TURI TOXICS USE REDUCTION INSTITUTE UMASS LOWELL

Quaternary Ammonium Compounds (QACs)

The TURA Science Advisory Board (SAB) has recommended that certain Didecyl Dimethyl Ammonium Chloride (DDAC) and Alkyl Dimethyl Benzyl Ammonium Chloride (ADBAC) chemicals be added to the TURA list of Toxic or Hazardous Substances. In reviewing the science about DDAC and ADBAC, the SAB had concerns related to these substances, including respiratory system irritation and inflammation including outcomes consistent with occupational asthma and work-exacerbated asthma; corrosive effects; hazard for aquatic life; and environmental fate and persistence. The SAB had additional concerns for reproductive effects and neural tube development.

This policy analysis summarizes key scientific information on DDAC and ADBAC; estimates the number of facilities that are likely to enter the program as a result of the proposed listing; analyzes opportunities and challenges new filers are likely to face; and discusses the implications of this policy measure for the TURA program. Based on this analysis, the Toxics Use Reduction Institute supports the SAB's recommendation that DDAC and ADBAC be added to the TURA list of Toxic or Hazardous Substances.

OVERVIEW

Quaternary ammonium compounds ("QACs" or "quats") are a broad class of several hundred chemicals. QACs were first discovered in the early 1940s and used mainly as active ingredients in antimicrobials, disinfectants, sanitizers, and surfactants. QACs are used in many products, including wood preservatives, herbicides, eye drops, mouthwashes, nasal sprays, detergents and shampoos, dryer sheets and fabric softeners.

DDAC and ADBAC QACs remain largely used in the United States as ingredients in antimicrobial products for use in consumer and institutional cleaning and disinfecting. Applications range from domestic to agricultural, industrial, and clinical. These products can be found in restaurants, medical settings, food production facilities, and households. They are considered to be effective against most vegetative bacteria, enveloped viruses, and some fungi. Ready-to-use products may contain 0.08-20% active QAC ingredients, and industrial concentrates can contain 20-80% active QAC ingredients. ADBAC and DDAC can be used in acid, neutral and alkaline formulations and is available in a dilutable concentrate that reduces shipping weight.

Although QACs have been used for over 80 years, they have had a recent increase in use. The demand for QAC-based disinfectants rose significantly as a result of the global SARS-CoV-2 pandemic. More than half of the products listed on the U.S. EPA's "List N: Disinfectants for Coronavirus" are QAC based.[1] As new QAC-based coatings and disinfectant formulations are introduced and overall use increases, environmental health and safety concerns about QAC exposure are also increasing. In 2020 alone, more than 700 hundred papers were published related to QAC research.[2]

Recommendation

After reviewing the science and the hazards of QACs, the TURA Science Advisory Board recommended in May 2021 that certain DDAC and ADBAC chemicals be added to the TURA list of Toxic or Hazardous Substances. The Toxics Use Reduction Institute considered the policy implications, and based on this analysis supports the SAB's recommendation that DDAC and ADBAC quaternary ammonium compounds be added to the TURA list of Toxic or Hazardous Substances.

BACKGROUND ON QACS

In the early years, EPA required all QACs to be individually registered as a new chemical under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), but in 1988 EPA issued a notice in which structurally similar QACs were clustered into the 4 groups listed below:

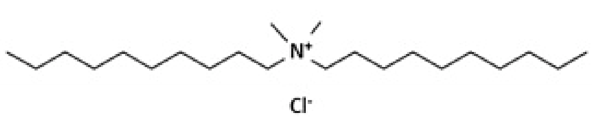
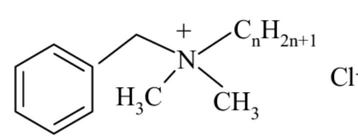
- ***Group I:*** The alkyl or hydroxyalkyl (straight chain) substituted Quats
- ***Group II:*** The non-halogenated benzyl substituted Quats (includes hydroxybenzyl, ethyl benzyl, hydroxyethybenzyl, napthylmethyl, dodecyl benzyl, and alkyl benzyl)
- ***Group III:*** The di- and tri-chlorobenzyl substituted
- ***Group IV:*** Quats with unusual substituents (charged heterocyclic ammonium compounds)

This policy analysis will focus on the commonly used disinfectants in Group I - Didecyl Dimethyl Ammonium Chloride (DDAC) and - Alkyl Dimethyl Benzyl Ammonium Chloride (ADBAC) in Group II. Multiple individual substances with unique CAS numbers fall within these subclasses.

DDAC AND ADBAC

The DDAC subclass in Group I consists of five individually registered compounds[3] and the ADBAC subclass in Group II consists of 19 compounds;[4] see Table 1 and Table 2 below for complete lists of individual compounds. Within these groups, the Toxics Use Reduction Act (TURA) Science Advisory Board (SAB) looked in detail at common DDAC and ADBAC chemicals as the representative compounds of each group. Both of these example compounds were selected because they are among the most commonly used in disinfecting products, have the highest number of active registrations, and are often found together in mixtures. The table below summarizes key properties for each of the representative substances.

