Peracetic Acid

Crops

Identification

Chemical Name(s):
Peroxyacetic Acid
Ethaneperoxic Acid

Other Names:
PAA, Per Acid, Periacetic acid

CAS Number:
79-21-0

Other Codes:
NIOSH Registry Number: SD8750000
UN/ID Number: UN3105

Summary Recommendation

Synthetic / Non-Synthetic:	Allowed or Prohibited:	Suggested Annotation:
Synthetic (consensus)	*Allowed (consensus)*	1. Allowed to disinfect equipment. Prohibited for soil (field) application. Allowed to disinfect seed and asexually propagated planting material (i.e., bulb, corm, tuber) used for planting crops. From hydrogen peroxide and fermented acetic acid sources only. *(consensus)* 2. Allowed for fireblight control with Experimental Use Permit with documentation that alternatives including biocontrols have been tried. *(1 in favor, 2 against)*

Characterization

Composition:
$C_2H_4O_3$. Peracetic acid is a mixture of acetic acid (CH_3COOH) and hydrogen peroxide (H_2O_2) in an aqueous solution. Acetic acid is the principle component of vinegar.

Properties:
Peracetic acid is a very strong oxidizing agent and has a stronger oxidation potential than chlorine or chlorine dioxide. It is a clear, colorless liquid with no foaming capability. It has a strong pungent acetic acid odor, pH is acid (2.8), specific gravity is 1.114, and weighs 9.28 pounds per gallon. Stable upon transport.

How Made:
Peracetic acid (PAA) is produced by reacting acetic acid and hydrogen peroxide. The reaction is allowed to continue for up to ten days in order to achieve high yields of product according to the following equation.

$$\underset{\text{acetic acid}}{CH_3\text{-}\overset{\overset{O}{||}}{C}\text{-}OH} + \underset{\text{hydrogen peroxide}}{H_2O_2} \longrightarrow \underset{\text{peroxyacetic acid}}{CH_3\overset{\overset{O}{||}}{C}\text{-}O\text{-}OH} + H_2O$$

The NOSB recommended that hydrogen peroxide be added to the National List of synthetic substances allowed for crop production (Austin, 1995).

Due to reaction limitations, PAA generation can be up to 15% with residual levels of hydrogen peroxide (up to 25%) and acetic acid (up to 35%) with water up to 25%. Additional methods of preparation involve the oxidation of acetaldehyde or alternatively as an end product of the reaction of acetic anhydride, hydrogen peroxide, and sulfuric acid.

Additional methods of preparation involve the oxidation of acetaldehyde (Budavari, 1996). Another method involves the reaction of tetraacetylethylenediamine (TAED) in the presence of an alkaline hydrogen peroxide solution (Davies and Deary, 1991). These sources appear to be used more frequently in pulp, paper, and textile manufacture (Pan, Spencer, and Leary, 1999).

Specific Uses:
Its major use in the food industry is as a sanitizer. Peroxyacetic acid is used to control deposits. odor, biofilms from food contact surfaces, and as a microbial control agent for both food contact surfaces and direct contact with fruits and vegetables.

Action:
The primary mode of action is oxidation. PAA disinfects by oxidizing of the outer cell membrane of vegetative bacterial cells, endospores, yeast, and mold spores. The mechanism of oxidation is the transfer of electrons, therefore the stronger the oxidizer, the faster electrons are transferred to the microorganism and the faster the microorganism is inactiviated or killed. It has also been reported to be virucidal (Arturo-Schaan, 1996).

Combinations:
Peracetic acid usually occurs with hydrogen peroxide, acetic acid, and a stabilizer in an aqueous solution. Most stabilizers used are EPA List 3 (unknown toxicity) and are not considered in this TAP review.

Status

OFPA
Falls under Production Aid (7 USC 6517(b)(1)(C)(i)).

Regulatory
EPA regular Section 3 registration (40 CFR 152.25(a)). First registered in 1985 (US EPA, 1993). Registered for indoor use only (US EPA, 1993). Some Special Local Need registrations (40 CFR 160) may have been granted for specific crops and applications (Cal-EPA, 2000).

