternatives to QACs. As disinfectants, citric acid and lactic acid are less effective than QACs or hydrogen peroxide and are not recommended as direct substitutes for QACs in situations where disinfectants are actually needed [40]. The Centers for Disease Control (CDC) rates QACs as being the least effective class of all the disinfectants they list for use in microbiological and clinical laboratory settings [40]. The CDC list does not include citric acid or lactic acid. They note that alcohols may be effective, but require at least 10 minutes of full immersion, which is not practical in most cleaning situations. Fogging and spraying of entire rooms with disinfectant increases the likelihood of exposure to building occupants, is not generally effective, and is not recommended by the CDC [35].
   - Whenever possible, use of spray products should be avoided. Instead, pour cleaner onto a cloth to wipe on the surface. Use of QACs for medical instruments, equipment, dishes, and other surfaces that might have contact with mouth, eyes, and other mucous membranes should be avoided.
   - In hospitals, there are pros and cons to disinfecting surfaces where skin contact is unlikely, like floors and table tops. The CDC states these areas can be cleaned with detergent, unless there is suspicion that blood, body fluids, or multi-drug resistant organisms have contacted these areas [35].
   - Institutions should consider the use of alternative safer cleaners and disinfectants if people in the area already have asthma.

2. Follow the Label Instructions Carefully

   - Disinfectants and cleaning supplies containing QACs should only be used on designated surfaces in the correct concentration, as specified on the label. Labels will also specify if surfaces are to be rinsed off after they are applied.
   - The exact dilution specified should be used. Workers should not use a cleaner at full strength when the instructions say to dilute it with water.

3. Obtain the Safety Data Sheet for the Cleaning Product

   - The Safety Data Sheet (SDS), formerly called the Material Safety Data Sheet (MSDS), contains essential information on the contents, hazards, and precautions for the product. However, allergens are often not considered toxicants and many SDSs for QAC products do not list asthma or skin allergies as risks.

4. Work Practices with QACs

   - Use closed automated mixers rather than manual mixing when diluting cleaners.
   - If spray products are essential, the nozzles should be set on stream mode instead of mist mode, when feasible.
   - As much ventilation as possible should be used, open doors and windows as needed. If spraying and poor ventilation cannot be avoided, properly fitted N95 NIOSH-approved respirators (or the type recom-

mended by the cleaning product manufacturer) will reduce exposures to QAC-containing particles. These will not, however, protect against vapors or gases from other possible ingredients of cleaning products, such as solvents or chlorine.

- Wear gloves and chemical-proof safety goggles if skin contact or splashes can occur. This is especially important when handling concentrated QAC solutions or handling and disposing of QAC solutions left in buckets, on rags, and on sponges.
- Cleaning products should not be combined. Mixing bleach and QACs, for example, can form poisonous gases.
- Cleaners should be stored in their original containers. Cleaning products should never be transferred into a beverage bottle or can.

5. Clean-up of Accidental Releases
   - Surfaces that have been unintentionally contaminated with QACs should be cleaned according to the manufacturer's instructions. In many cases soap and water will be sufficient to remove QACs.