Properties of DDAC and ADBAC*

Property	DDAC	ADBAC
CAS Number	7173-51-5	68424-85-1
Melting Point	228.81˚C	241.02˚C
Boiling Point	>180 °C[5]	>560.84 °C
Vapor Pressure	2.33 x 10^{-11} mm Hg	3.53x 10^{-12} mm Hg
Flash Point	26.4°C[6]	32°C[7]
pH	6.8 - 6.9	7.59
Log K_{ow}	4.66	3.91
Structure		

*Properties sourced from EPA Registration Documents and Final Work Plans unless otherwise noted.

SUMMARY OF SCIENTIFIC INFORMATION

The TURA SAB makes recommendations about chemical listings based on hazard. In reviewing the science about DDAC and ADBAC, the SAB noted respiratory system irritation and inflammation including outcomes consistent with occupational asthma and work-exacerbated asthma; corrosive effects; aquatic life hazards; and environmental fate and persistence as the basis for listing. The SAB had additional concerns for reproductive effects and neural tube development.

QACs are associated with both acute (short-term) and chronic (long-term) health effects. Exposure can occur by inhalation, dermal, and oral routes. QACs pose concerns for people using them for cleaning both in the home and in the workplace. In addition, the residues from treated surfaces, including utensils, countertops, equipment, and appliances, can migrate to food, resulting in ingestion by humans.

The majority of data that regulatory agencies have used to make determinations on use as antimicrobials, are based on an individual chemical. However, many of the product formulations on the market contain several different QAC substances, in addition to other ingredients that may be irritating or sensitizing.[8]

Acute Health Effects

EPA classifies five types of acute exposures to pesticides (oral, dermal, inhalation, skin and eye irritation) into four Toxicity Categories, with Category I being the highest hazard. ADBAC and DDAC are acutely toxic through the oral, dermal, and inhalation exposure routes. EPA classifies both substances in Toxicity Category II for the oral and inhalation route, and Toxicity Category III for the dermal route.

Irritant: Eyes, nose, throat, or lung irritation have all been reported among workers exposed to QACs. For skin and eye irritation EPA has categorized DDAC and ADBAC as Toxicity Category I: Corrosive. According to the European Union's harmonized classification they are considered irritants and corrosive to the skin and eyes.

Chronic Health Effects

Chronic occupational health hazards associated with using QACs include dermal irritation that may lead to skin sensitization, and an increased risk of asthma.[9,10,11,12] The Association of Occupation and Environmental Clinics (AOEC) lists both DDAC and ADBAC as asthmagens and respiratory sensitizers.[13,14]

Respiratory Effects/Asthma: Surveillance studies, case reports, and animal studies indicate that DDAC and ADBAC are associated with respiratory system irritation and inflammation including outcomes consistent with occupational asthma and work-exacerbated asthma. Recent studies have suggested that occupational exposure to cleaning agents and disinfectants containing DDAC and ADBAC may cause work-related asthma, chronic obstructive pulmonary disease, and other respiratory illnesses in occupations such as laundry workers, pharmacists, janitors, nursing/medical assistants, health technicians, and housekeepers.[15,16] Exposure to QACs was found to significantly increase the risk of nasal symptoms and physician diagnosed asthma at work more than any other potentially hazardous exposures including glutaraldehyde, latex gloves, or chlorinated/bleach products.[17]

Dermal Effects: ADBAC and DDAC are highly irritating to the skin, and long-term exposure may result in skin sensitization or allergic dermatitis. There have been several cases in which workers reported symptoms of skin sensitization. More recent animal studies have documented that mice dermally exposed to these substances developed not only irritation but also allergic sensitization.[18]

Emerging Evidence

Reproductive/Developmental Effects: Some emerging evidence has suggested that exposure to QACs such as DDAC and ADBAC may affect reproduction and development in animals.[19] The SAB noted during their review that these early studies are concerning and warrant follow-up, but that the evidence was not yet conclusive and there is mixed evidence for frank birth defects. Mice experienced adverse effects after exposure to a ready-to-use product that contained both ADBAC and DDAC, including decreased fertility, fewer pregnancies, reduced number of offspring, disruption of hormone-regulated processes such as ovulation, and birth defects.[20,21,22,23] Exposure to a disinfectant containing both ADBAC and DDAC was associated with delayed neural tube closing in both mice and rats.[24] Some of these effects may relate to potential endocrine activity.

Other Human Health Effects: A human biomonitoring study of 43 random volunteers detected measurable concentrations of QACs in the blood of 80% of participants and identified correlations between levels of QACs, cellular disruption and specific biomarkers related to human health.[25] This was the first study to measure QACs in human blood and to find evidence that QAC concentrations may influence important biomarkers. Some recent studies have shown that QACs can worsen inflammation and disrupt overall cellular function and regulation.[26,27]

Environmental Fate

QACs usually go down the drain and to wastewater treatment plants, which remove some but not all of the QACs prior to discharge to the environment. QACs have been found in surface waters, soil, sediments, and wastewater sludge. Researchers have raised concerns for microorganisms and aquatic organisms as well as the impact of QACs on wastewater treatment plants. DDAC and ADBAC are recognized as toxic to aquatic life. They are considered immobile in soil by both EPA and ECHA. Due to their low volatility, they are expected to bind to sediments and soils. There are also concerns that the overuse of DDAC, ADBAC, and other QACs could lead to development of antibiotic-resistant bacteria.

