Quaternary Ammonium Compounds

ADBAC and DDAC FACT SHEET

What are quaternary ammonium compounds or quats?

Quaternary Ammonium Compounds (sometimes called 'quats' or 'QACs') are a category of human-made chemicals. They have a variety of uses, including controlling bacteria, viruses, and other germs on surfaces. This fact sheet will refer to quaternary ammonium compounds as quats. For a list of all unique chemicals within quats, and how they are grouped, see NPIC's page "**What are quaternary ammonium compounds?**"

photo credit: NPIC

The U.S. Environmental Protection Agency (US EPA) divides quats into four categories based on their chemical structure. This fact sheet will discuss two of the categories. One category is the didecyl dimethyl ammonium chloride (DDAC) group.[1,2] It contains five similar chemicals.[2] Another category is the alkyl dimethyl benzyl ammonium chloride (ADBAC) group.[1] This group contains 24 similar chemicals.[3] Sometimes ADBAC is called benzalkonium chloride, or BAC.[4]

Disinfectants sometimes have more than one quat in them. Researchers study ADBAC and DDAC together because they behave similarly in the body and in the environment.[5,6] This fact sheet will mostly address the DDAC and ADBAC categories. If information about the two categories is combined, this fact sheet will refer to them as "quats."

What are some products that contain quats?

Quats are used in antimicrobial **products** and are considered pesticides. These include disinfectants and sanitizers that kill bacteria and viruses on surfaces. See NPIC's fact sheet about **antimicrobials** for general information. There are over 2,000 pesticide products containing quats.[7] Quats are found in ready-to-use sprays, aerosols, wipes, wettable powders, soluble concentrates, and pressurized liquids.[2,3]

Depending on the product, quats may be used in homes, schools, medical offices, industrial sites, and on food processing equipment. Some are used to kill fungi, algae, mold, and mildew. Some products are used in swimming pools, watering lines, and industrial water systems to prevent the growth of algae and other organisms.[2,3] The first antimicrobial pesticide containing a quaternary ammonium compound was registered in 1947.[3]

Medical products and cosmetics may also contain quats. This includes prescription and over-the-counter products like lotion, topical antiseptics, and nasal sprays which are regulated by the U.S. Food and Drug Administration (FDA).[5] Even if they contain quats, medical products and cosmetics are different than antimicrobial products. Antimicrobial products are pesticides and should never be used on people. Always read and follow your product's label directions.

Technical Grade Quats: This fact sheet refers to the technical grade, or "pure" quats only. Products you buy from the store include other ingredients as well. While many of the chemicals used as other ingredients may not pose environmental or health risks, some of them can be toxic. In some cases, the other ingredients can pose greater risks than the active ingredient itself.

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How do quats work?

Quats kill germs including bacteria, viruses, and other microorganisms that could make us sick. They work by breaking open the membranes of bacteria and outer coatings of viruses. A membrane is the outside layer of a bacteria cell. Breaking the membrane causes cell death. The length of time it takes to kill germs depends on the quat and its concentration.[8,9] Some quats must touch a germ for minutes before the germ dies.[9]

How can I use quats effectively to kill germs?

Always read and follow the **label directions** when using antimicrobial products. The concentration and mixture of a specific product will affect which germs it can control. Check to make sure the types of germs you want to control are listed on your product's label. Check the label for ***contact time***. This is the amount of time a surface must stay visibly wet to kill germs. It may also be called called dwell time. Antimicrobial products are not typically meant to be sprayed in the air to kill germs.

Reducing Antimicrobial Risks

- Do not overuse antimicrobials and disinfectants. They are not meant for routine cleaning. Use soap and water for routine cleaning.
- Avoid touching wet surfaces and wash your hands after each use. Consider wearing protective gloves when using antimicrobials to reduce skin exposure.
- Reduce the amount you breathe in by ventilating the area with fresh air during and after use.
- Do not allow children to apply disinfectants including wipes.
- Follow all product instructions, including where the product can be used, and how long a surface must stay wet to be effective.
- After using a disinfectant or antimicrobial on surfaces that touch food, rinse with drinkable water.

How might I be exposed to quats?