References

1. Rosenman KD. 2006. Cleaning Products - Related Asthma. Clinical Pulmonary Medicine. 13(4): p. 221-228.
2. Warshaw EM, et al. 2007. Contact dermatitis of the hands: cross-sectional analyses of North American Contact Dermatitis Group Data, 1994-2004. Journal of the American Academy of Dermatology. 57(2): p. 301-314.
3. Perrenoud D, et al. 1994. Frequency of sensitization to 13 common preservatives in Switzerland. Contact Dermatitis. 30(5): p. 276-9.
4. Rosenman, K. 2008. Disinfectants and Asthma. Project SENSOR. Accessed Aug 2015 at: http://www.oem.msu.edu/userfiles/file/News/v20n1.pdf
5. Environmental Protection Agency Chart. EPA Registered hard surface disinfectants comparison chart. Accessed Aug 2015 at: http://www.education.nh.gov/instruction/school_health/documents/disinfectants.pdf
6. U.S. Environmental Protection Agency. 2006. Reregistration Eligibility Decision for Alkyl Dimethyl Benzyl Ammonium Chloride (ADBAC) accessed Jan. 2015 at : http://archive.epa.gov/pesticides/reregistration/web/pdf/adbac_red.pdf
7. U.S. Environmental Protection Agency. 2006. Reregistration Eligibility Decision for Aliphatic Alkyl Quaternaries (DDAC) accessed Jan. 2015 at: http://archive.epa.gov/pesticides/reregistration/web/pdf/ddac_red.pdf
8. Li Xialon and Brownawell Bruce. 2010. Quaternary Ammonium Compounds in Urban Estuarine Sediment Environments - A Class of Contaminants in Need of Increased Attention? Environmental Science and Technology 44: 7561–7568.
9. Hazardous Substances Data Bank. 2010. Benzalkonium Chloride Compounds. Accessed Aug. 2015 at: http://toxnet.nlm.nih.gov/cgi-bin/sis/search2/r?dbs+hsdb:term+@DOCNO+234
10. EPA. 2009. 40 CFR 156.10. Labeling Requirements for Pesticides and Devices. Accessed Aug. 2015 at: http://www.gpo.gov/fdsys/granule/CFR-2009-title40-vol23/CFR-2009-title40-vol23-sec156-10
11. Arugonda SK. 1998. Quaternary Ammonium. Accessed Aug. 2015 at: http://www.inchem.org/documents/pims/chemical/pimg022.htm
12. Dejobert Y., et al. 1997. Contact dermatitis from didecyldimethylammonium chloride and bis (aminopropyl) laurylamine in a detergent disinfectant used in hospital. Contact Dermatitis. 37(2): p. 95-95.
13. de Quintana Sancho A, Raton JA, Eizaguirre X. 2014 Occupational allergic contact dermatitis caused by N,N-didecyl-N-methyl-poly(oxyethyl) ammonium propionate in a dental assistant. Contact Dermatitis 70:379-380.
14. Gallo R, Basso M, Voltolini S, et al. 2001 Allergic contact dermatitis from Laureth-9 and polyquaternium-7 in a skin care product. Contact Dermatitis 45: 356–357.
15. Steinkjer B. 1998. Contact dermatitis from cetyl pyridinium chloride in latex surgical gloves. Contact Dermatitis 39:29-30.
16. Smedley, J. on behalf of the OHCEU and BOHRF Dermatitis guideline development groups. 2010. Concise guidance: diagnosis, management and prevention of occupational contact dermatitis. Clinical Medicine. 10:487-90.
17. Malo JL, Chan-Yeung M, and Bernstein DI. Asthma in the Workplace, Fourth Edition. CRC Press / Taylor & Francis, 2013.
18. Henneberger PK, Redlich CA, Callahan DB, et al. 2011. An official American Thoracic Society Statement: Work-Exacerbated Asthma. American Journal of Respiratory & Critical Care Medicine 184:368-378.
19. Project SENSOR News: Disinfectants and Asthma, Part 2. 20(2), 2009. Accessed Aug. 2015 at: http://www.oem.msu.edu/userfiles/file/News/v20n2.pdf
20. Centers for Disease Control and Prevention. 1999. CDC Surveillance Summaries. MMWR June 25, 1999 [cited 48 SS-3]; Accessed Aug. 2015 at: http://www.cdc.gov/mmwr/pdf/ss/ss4803.pdf

21. Centers for Disease Control. 2012. Work-related asthma: Most frequently reported agents associated with work-related asthma cases by asthma classification, 1993–2008. Accessed Aug. 2015 at: http://www2a.cdc.gov/drds/WorldReportData/FigureTableDetails.asp?FigureTableID=2611&GroupRefNumber=T09-05A

22. Rosenman KD, Reilly MJ, Schill DP et. Al. 2003. Cleaning Products and Work-Related Asthma. Journal of Occupational and Environmental Medicine 45(5): 556-563.

23. Paris C et al. 2012. Work-related asthma in France: recent trends for the period 2001–2009. Occupational and Environmental Medicine. 69(6): p. 391-397.

24. Bernstein JA, et al. 1994. A combined respiratory and cutaneous hypersensitivity syndrome induced by work exposure to quaternary amines. Journal of Allergy and Clinical Immunolology, 94(2 Pt 1): p. 257-9.

25. Burge PS and Richardson MN 1994. Occupational asthma due to indirect exposure to lauryl dimethyl benzyl ammonium chloride used in a floor cleaner. Thorax, 49(8): p. 842-3.

26. Purohit A et al. 2000. Quaternary ammonium compounds and occupational asthma. International Archives of Occupational and Environmental Health. 73(6): p. 423-427.

27. Vandenplas O, D'Alpaos V, Evrard G, et al. 2013. Asthma related to cleaning agents: a clinical insight. British Medical Journal Open-2013-003568 2013 3: Accessed Aug. 2015 at: http://bmjopen.bmj.com/content/3/9/e003568.full.html

28. Gonzalez M et al. 2013. Asthma among workers in healthcare settings: role of disinfection with quaternary ammonium compounds. Clinical and Experimental Allergy. Accessed oct. 2015 at: http://www.ncbi.nlm.nih.gov/pubmed/24128009

29. Rosenman KD, Beckett WS. 2015. Web based listing of agents associated with new onset work-related asthma. Respiratory Medicine. Accessed Aug. 2015 at: http://www.sciencedirect.com/science/article/pii/S0954611115001031

30. Friedman-Jimenez, G. Harrison, D., Luo, H. 2015. Occupational asthma and work-exacerbated asthma. Semin Resp Crit Care Med. 36(2): 388-407.