QACs have also been detected on surfaces long after being used, and in household dust, meaning they may have the potential to persist in the environment, our workplaces, and our homes. A recent study detected 19 different QAC substances in residential dust samples. QACs, the majority of which were ADBAC substances, were found in over 90% of samples taken. When compared to pre-COVID dust samples, the level of QAC concentrations had nearly doubled.[28]

Chemicals Included in SAB Recommendation

Table 1: Individual DDAC Chemicals

CAS Number	Ingredient Name
7173-51-5	Didecyl dimethyl ammonium chloride
32426-11-2	1-Decanaminium, N,N-dimethyl-N-octyl-, chloride
5538-94-3	1-Octanaminium, N,N-dimethyl-N-octyl-, chloride
68607-28-3	Oxydiethylenebis(alkyl*dimethyl ammonium chloride) *(as in fatty acids of coconut oil)
61789-18-2	Alkyl* trimethyl ammonium chloride*(as in fatty acids of coconut oil)

Table 2: Individual ADBAC Chemicals

CAS Number	Ingredient Name
53516-76-0	Alkyl (60%C_{14}, 30%C_{16}, 5%C_{18}, 5%C_{12}) dimethyl benzyl ammonium chloride
68424-85-1	Alkyl (50%C_{14}, 40%C_{12}, 10%C_{16}) dimethyl benzyl ammonium chloride
8001-54-5	Alkyl (50%C_{12}, 30%C_{14}, 17%C_{16}, 3%C_{18}) dimethyl benzyl ammonium chloride
139-08-2	Alkyl (100% C_{14}) dimethyl benzyl ammonium chloride
8045-21-4	Alkyl (50%C_{12}, 30%C_{14}, 17%C_{16}, 3%C_{18}) dimethyl ethylbenzyl ammonium chloride
73049-75-9	Dialkyl (60% C_{14}, 30% C_{16}, 5% C_{18}, 5% C_{12}) methyl benzyl ammonium chloride
121-54-0	Benzenemethanaminium, N,N-dimethyl-N-(2-(2-(4 (1,1,3,3tetramethylbutyl)phenoxy)ethoxy)ethyl)-, chloride
1330-85-4	Dodecylbenzyl trimethyl ammonium chloride
68424-85-1	Alkyl (60%C_{14}, 25%C_{12}, 15%C_{16}) dimethyl benzyl ammonium chloride
61789-71-7	Alkyl (61% C_{12}, 23% C_{14}, 11% C_{16}, 2.5% C_{18}, 2.5% C_{10}, traceC_8) dimethyl benzyl ammonium chloride
68424-85-1	Alkyl (58%C_{14}, 28%C_{16}, 14%C_{12}) dimethyl benzyl ammonium chloride
85409-23-0	Alkyl (68%C_{12}, 32%C_{14}) dimethyl ethylbenzyl ammonium chloride
68956-79-6	Alkyl (60%C_{14}, 30%C_{16}, 5%C_{12}, 5%C_{18}) dimethyl ethylbenzyl ammonium chloride
68989-01-5	Alkyl (50% C_{14}, 40% C_{12}, 10% C_{16}) dimethyl benzyl ammonium saccharinate
68391-01-5	Alkyl (67%C_{12}, 25%C_{14}, 7%C_{16}, 1%C_{18}) dimethyl benzyl ammonium chloride
68424-85-1	Alkyl (95%C_{14}, 3%C_{12}, 2%C_{16}) dimethyl benzyl ammonium chloride
68391-01-5	Alkyl (41%C_{14}, 28%C_{12}, 19%C_{18}, 12%C_{16}) dimethyl benzyl ammonium chloride
63449-41-2	Alkyl (67%C_{12}, 25%C_{14}, 7%C_{16}, 1%C8, C_{10}, and C_{18}) dimethyl benzyl ammonium chloride
61789-18-2	Alkyl (as in fatty acids of coconut oil) trimethyl ammonium chloride

* Table 1 and 2 list the active ingredients listed for Group 1 and Group 2 in EPA 2017 Final Work Plans

USE INFORMATION

In the US, ADBAC and DDAC were some of the first QACs to be used as antimicrobials, registering as active ingredients under EPA's Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) in 1947 and 1962 respectively. ADBAC and DDAC are considered High Production Volume chemicals, which means more than one million pounds are manufactured or imported into the US each year. Data for the years 2011 through 2014 indicate that approximately 198 million pounds of ADBAC and 99 million pounds of DDAC are sold per year in the US.[3] QAC use increased dramatically during the pandemic, accounting for the highest revenue share of the U.S. antiseptics and disinfectants market in 2020.[29]

There are over 600 EPA-registered products that contain ADBAC as an active ingredient. DDAC is registered as the active ingredient in almost 300 antimicrobial EPA-registered products. Many DDAC and ADBAC products contain several ingredients, including other DDAC- and ADBAC-related compounds, isopropyl alcohol, glutaraldehyde, chlorine dioxide, and fragrances.