You may be exposed to quats while using a product at work, at home, or in school. You could get it on your skin while handling disinfectant wipes or if you touch a wet surface. You might breathe in droplets if someone is spraying a product nearby. You could also get it in your eyes if there are droplets in the air, or if you accidentally touch your eyes with wet hands. You could ingest quats if you eat food that was prepared on a surface where the product was used.

Quats are not applied directly to food crops. However, some products containing quats are used to disinfect food processing equipment. They should only be used on surfaces that contact food if it is stated on the product label. The EPA has set limits for quat residues on food processing equipment.[2,3] These limits are designed to keep residue that gets on food very low.

IMPORTANT: Always **follow label instructions** and take steps to **minimize exposure**. If any exposures occur, follow the First Aid instructions on the product label carefully. For additional treatment advice, contact the Poison Control Center at 800-222-1222. If you wish to **discuss a pesticide problem**, please call NPIC at 800-858-7378.

What are some signs and symptoms from a brief exposure to quats?

If **inhaled**, quats are moderate in toxicity.[2,3]

- People who have inhaled products containing quats have reported irritation in the mouth, lungs, nose, and throat. They have also reported coughing, shortness of breath, dizziness, headache, and flu-like symptoms.[6]
- Mice that inhaled quats for 30 minutes had shallower breathing compared to unexposed mice. When exposed to higher doses of quats, they also developed more inflammatory cells in their lung fluid.[10]

If **eaten**, quats are moderate in toxicity.[2,3]

- People who have swallowed products containing quats reported irritation or burning in the mouth, nose, and throat. They also reported headache, dizziness, nausea, abdominal pain, vomiting, and excessive salivation or drooling.[6,11]
- Ingesting concentrated quats may cause ulcers of mucous membranes (like the inside of the nose, mouth, and stomach) and bloody vomit. In serious cases it may cause low blood pressure, weakness, confusion, and difficulty breathing. Death may occur within 1 to 2 hours after ingestion of concentrated quats.[12]
- Five elderly people accidentally ingested a disinfectant product containing a 10% solution of quats. One of them, an 84-year-old woman, died three hours later. She had damage to her mouth, throat, and stomach.[11]

When they get **on the skin**, quats are low in toxicity.[2,3] This means it would take a very large amount on the skin before someone became sick or died. However, quats can be severely irritating or corrosive to the skin.[2,3] The effects depend on the concentration of quats in a formula. **See the text box on Technical Grade Quats.**

- Researchers who applied ADBAC (a category of quats) to the skin of rats did not observe effects in other parts of the animals' bodies. The concentration of ADBAC used to test this was not high enough to be extremely irritating to skin.[13]
- Concentrations of 0.1-0.5% ADBAC are irritating to mucous membranes, such as the lining of the mouth and nose. Concentrations of ADBAC above 10% can damage the surface of mucous membranes.[12]
- Concentrations of 80% or more ADBAC and DDAC (categories of quats) were corrosive to the skin of rabbits.[5]
- Products with less than 10% concentration of ADBAC are irritating to the skin.[12]
- Some people who got products containing quats on their skin reported burning, irritation, rash, itching, redness, blistering, and numbness.[6]

Skin sensitization is an allergic reaction after repeated contact with a substance. Substances that cause this are called sensitizers. Regulatory agencies do not consider ADBAC and DDAC (categories of quats) to be skin sensitizers based on animal studies.[2,3,5] However, some human experiments have found sensitization after people were exposed to quats:

- When researchers applied concentrations of 0.25% DDAC to mouse skin it activated cells that can cause over-reaction (hypersensitivity) in the skin.[14]
- Workers who were exposed regularly to products containing quats have reported sensitization.[5,6,15]
- Scientists tested quats on the skin of human volunteers. In their study, 5.5% of participants aged 7-90 years tested positive for sensitization from quats. They concluded that skin sensitization from quats may be more common than previously believed.[15]
- A health care worker developed eczema after using disinfectants that included DDAC. Her skin showed a similar reaction when doctors intentionally applied DDAC to it. Her symptoms went away after she stopped using the products.[16]

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Quats can be irritating or corrosive to **eye tissue** depending on the concentration.[2,3,5]

- People who got products containing quats in their eyes have reported irritation, burning, pain, and swelling.[6]
- Concentrations of 0.1-0.5% DDAC (a category of quats) are irritating to the eyes of rabbits.[5]
- When researchers applied 80% DDAC to the eyes of rabbits, they developed severe irritation and scarring within one hour.[5]

For more information about how NPIC finds scientific studies, see our page on **Writing NPIC Fact Sheets**.