EPA/NIEHS/Other Appropriate Sources
OFPA 6518 (l)(1) states. "In establishing the National List or proposed amendments to the National List, the Board shall review available information from the Environmental Protection Agency, the National Institute of Environmental Health Studies, and such other sources as appropriate, concerning the potential for adverse human and environmental effects of substances considered for inclusion in the proposed National List."

EPA: It is on EPA's Extremely Hazardous Substances list (US EPA, 2000). See the Re-registration Eligibility Document for Peroxy Compunds (US EPA, 1993).

NIEHS: See attachment from the National Toxicology Program.

Other sources: See New Jersey Department of Health and Senior Services attachment.

Status Among U.S. Certifiers
None appear to explicitly allow it for crop use.

Historic Use
Peracetic acid was patented in 1950 to treat fruits and vegetables to reduce spoilage from bacteria and fungi destined for processing (Greenspan and Margulies, 1950). It has since been used in systems to disinfect recirculated wash water used to handle fresh produce (Lokkesmoe and Olson, 1995). It is used to treat bulbs (Hanks and Linfield, 1999), to disinfect potting soil, clean irrigation equipment, (Larose, 1998), and in seed treatment to inactivate fungal or other types of plant disease. While there is a long history of experimental field use as a fungicide / bactericide, efficacy has only recently been established (Hei, 2000). Peracetic acid is effective at reducing *Escherichia coli* O157:H7 on apples when used in a wash and as a chemical sanitizer (Wright et al., 2000).

International
Peracetic acid does not appear on IFOAM Appendix 2 for Plant Pest and Disease Control (IFOAM, 2000). It does not appear on EU 2092/91 Annex II. Field use of this material is not allowed under any known International Organic Standards. Post-harvest application is discussed in the processing TAP review.

OFPA 2119(m) Criteria

1. *The potential of such substances for detrimental chemical interactions with other materials used in organic farming systems.*
   This material is a strong oxidizing agent. It can react violently with acetic acid anhydride, olefins (e.g., mineral oil), and organic matter (NTP, 2000).

2. *The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.*
   Toxicity high via oral for guinea pigs; moderate via oral and dermal routes for rats and rabbits (Sax, 1979). Skin and Eye Irritation Data: skin-rabbit 500 mg open SEV; eye-rabbit 1 mg SEV (NTP, 2000). An experimental neoplastinogen (tumor-causing agent) via dermal route (NTP, 2000). It is on EPA's Extremely Hazardous Substances list (US EPA, 2000).

   Peracetic acid is an irritant of the skin, eyes, mucous membranes, and respiratory tract (NTP, 2000; Budavari, 1996; Lenga, 1985). When heated to decomposition, it emits acrid smoke and toxic fumes of carbon monoxide and carbon dioxide. The vapor is heavier than air and can travel a considerable distance to a source of ignition and flash back (NTP, 2000). Breakdown products are acetic acid (same acid found in vinegar at 5% level) and hydrogen peroxide that breaks down to O_2 and H_2O.

   The primary mode of action is oxidation. with mechanism of oxidation is the transfer of electrons, therefore the stronger the oxidizer, the faster electrons are transferred to the microorganism and the faster the microorganism is inactivated or killed.

Table 1
Oxidation Capacity of Selected Sanitizers

Sanitizer	eV*
Ozone	2.07
Peracetic Acid	1.81
Chlorine dioxide	1.57
Sodium hypochlorite (chlorine bleach)	1.36
*electron-Volts	

   Therefore PAA has a higher oxidation potential than chlorine sanitizers but less than ozone.

3. *The probability of environmental contamination during manufacture, use, misuse or disposal of such substance.*
   Production from hydrogen peroxide and acetic acid would depend on the process used. Hydrogen peroxide is commonly produced by the electrolysis of water (Kirchner, 1981). Acetic acid may be produced by fermentation (vinegar) or distillation from plant sources. However, acetic acid may also be synthesized by hydrolysis of acetylene or oxidation of acetylaldehyde (Budavari, 1996). Acetylene and acetaldehyde are generally produced from petrochemical sources. The environmental consequences of petroleum production and refining are beyond the scope of this TAP review.

   Misuse in handling would cause a bleaching out effect on the color of fresh fruits and vegetables resulting in loss of quality that could be visually detected. Under normal use and disposal conditions, PAA decomposes into acetic acid, oxygen, and water.