EPCRA Tier II Data

EPCRA Tier II requires reporting of any chemical with a Safety Data Sheet if it is stored at 10,000 pounds or more at a facility (or at 500 pounds or more if the chemical is designated as an extremely hazardous substance). A review of the 2021 Tier II data shows 25 records for QAC chemicals, and 10 of which fall within the category of DDAC or ADBAC. Only five of these filers are in TURA Covered SIC codes, have 10 or more employees and appear to be using over 10,000 pounds of QAC. Based upon Tier II data, approximately 40% of the QAC reporting is by TURA filers.

Additionally, a recent project with manufacturers of food products uncovered two facilities using quaternary ammonium compounds, one of which was using QAC over TURA reporting thresholds.

Given this information, and the known limitations of Tier II data, the program estimates between 5 and 10 filers.

OPPORTUNITIES FOR TUR

There are numerous alternatives to QACs for disinfecting applications, including against SARS-CoV-2 (COVID-19). These include chemical alternatives as well as non-chemical disinfecting technologies. Safer active disinfectant ingredients include hydrogen peroxide, alcohol (isopropyl alcohol or ethanol), caprylic acid, citric acid, and lactic acid. Hydrogen peroxide, ethanol, citric acid, and L-lactic acid have been evaluated by EPA's Design for the Environment (DfE) program and are considered safer active ingredients.[30] The TURI Laboratory has investigated the performance of many of these products in addition to other safer alternative disinfectants. Listed below are some of the safer active ingredients and disinfecting technologies available as alternatives to QACs. All products must be used in accordance with the manufacturer's label directions, including dilution rates and dwell time on surfaces, in order to ensure proper disinfection. See Appendix I for a summary table comparing several of the following alternatives.

CAPRYLIC ACID: Caprylic or octanoic acid is a natural agent produced by the distillation of coconut or palm kernel oils. In its pure form it is a colorless and corrosive liquid with a relative shelf life of two years. Caprylic acid is used in small percentages as the active ingredient in ready to use disinfecting products. Caprylic acid is biodegradable and considered to have low toxicity.

CITRIC ACID: Citric acid is a naturally occurring substance that can be extracted from pineapple waste and citrus fruits. It is used as an active ingredient ranging anywhere from 0.7-6% in ready to use antimicrobial products but can be corrosive in its concentrated form. It is always important to read specific product labels for effectiveness claims but many of these products are effective against a variety of microbes including H1N1, MRSA, HBV, HIV, and COVID-19.[31]

HYDROGEN PEROXIDE: Hydrogen peroxide is a clear liquid that is fairly inexpensive and is easily accessible at most stores as a dilute 3% formulation. Many of these products can have a shelf life up to two years and are effective against a broad spectrum of microbes such as H1N1, norovirus, MRSA, and the virus causing COVID-19.[32] Products that contain hydrogen peroxide as the only active ingredient are generally considered safer alternatives. However, there is evidence that hydrogen peroxide and peroxyacetic acid together are respiratory sensitizers and may cause asthma, therefore they are **not** considered safer alternatives.[33]

L-LACTIC ACID: L-Lactic acid is a naturally occurring organic acid that can be used in a variety of applications and on various surfaces as an antimicrobial solution. At the highest level of purification, lactic acid is a colorless and odorless liquid. Concentrated L-Lactic Acid is corrosive and a severe skin and eye irritant. Lactic acid is used as the active ingredient in ready to use disinfecting products ranging anywhere from 0.5-5%.

Additional alternative chemicals

In addition, other active ingredients and disinfecting technologies are useful in some circumstances.

ALCOHOLS: Alcohols such as isopropanol (IPA) and ethanol (ethyl alcohol) are clear colorless liquids in their pure form; they evaporate quickly and are best used for spot cleaning. 70% IPA is also commonly referred to as rubbing alcohol. Concentrated alcohols are flammable and exposure may cause nausea, dizziness, headache, and irritating effects to the skin, eyes, and throat. IPA and ethanol have a shelf life of roughly 2-3 years and are effective against a broad spectrum of microbes such as MRSA, HBV, HIV, H1N1, and the virus causing COVID-19.[34]

Aqueous Ozone: Aqueous ozone is a water-based sanitizer that has been used for years primarily for drinking water disinfection. Only requiring water and electricity, the solution is produced at the point of use in an ozone generator. The technology can be hard piped for large production facilities, smaller portable equipment, and handheld spray bottle devices. Aqueous ozone has a short shelf life as the ozone readily reverts back to oxygen. Ozone gas is on the TURA list of Toxic or Hazardous Substances, and chemical and inhalation exposure at high concentrations can cause respiratory irritation and exacerbate asthma.