TOXICITY CLASSIFICATION - Quaternary Ammonium Compounds (ADBAC/DDAC)[2,3] (see the text box about **mg/kg**)

	High Toxicity	Moderate Toxicity	Low Toxicity	Very Low Toxicity
Acute Oral LD_{50}	≤ 50 mg/kg	> 50 – 500 mg/kg	> 500 – 5000 mg/kg	> 5000 mg/kg
Inhalation LC_{50}	≤ 0.05 mg/L	> 0.05 – 0.5 mg/L	> 0.5 – 2.0 mg/L	> 2.0 mg/L
Dermal LD_{50}	≤ 200 mg/kg	> 200 - 2000 mg/kg	> 2000 – 5000 mg/kg	> 5000 mg/kg
Primary Eye Irritation	Corrosive (irreversible destruction of ocular tissue) or corneal involvement or irritation persisting for more than 21 days	Corneal involvement or other eye irritation clearing in 8 - 21 days	Corneal involvement or other eye irritation clearing in 7 days or less	Minimal effects clearing in less than 24 hours
Primary Skin Irritation	Corrosive (tissue destruction into the dermis and/or scarring)	Severe irritation at 72 hours (severe erythema or edema)	Moderate irritation at 72 hours (moderate erythema)	Mild or slight irritation at 72 hours (no irritation or erythema)

The shaded boxes reflect the signs and symptoms from a brief exposure discussed in this fact sheet. Modeled after the U.S. Environmental Protection Agency, Office of Pesticide Programs, Label Review Manual, Chapter 7: Precautionary Statements. https://www.epa.gov/sites/default/files/2018-04/documents/chap-07-mar-2018.pdf.

You may be wondering why the "High Toxicity" column has smaller numbers than the "Low Toxicity" column. This is because if a smaller amount of the pesticide caused a health effect, it's more toxic. If it takes a larger amount of the pesticide to cause a health effect, it's less toxic.

What is a mg/kg?

"Mg/kg" is a way to measure a chemical dose. This can tell us how toxic a chemical is. "Mg" means milligrams of a chemical. "Kg" means one kilogram of an animal's body weight. Something that is highly toxic may kill a person with a very small amount of chemical. If something is very low in toxicity, it may take much more for that same person to become very sick or die. Regardless of how toxic something is, there must be an exposure for there to be harm. For more information, see the Pesticide Hazard vs. Risk Fact Sheet.

What happens to quats when they enter the body?

Small amounts of quats can pass through human **skin**.[13,17]

- When researchers applied a solution of 0.1% DDAC (a category of quats) to human skin, 9.4% penetrated the skin after 24 hours.[17]
- Researchers concluded that skin absorbs about 10% of ADBAC and DDAC (categories of quats). This is when the concentration of ADBAC or DDAC is not corrosive, meaning not concentrated enough to damage the skin.[13,17]
- One study found that single and repeated four-hour skin exposures to concentrated quats made skin more permeable. This means it was easier for chemicals to be absorbed through it. The experiment used isolated skin samples from donors.[18]

Quats are not absorbed well when **eaten**. The body quickly excretes most of the chemical.[13,17]

- Researchers expect the body to absorb 10% or less of ingested quats when the concentration of quats is not corrosive.[13,17]
- When researchers fed quats to rats, the rats' digestive systems absorbed 3-7% of the chemical.[5]
- Quats mostly stay in the digestive tract when eaten. Small amounts may get into the kidney and liver but are quickly removed.[13,17]
- In one case of a fatal poisoning, a woman who drank quats had them in her blood within three hours of drinking them.[11]
- Laboratory animals who ate quats excreted 80-90% in their feces, 3-8% in their urine, and 2-4% in their bile. They excreted most from their body within 24 to 72 hours. Both the time it took, and the amount depended on the type of quat ingested.[13,17]
- In one study, researchers found no traces of quats in the body 7 days after an exposure.[17]
- Most quats are excreted from the body unchanged.[19]