31. Malo JL, Lerniere C, Cartier A, Chan-Yeung M. UpToDate 2014. Occupational asthma: Clinical Features and Diagnosis.

32. National Heart, Lung, and Blood Institute. 2007. National Asthma Education and Prevention Program: Expert panel report III: Guidelines for the diagnosis and management of asthma. (NIH publication no. 07-4051). Bethesda, MD.

33. Global Initiative for Asthma. 2014. Global Strategy for Asthma Management and Prevention. Available from: www.ginasthma.org.

34. LaDou J and Harrison RJ. 2014. Current Diagnosis & Treatment: Occupational & Environmental Medicine, 5th Ed. McGraw-Hill Education. Columbus, OH.

35. Rutala WA, Weber DJ et al. 2008. Guideline for Disinfection and Sterilization in Healthcare Facilities. Centers for Disease Control. Accessed Aug. 2015 at: http://www.cdc.gov/hicpac/Disinfection_Sterilization/17_00Recommendations.html

36. Hegstad K et al. 2010. Does the wide use of quaternary ammonium compounds enhance the selection and spread of antimicrobial resistance and thus threaten our health? Microbial Drug Resistance 16(2): p. 91-104. http://www.ncbi.nlm.nih.gov/pubmed/20370507

37. He, Gui-Xin et al. 2014. Detection of benzalkonium chloride resistance in community environmental isolates of staphylococci. J. Med. Microbiol. 63:735-741. Accessed Aug. 2015 at: http://jmm.sgmjournals.org/content/63/Pt_5/735.full.pdf+html

38. Carson R., Larson E., Levy S. et al. 2008 Use of antibacterial consumer products containing quaternary ammonium compounds and drug resistance in the community. J. Antimicrobial Chemotherapy; 62:1160-1162.

39. Rutala WA. 2014. Selection of the ideal disinfectant. Infection Control & Hospital Epidemiology 35(7), pp 855-865.

40. Centers for Disease Control and National Institutes of Health. 2009. Table 2. Activity Level of Selected Liquid Germicides. In: Biosafety in Microbiological and Biomedical Laboratories. HHS Publication No. (CDC) 21-1112. 5th Edition (revised). Accessed Aug. 2015 at: http://www.cdc.gov/biosafety/publications/bmbl5/bmbl.pdf

41. Pechter E and Summer. 2013. Disinfecting Surfaces and Asthma. SENSOR Occupational Lung Disease Bulletin, Massachusetts Department of Public Health, Boston, MA. Accessed Aug. 2015 at: http://www.mass.gov/eohhs/docs/dph/occupational-health/sensor-lung-disease-bulletins/summer2013.pdf

42. Environmental Protection Agency. 2014. Design for the Environment Antimicrobial Pesticide Pilot Project: Moving Toward the Green End of the Pesticide Spectrum. Accessed Aug. 2015 at: http://www2.epa.gov/pesticide-labels/design-environment-antimicrobial-pesticide-pilot-project-moving-toward-green-end

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Bellevue/NYU Occupational & Environmental Medicine Clinic (BNOEMC) is a comprehensive occupational health program dedicated to improving health in the workplace through early recognition, accurate diagnosis, and evidence-based treatment and prevention of work-related diseases.

BNOEMC is one of eight regional occupational health centers established by the New York State Department of Health Occupational Health Clinic Network. The primary mission of the BNOEMC is to provide the highest quality clinical and preventive occupational and environmental medicine services to those workers in New York City who are at high risk for work-related diseases and most in need of these services, regardless of ability to pay. The clinic does medical evaluations, industrial hygiene workplace environmental evaluations, and occupational health education programs for employees and employers.

The clinic is affiliated with NYC Health and Hospitals Corporation, Bellevue Hospital Center, NYU School of Medicine, and NYU Langone Medical Center and is the only publicly accessible Occupational and Environmental Medicine clinic in the New York City public hospital system. In addition to the clinical program, we are developing occupational medicine research and educational programs. Bellevue accepts most medical insurance and (in appropriate cases) Workers' Compensation, and has a sliding fee scale for others. We speak English, Spanish, Chinese, Italian and French and many other languages are available through medical interpreters.

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