Hypochlorous Acid: Hypochlorous acid is a chlorine solution that can be generated by dissolving concentrated sodium dichloroisocyanurate (NaDCC) tablets in water, or by using electrolyzed water systems, which use salt and, in some instances, vinegar, in water that is electrolyzed in small units. Hypochlorous acid has a short shelf life and a slightly acidic pH between 4.5 and 6.0. Chlorine solutions have inherent hazards, but TURI lab testing has found that airborne chlorine is lower for hypochlorous acid solutions than for bleach (sodium hypochlorite) solutions. For more information on hypochlorous acid, see TURI's fact sheet.

Non-chemical alternatives

Non-chemical technologies for disinfection include UV light and steam.

Steam: High temperature, low-moisture or dry steam does not leave a residue or chemical film and is effective and suitable for many surfaces. The use of a pressurized system to generate steam at a high temperature creates a risk of burns.

UV Light: UVC light may be appropriate for specific disinfecting applications. For example, it can be used to disinfect unoccupied medical rooms and high-tech electronic devices and can be used inside air ducts to disinfect the air. UV light exposure can be hazardous for the eyes and skin.

REGULATORY CONTEXT

ADBAC and DDAC are active ingredients for use in antimicrobial products registered with the U.S. EPA and other agencies around the world. These QACs are regulated under U.S. FIFRA and the European Union Biocidal Products Regulation (BPR), as well as legislation in Canada and California, among other jurisdictions.

Several of these QAC are chemicals approved for use in food contact surface sanitizing solutions under 40 CFR 180.940.[35] There are over 100 other approved sanitizers on this list. Massachusetts food manufacturing regulations, such as 105 CMR 500, reference 40 CFR 180.940.

QACs are not on the approved active ingredients list for disinfection products according to the Massachusetts Operational Services Division specification document FAC118 - Environmentally Preferable Cleaning Products, Programs, Equipment and Supplies.[36] In addition, the statewide contract for FAC114: Janitorial Services contract requires adherence to the FAC118 specifications.

IMPLICATIONS FOR THE TURA PROGRAM

This section presents the expected implications for the TURA program of adding a QAC category to the TURA list. This includes implications of category designation; implications for and applicability of TURA program services; and implications for fees and costs.

IMPLICATIONS OF CATEGORY DESIGNATION

Chemical categories are used in the TURA list in a number of cases. The TURA program's approach to categories has generally been based on the approach used under the federal Emergency Planning and Community Right-to-Know Act (EPCRA). In this case, as in some others, the category is defined using a delimited list of CAS numbers to assist the regulated community.

Defining a chemical category is appropriate in a number of circumstances, and can provide several advantages compared with listing chemicals individually. Advantages to the use of delimited chemical categories include avoiding adverse substitutions; and addressing a set of chemicals with similar health or environmental effects together. It is also appropriate when members of the category are often present as mixtures in commercial products.

- **Adverse substitutions:** One important reason to create a chemical category is to address concerns related to adverse, or "regrettable," substitutions. If a large group of chemicals that are structurally similar may potentially be used as substitutes for one another, regulating them one at a time can create unintended consequences, in which a more-regulated chemical may be replaced by an equally hazardous, less-regulated chemical. Creating a category provides clear guidance to chemical users, and helps to avoid such adverse substitutions.
- **Similar hazards across a group:** A category is also useful when a number of structurally similar chemicals have, or are reasonably anticipated to have, similar health or environmental impacts. This makes it possible to address these hazards proactively by addressing the group of chemicals together. A category is also helpful when members within a group of chemicals are manufactured or used as mixtures.

The proposed QAC category is appropriate, as a number of the chemicals may be reasonably anticipated to be used as substitutes for one another, they are commonly used in mixtures, and across the group of chemicals, and specific health and environmental impacts (e.g., respiratory effects) appear frequently.

By defining and listing a QAC category, the TURA program can efficiently address this group of chemicals. The TURA program can provide clear, proactive guidance to businesses to assist them in addressing all chemicals in the category.

TURA PROGRAM SERVICES

Both the Office of Technical Assistance (OTA) and TURI are available as a resource for new filers entering the program.

The TURI Lab has significant experience helping large and small users identify safer cleaning and disinfecting alternatives. The TURI Lab has conducted cleaning alternative testing since 1993, assisting businesses in making the transition to less toxic alternatives without compromising performance. In addition, the TURI lab has recently focused on safer alternatives for janitorial and disinfection chemicals.

TURI has an academic research grant program that can target seed funding to researchers who are developing safer alternatives to toxic chemicals for specific applications. When specific industry needs are identified, along with companies willing to share performance criteria, materials and/or other forms of expertise, TURI can identify university researchers interested in focusing their R&D efforts for solutions. If a specific application of the use of chemicals in the QAC category presents an ongoing challenge for companies with respect to shifting to safer alternatives, TURI could support R&D to find feasible solutions. Additionally, TURI business grants may be available to assist companies in implementing identified alternatives.