There are not many studies about absorption of quats when **inhaled**. Some researchers concluded that the size of quat particles prevents them from being absorbed by the lungs because they stay in the upper respiratory system. However, other researchers think smaller quat particles can move deeper into the lungs.[19]

Researchers tested the blood of 43 volunteers from a college campus for quats, including ADBAC and DDAC. They found that 35 of the volunteers had at least one type of quat in their blood. The amount of quats detected in volunteers' blood varied widely.[20]

Are quats likely to contribute to the development of cancer or birth defects?

The US EPA classified ADBAC (a category of quats) as not likely to cause cancer in humans. They classified DDAC (a category of quats) as non-carcinogenic in humans.[21]

Several studies on rats and mice concluded that eating quats did not increase cancer risk.[5,13,17] ADBAC and DDAC also did not cause gene mutations.[13,17]

Has anyone studied the developmental and reproductive effects of quats?

Regulatory agencies who evaluate ADBAC and DDAC (categories of quats) do not consider them reproductive or developmental toxins.[5,13,17] Although some animal experiments have found effects on development and fertility, most studies concluded that quats have no effect on development and fertility when the exposure is less than what would also make the mothers visibly sick.[5,13,17,22,23,24] There are currently no human studies about the developmental or reproductive effects of quats available.

Effects on reproduction

- Researchers force-fed female rats different amounts of ADBAC and DDAC (categories of quats) during pregnancy. They did not see any effects in the fetuses. The mother rats fed 10 or more mg/kg/day of DDAC or 30 or more mg/kg/day of ADBAC gained less weight and ate less food. They also appeared visibly sick.[5]
- Several studies looked at the effects of exposure to quats over two generations of rats. In these studies, male and female rats ate different amounts of either ADBAC or DDAC starting up to 10 weeks before they mated until the pups of their offspring were weaned. The rats that ate more quats weighed less or gained less weight and ate less food. None of the experiments found effects on reproduction.[5]
- Researchers fed rats either ADBAC or DDAC continuously in their food for two generations at doses of up to 118 mg/kg of ADBAC or 91 mg/kg of DDAC. There were no effects on the rats' survival or fertility.[24]
- Two studies tested the effects of exposure to cleaning products containing quats on mice. They kept the mice in cages cleaned with a commercial cleaning product and force-fed them the product. The researchers found declines in pregnancies and sperm counts at concentrations that also made the mice sick.[25,26] Other researchers have criticized these studies for not using rigorous, repeatable methods in their study.[22] This means that other factors besides the disinfectant exposure could have caused the results.

Effects on development

- In one experiment, pregnant rats and rabbits were fed DDAC (a category of quats) at doses that were toxic to them. They had more dead fetuses and fetuses with lower body weight than unexposed pregnant rats and rabbits.[5]
- In another experiment, feeding pregnant rats and rabbits ADBAC (a category of quats) did not lead to effects on the fetuses even when the doses fed to the mother rats and rabbits were high enough to make them visibly sick.[5]
- Scientists fed pregnant rats and rabbits ADBAC or DDAC daily for 9 days in the middle of their pregnancies. The treatments did not cause fetal malformations or affect growth or number of live fetuses in either rabbits or rats. Mothers fed ADBAC were visibly sick at doses of 30 mg/kg/day for the rabbits and 9 mg/kg/day for the rats. Mothers fed DDAC were visibly sickened by doses of 3 mg/kg/day or more for rats, and 10 mg/kg/day for rabbits.[23]

- Other scientists fed mother rats 120 mg/kg/day starting before pregnancy until they gave birth. This is considered a high dose. They found that ADBAC crossed the placenta and changed sterol and lipid levels in the developing brain.[27]

What are some other non-cancer effects of exposure to quats?