In addition to the TURA program's ongoing trainings for businesses, OTA provides free, confidential, onsite technical assistance to Massachusetts manufacturers, businesses, and institutions.

FEES AND PLANNING-RELATED COSTS

There would be some additional cost to companies that would begin reporting the QAC Category, including preparing annual toxics use reports and biennial toxics use reduction plans, and paying toxics use fees. All facilities currently reporting QAC under Tier II are already filing under TURA for other chemicals, so these facilities would not incur a base fee due to this listing. If they are not already paying the maximum fee, they would begin to pay an additional per-chemical fee of $1,100.

All potential filers are estimated to be current TURA filers, so additional planning costs would be modest. If there are new filers that only need to report the QAC category, the cost of hiring a planner will likely be in the range of $1,000 - $3,000. Companies that want to have their own in-house TUR planner can qualify either by relying on past work experience in toxics use reduction or by having a staff member take the TUR Planners' training course. Those facilities with experienced staff can become certified for as little as $100. For those that want staff to take a course, the cost will be between $650 - $2000, depending on whether the company has previously filed a TURA report. Companies with in-house toxics use reduction planners are likely to reap ancillary benefits from having an employee on staff who is knowledgeable about methods for reducing the costs and liabilities of toxics use. Additionally, through the process of planning and reducing or eliminating use of chemicals in the category, facilities may be able to expand their markets, better comply with other regulations and reduce their overall regulatory burden.

The total additional cost in fees to filers (and revenue to the program) could be $5,500 to $11,100 in per-chemical fees (3-6 filers for QAC). No new base fees are estimated at this time.

APPENDIX I

Comparison Chart for Hard-Surface Disinfectants Registered by the U.S. Environmental Protection Agency[37]

Disinfectants Comparison Chart (Source: infection Control Handbook for Schools)									
	AVOID		**USE WITH CAUTION**				**PREFERRED**		
Disinfectant Characteristics	**Bleach - sodium hypochlorite**	**Quaternary Ammonium Compounds – QACs or Quats**	**Thymol** (e.g. Benefect®)**	**Hydrogen Peroxide - H2O2 and Peroxyacetic Acid - PAA (e.g. Oxycide Daily Disinfectant Cleaner)**	**Hypochlorous Acid*** (e.g. Brutabs /PurTab/CDiff ViroTab Tablets)**	**Hypochlorous Acid*** (e.g. Force of Nature, Envirocleanse A)**	**Hydrogen Peroxide (e.g. Oxivir TB)**	**Ethanol (e.g. Purell Professional Surface Disinfectant)**	**Citric Acid (e.g. CleanCide and Betco GE Fight Bac- same product privately labeled)**
Status of DfE review*	Will not pass DfE screen (see below)	Will not pass DfE screen (see below)	Will not pass DfE screen (see below)	H2O2 and PAA have passed the DfE screen individually but not together (see below)	Has not been evaluated using the DfE screen (see below)	Has not been evaluated using the DfE screen (see below)	Active ingredient has passed DfE screen (see below)	This product has passed DfE screen (see below)	CleanCide has passed DfE screen (see below)
Product description	EPA-registered chlorine bleach (use only EPA-registered products for	Names of individual QACs include - Benzalkonium chloride, Alkyl dimethyl benzyl	Benefect® is an EPA registered product with natural disinfecting	Oxycide Daily is an EPA registered disinfectant/sanitizer using a combination of hydrogen peroxide and	EPA registered disinfectant and sanitizer, bleach alternative Generated from sodium dichloro-	EPA registered disinfectants, bleach alternative. Generated by a combination of salt, acid and water	EPA registered hydrogen peroxide product in synergy with a blend of commonly	EPA registered ethanol-based mixture designed to disinfect hard surfaces and sanitize soft surfaces	EPA registered disinfectants formulated for hard, nonporous surfaces

	disinfecting)	ammonium chlorides, Benzyl-C12-18-alkyldimethyl, chlorides, Didecyl dimethyl benzyl ammonium chlorides	characteristics	peroxyacetic acid Some products using this combination of active ingredients use high levels of (15% active) peroxyacetic acid	isocyanurate tablets	electrolyzed in an application device	used detergent ingredients		
CDC disinfection level*	Intermediate-level disinfectant	Low-level disinfectant	Intermediate-level disinfectant	High-level disinfectant	Low to high-level disinfectant depending on the product	Low-level disinfectant	Product-specific low- or intermediate-level disinfectant	Product-specific low- or intermediate-level disinfectant	Product-specific low- or intermediate-level disinfectant
EPA Acute toxicity category*	Category I	Category III	Category IV	Category III or IV, product specific	Category III	Category III	Category III or IV, product specific	Category IV	Category IV
Storage	If used for disinfecting purposes, bleach should not be stored longer than 3 months	Stable in storage	Stable in storage 2-year shelf life	Store concentrate in a well-ventilated place Keep container tightly closed Store away from other materials	Stable in storage Shelf life up to 5 years	Stable in storage Tablets/capsules for some products have a 3-year shelf life Read product label	Stable in storage 2-year shelf life	Stable in storage 3-year shelf life	Stable in storage

Effective-ness	Effective against most bacteria and some viruses Some products are registered as effective against the virus causing COVID-19, HIV, HBV, H1N1, MRSA, and TB Read product label for specific claims	Generally effective against a broad spectrum of microbes, including MRSA and H1N1, but typically not proven effective against spores Read product label for effectiveness against TB and the virus causing COVID-19 or check the EPA's List N	Effective against a broad spectrum of microbes including H1N1, TB, and MRSA **Benefect®** is effective against the virus causing COVID-19	Effective against a broad spectrum of microbes including C.Diff, norovirus, and the virus causing COVID–19 Read product label for specific claims	Generally effective against a broad spectrum of microbes including H1N1, MRSA, and HIV Read product label for specific claims against the virus causing COVID-19 or check the EPA's List N	Generally effective against a broad spectrum of microbes including H1N1, MRSA, and HIV Read product label for specific claims against the virus causing COVID–19 or check the EPA's List N	Effective against a broad spectrum of microbes, including H1N1, norovirus, MRSA, and the virus causing COVID-19 Read product label for specific claims, including effectiveness against TB	Effective on hard and some soft surfaces against a broad spectrum of microbes including H1N1, MRSA, and the virus causing COVID-19 Read product label for specific claim	Effective against a broad spectrum of microbes including H1N1, MRSA, HIV, and the virus causing COVID–19 Read product label for specific claims
Contact time* **For examples** *Read product labels for recommended contact times*	30 second –10 minute contact time for virus causing COVID-19	Generally 10-minute contact time for virus causing COVID-19	10-minute contact time	3 minutes for virus causing COVID–19 5 minutes for other microbes.	1 minute to 10 minutes	Generally 5-10 minute contact time	30 seconds to 10-minute contact time	30 second contact time for virus causing COVID–19	5 minute contact time for virus causing COVID–19

Health effects	Mixing with ammonia, QACs, and other acidic products can create poisonous gas[5] Corrosive to eyes and skin[6] Generates chlorine gas when in use, which is a respiratory irritant and an asthmagen ,	Can cause contact dermatitis and nasal irritation Certain QACs (including benzalkonium chloride, dodecyl-dimethyl-benzyl ammonium chloride, and lauryl dimethyl benzyl ammonium chloride) are respiratory sensitizers and associated with asthma	Skin sensitizer	"The combination of hydrogen peroxide and peroxyacetic acid (peracetic acid) has caused the initial onset of asthma in some individuals while triggering asthma symptoms in others. Avoid products that contain the combination of these ingredients." Toxics Use Reduction Institute	Mixing with ammonia, QACs, and other acidic products can create poisonous gas May cause eye, skin and respiratory irritation Generates chlorine gas, which is a respiratory irritant and an asthmagen, when in use	Mixing with ammonia, QACs, and other acidic products can create poisonous gas Force of Nature has been third-party certified by GreenSeal to meet environmental and human health criteria for safer products (See notes)	DfE has approved hydrogen peroxide as an active ingredient meeting the Safer Choice standards (See below)	DfE has certified this and other products using ethanol as the active ingredient as meeting the Safer Choice standards (See below)	DfE has certified this and other products using citric acid as the active ingredient as meeting the Safer Choice standards (See below)
Environ-mental Health Effects	Very toxic to aquatic organisms	Very toxic to aquatic organisms See the product SDS Associated with antimicrobial resistance	Toxic to aquatic organisms	Toxic to aquatic organisms	The product is considered harmful to aquatic organisms	The product is not considered harmful to aquatic organisms or to cause long-term adverse effects in the environment	Some toxicity to aquatic organisms Some products using this technology have been approved by DfE to meet environmental and human health criteria (see below)	This product has been approved by DfE to meet environmental and human health criteria (see below)	Citric acid, in the concentrations found in antimicrobial cleaning products, is not known to have any aquatic toxicity or other environmental risks.

Exposure controls*	PPE and/or increased ventilation should be used	Requires PPE and proper ventilation	No special requirements; regular ventilation is adequate	Oxycide Daily Disinfectant Cleaner requires no special protective equipment when diluted following label instructions Concentrate requires eye protection, gloves and a respirator	Requires PPE and increased ventilation	PPE and/or increased ventilation should be used for some products. Regular ventilation is adequate for others. See SDS for individual products.	No special requirements; regular ventilation is adequate	No special requirements	No protective equipment is needed under normal use conditions.
Additional disadvantages	May damage floor finishes, carpets, clothing, and other fibers when used in higher concentrations Has an unpleasant odor Must be stored separately from ammonia and flammable products	Thorough rinsing required See product label for specifics	Not widely available through vendors Strong odor	Concentrate requires special handling and storage	May cause skin irritation in some people Oxidizer	May cause skin irritation in some people Oxidizer	Rinsing is required if direct skin or oral contact can occur (e.g., children's toys)	Flammable	May be mildly irritating to skin and eyes