Effects when eaten

Researchers fed rats, mice, and beagle dogs quats at doses of up to 225.5 mg/kg/day for up to 90 days. At lower doses, animals lost weight and ate less food. The scientists thought this may be because quats are irritating to the stomach and mucous membranes. The animals at the highest dose died more often.[5]

Effects when inhaled

Scientists have done studies on both humans and laboratory animals to look at the effects of breathing in quats. Studies in humans looked at people who used products containing quats, like disinfectants and cleaning products. Because the products they used are mixtures of quats and other ingredients, the effects could be related to the quats, the other ingredients, or both.

- Scientists made rats inhale DDAC (a category of quat) by pumping it into their air. Depending on the study, the air concentrations ranged from 0.11 to 3.6 milligrams per cubic meter (mg/m3) of air and the exposures lasted from 2 to 13 weeks. Some of the rats weighed less, had damage to nose tissue and lung cells, had inflammation in their lungs, or had a type of inflammatory pneumonia. Specifically, the study found "interstitial pneumonia" which is a type of pneumonia not caused by an infection.[5]
- Some scientists have concluded that quats are unlikely to cause allergic reactions in the respiratory system, also known as respiratory sensitization.[13,17] However, another study reviewed cases of patients who had both occupational asthma and were exposed to quats. They intentionally exposed the patients to products containing ADBAC and DDAC, then measured their lung function. Their respiratory system and lung function showed respiratory sensitization.[28]
- Several studies found asthma was more common in workers who used cleaning products containing quats compared with workers who didn't.[29,30] Using quats also had more nasal symptoms like runny noses and sneezing.[29]
- Some nurses developed asthma or had their asthma symptoms get worse after working with products containing quats.[31,32] Workers in factories making quat products have also been affected.[33]
- The Nurses' Health Study II followed the health of thousands of female nurses over many years. One analysis of the study's data looked at nurses who had been at their jobs for many years and developed asthma. It found that nurses who developed asthma were not more likely to use quats frequently than nurses who did not develop asthma.[34]
- A second analysis of the Nurses' Health Study II looked at female nurses who already had asthma. Nurses who used quats at work did not have a harder time controlling their asthma than nurses who did not use quats at work.[34] However, female nurses who used cleaning products at work, including those with quats, had higher rates of chronic obstructive pulmonary disorder (COPD).[35]

Quats have been found at very low concentrations in breast milk. Samples were collected just prior to the COVID-19 pandemic.[36]

Are children more sensitive to quats than adults?

The US EPA has concluded that children are not more sensitive to quats than adults.[2,3] However, children may act in ways that make them more likely to be exposed. For example, they may be more likely to put their hands in their mouths after touching treated areas. Children should not apply antimicrobial sprays or use antimicrobial wipes.

What happens to quats in the environment?

Scientists expect ADBAC and DDAC (categories of quats) to biodegrade in the **environment**.[37,38] The amount of time this takes depends on the specific chemical, its concentration, and the presence of microbes.[38,39]

Air

Quats are not expected to turn into a vapor and get into the air after they have dried.[2,3]

Water

Quats dissolve well in water.[2,3]


photo credit: Gundula Vogel, pixabay

Scientists expect ADBAC (a category of quats) will typically break down before it reaches waterways.[3] However, researchers have found ADBAC present in river water downstream from wastewater treatment and pharmaceutical manufacturing sites.[40,41]

Water and light do not break down quats very effectively.[2,3] DDAC (a category of quats) breaks down in water that has oxygen. More than 70% of it broke down in 28 days.[42] The **half-life** of DDAC in flooded river water was 180 days for water with oxygen and 261 days for water without oxygen.[8] The half-life of ADBAC in water at pH 9 is 379 days, and 150-183 days at pH 5 and pH 7.[3]

Soil

The amount of time quats last in the soil depends on the compound as well as environmental conditions. DDAC (a category of quats) in sandy loam soil with microbes had a **half-life** of 1,048 days.[43] ADBAC (a category of quats) broke down in 13 days in soil with microbes.[3] In flooded sandy loam soil without air, ADBAC did not degrade well. Its half-life was 1,815 days.[37]

ADBAC and DDAC bind tightly to soil and sediment particles. This means they do not move easily through soil and should not move through soil into groundwater.[2,3,43] One study tested a variety of soils and found that higher levels of clay in soil led to more binding and reduced movement in the soil.[44]

In river soil, the half-life of quats is 11 days for non-clay soil, and 45 days for clay soil.[8]

Can quats affect birds, fish, or other wildlife?

Aquatic life

Quats are toxic to fish.[39]

- DDAC (a category of quats) is moderately to highly toxic to fish, depending on the specific chemical.[8]
- ADBAC (a category of quats) is highly toxic to fish.[3]

Scientists exposed fish (*Orzias latipes*) to the same levels of ADBAC they found in surface water near a pharmaceutical manufacturing plant. They exposed the eggs and young fish for a total of 38 days. The fish did not have changes in survival, growth, or reproduction up to concentrations of 113.4 µg/L of ADBAC. However, they did have changes in their genes that indicated ADBAC was disrupting estrogen when the fish were exposed to 3.0 µg/L ADBAC.[41] Quats bind tightly to soil and to dissolved sediment in water.[2,3] This may make them less available to fish and other aquatic life.[39,43]

ADBAC and DDAC are highly toxic to aquatic invertebrates.[3,8] Products with ADBAC and DDAC are used to kill algae, barnacles, and mollusks such as mussels.[2,3,7] Because they bind to sediment, quats may accumulate in the bodies of animals, like mussels, that filter water containing sediment.[8]

Scientists exposed water fleas (*Daphnia magna*) for 21 days to the same levels of ADBAC they found in surface water near a pharmaceutical manufacturing plant. The water fleas did not have any changes to survival, growth, or reproduction when exposed up to 10.8 µg/L of ADBAC.[41]

Terrestrial animals (birds and mammals)

Quats do not accumulate in the bodies of most animals.[8] Quats are moderately toxic when birds ingest them.[3,8] They are only slightly toxic to mammals.[3]

Bees

DDAC is low in toxicity to bees. No information was available on the toxicity of ADBAC to bees. The US EPA decided that honeybee studies done on DDAC should also apply to ADBAC.[45]

See the text box on Ecotoxicity Classifications and Honeybee Ratings.

Where can I get more information?

For more detailed information about Quaternary Ammonium Compounds (ADBAC/DDAC), call the National Pesticide Information Center, Monday - Friday, between 8:00am - 12:00pm Pacific Time (11:00am - 3:00pm Eastern Time) at 800-858-7378, or visit us on the web at **npic.orst.edu**. NPIC provides objective, science-based answers to questions about pesticides.

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ECOTOXICOLOGY CLASSIFICATION - Quaternary Ammonium Compounds (ADBAC/DDAC)[3,8,45]

	High Toxicity	Moderate Toxicity	Low Toxicity	Very Low Toxicity
Avian (single dose) Oral LD_{50}	≤ 50 mg/kg	**> 50-500 mg/kg**	> 500-2000 mg/kg	> 2000 mg/kg
Fish LC_{50}	**≤ 1 mg/L**	**> 1 - 10 mg/L**	> 10 – 100 mg/L	> 100 mg/L
Aquatic Invertebrate LC_{50}	**≤ 1 mg/L**	> 1 - 10 mg/L	> 10 – 100 mg/L	> 100 mg/L

HONEYBEE RATINGS[43]

	High Toxicity	Moderate Toxicity	Low Toxicity
Honeybee (direct contact or oral exposure) Acute LD_{50}	≤ 2 µg/bee	> 2-11 µg/bee	**> 11 µg/bee**

The shaded boxes reflect the effects on birds, fish, and other wildlife mentioned in this fact sheet. Modeled after the U.S. Environmental Protection Agency, Office of Pesticide Programs, Ecotoxicity Categories for Terrestrial and Aquatic Organisms. https://www.epa.gov/pesticide-science-and-assessing-pesticide-risks/technical-overview-ecological-risk-assessment-0

You may be wondering why the "High Toxicity" column has smaller numbers than the "Low Toxicity" column. This is because if a smaller amount of the pesticide caused a health effect, it's more toxic. If it takes a larger amount of the pesticide to cause a health effect, it's less toxic.

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