	Rinsing is required in applications where direct skin or oral contact can occur (e.g., children's toys)								
Advantages	Inexpensive; readily available The same product can be used for routine and special-event tasks, by changing the concentration	Readily available	Noncorrosive No rinsing or wiping required	Readily available Comes as a concentrate No rinsing required	Readily available Reduced exposure to chlorine as compared to bleach Read label for rinsing requirements	Readily available Stable source of HOCl prolongs the microbicidal effect Reduced exposure to chlorine as compared to bleach No rinsing required	Readily available Noncorrosive in diluted form; some products are odorless No rinsing required except if direct skin or oral contact can occur (e.g., children's toys)	Readily available No rinsing required	No rinsing or wiping is required, except on direct food contact surfaces or toys which require a potable water rinse after treatment

Abbreviations: CDC, Centers for Disease Control and Prevention ;; HBV, hepatitis B virus; H1N1, a subtype of influenza virus A; HIV, human immunodeficiency virus; MRSA, methicillin-resistant *Staphylococcus aureus*; SDS, Safety Data Sheet; PPE, personal protective equipment; QAC, quaternary ammonium compounds; TB, tuberculosis. (Although tuberculosis is not a common microbe found in schools, products that are registered to kill tuberculosis will inactive most microbes.)

Notes:

CDC disinfection level – The CDC defines three levels of disinfection (i.e., the use of a chemical procedure that eliminates virtually all recognized pathogenic microorganisms but not necessarily all microbial forms [e.g., bacterial endospores] on inanimate objects):

- *High-level disinfection* kills all organisms, except high levels of bacterial spores, and is effected using a chemical germicide cleared for marketing as a sterilant by the FDA. Typically not used for generalized disinfecting.

- *Intermediate-level disinfection* kills mycobacterium, most viruses, and bacteria using a chemical germicide registered as a "tuberculocide" by the EPA.
- *Low-level disinfection* kills some viruses and bacteria using a chemical germicide registered as a hospital disinfectant by the EPA.

Costs – When comparing costs, life-cycle costs must be considered. Although a product may be less expensive to buy, its negative impact on surface materials may require replacing hard surfaces more frequently, may increase worker's compensation claims, and may cause environmental damage.

Design for the Environment is a program of the **EPA's** Office of Pesticide Programs. EPA established the Design for the Environment (DfE) program for pesticide products to help consumers find products that have been reviewed by EPA and found to meet the DfE's Safer Choice standards. DfE allows qualifying antimicrobial products to carry a logo on their labels that indicates the product meets this criteria. DfE qualifying products:

- are in the least-hazardous classes (i.e., III and IV) of EPA's acute toxicity category hierarchy;
- are unlikely to have carcinogenic or endocrine disruptor properties;
- are unlikely to cause developmental, reproductive, mutagenic, or neurotoxicity issues;
- all ingredients have been reviewed, including inert ingredients;
- do not require the use of Agency-mandated personal protective equipment;
- have no unresolved or unreasonable adverse effects reported;
- have no unresolved efficacy failures (associated with the Antimicrobial Testing Program or otherwise);
- have no unresolved compliance or enforcement actions associated with it; and
- have the identical formulation as the one identified in the DfE application approved by EPA.

**Products must be submitted to DfE in order to be reviewed for approval. Some products such as those using Thymol as the active ingredient were not approved because of issues such as genotoxicity, developmental toxicity, and repeated dose toxicity endpoints.

*** Referring to products that have not been reviewed, Safer Choice notes that chemicals associated with health impacts are not allowed in products that would bear the DfE label.

Contact time – Contact time is product specific. All disinfectants are tested and labeled for the specific amount of time they must remain in contact with the surface to kill the microbes. The times listed are approximate only.

Green Seal® is a non-profit environmental standard development and certification organization. Its flagship program is the certification of products, services, restaurants, and hotels. Certification is based on Green Seal standards, which contain performance, health, and sustainability criteria.

EPA toxicity categories require the following warnings –

Signal Word	Category	On the Basis of
DANGER, POISON (skull and crossbones)	I Highly toxic	Oral, dermal, or inhalation toxicity
WARNING	II Moderately toxic	Skin or eye irritation or dermal sensitization
CAUTION	III Slightly toxic	The results of all required acute toxicity studies
CAUTION	IV Relatively nontoxic	The results of all required acute toxicity studies

Information – Sources of information include the SDS; The Toxics Use Reduction Institute (TURI)- https://www.turi.org/; Green Seal - https://greenseal.org/certified-products-services?s=+force+of+nature; Design for the Environment - https://www.epa.gov/pesticide-labels/design-environment-logo-antimicrobial-pesticide-products and product information sheets.

pH – pH is a measure of how acidic or basic a product is. Look for products with a neutral pH of 7 or as close to this number as possible.

PPE – PPE may be required for the concentrated form of some products but not for the ready-to-use or pre-diluted form. Check the label and the MSDS.

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