4. *The effect of the substance on human health.*
   Peracetic acid is an irritant of the skin, eyes, mucous membranes, and respiratory tract (NTP, 2000; Budavari, 1996; Lenga, 1985). When heated to decomposition, it emits acrid smoke and toxic fumes of carbon monoxide and carbon dioxide. The vapor is heavier than air and can travel a considerable distance to a source of ignition and flash back (NTP, 2000).

   While it is not rated as a carcinogen by itself (NTP, 2000), studies indicate that it is a possible co-carcinogen, promoting tumor production by known carcinogens (Bock, Myers, and Fox, 1976, from abstract).

5. *The effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops, and livestock.*
The substance is used *because* of its biological and chemical interactions and its physiological effects on microorganisms, including many that are naturally found in a soil environment. Among the model organisms that show significant reductions in populations after exposure to PAA are *Bacillus cereus* (Blackiston et al., 1999); *B. subtilis* (Leaper, 1984; Blackiston et al., 1999; Lindsay and von Holy, 1999); *B.. stearothermophilus* (Blackiston et al., 1999); *Clostridium botulinum* (Blackiston et al., 1999); *C. butyricum* (Blackiston et al., 1999); *C. sporogenes* (Blackiston et al., 1999); *Ditylenchus dipsaci* (Hanks and Linfield, 1999); *Enterococcus faecium* (Andrade et al., 1998); *Escherichia coli* (Arturo-Schaan et al., 1996), including *E. coli* O157:H7 (Farrell et al., 1998), *Fusarium oxysporum* (Hanks and Linfield, 1999); *Gluconobacter oxydans* (Winniczuk and Parish, 1997), *Lactobacillus plantarum* (Winniczuk and Parish, 1997), *L. thermophilus* (Langeveld and Montfort-Quasig, 1996); *Leuconostoc mesenteroides* (Winniczuk and Parish, 1997); *Listeria monocytogenes* (Mosteller and Bishop, 1993; Restaino et al., 1994); *Pseudomonas aeruginosa* (Restaino et al., 1994; Lambert et al., 1999); *P. fluorescens* (Mosteller and Bishop, 1993; Lindsay and von Holy, 1999); *Saccharomyces cerevisiae*(Winniczuk and Parish, 1997); *Salmonella typhimurium* (Restaino et al., 1994); *Staphylococcus aureus* (Restaino et al., 1994; Lambert et al., 1999); *Streptococcus delbreuckii* subsp *bulgaricus* (Langeveld and Montfort-Quasig, 1996); and
Yersinia enterocolitica (Mosteller and Bishop, 1993).

The immediate effect against soil organisms would be broad-spectrum and, if mishandled, potentially violent. The toxic effects would be short-lived, and somewhat selective, favoring acid-tolerant and aerobic bacteria. For example, experimental evidence indicates that *Bacillus* spp. would likely be less affected and would recover more quickly than *Clostridium* spp. (Blackiston et al., 1999). However, at least one study indicates no difference between the susceptibility of plasmid-containing *E. coli* strains and those strains that do not contain plasmids (Arturo-Schaan, 1996). The breakdown products--oxygen, water, and acetic acid--are all part of the agroecosystem. Acetic acid is produced in nature as a function of acetobacter species of microorganism found in soil, and is part of the natural carbon cycle (Alexander, 1991).

Salt Index: The salt index has not been calculated for this substance.

Solubility: Water: 100mg/ml at 19°C. (freely soluble). Also soluble in alcohol.

6. *The alternatives to using the substance in terms of practices or other available materials.*
Organic alternatives for post-harvest handling include hot water and steam. It is an alternative to such conventional treatments as formaldehyde and thiabendazole (Hanks and Linfield, 1999).

For fireblight control: Cultural practices such as pruning and sanitation; biological controls such as *Pseudomonas fluorescens* (non-GMO); and copper products. Antibiotics such as oxytetracycline and streptomycin are registered for fireblight. The NOSB recommended that these be added to the National List (Austin, 1995).

7. *Its compatibility with a system of sustainable agriculture.*
Peracetic acid is a synthetic pesticide. As such, it is in a category that is generally considered incompatible with sustainable agriculture, with only a few exceptions. PAA's broad-spectrum nature and its tendency to oxidize organic matter make it antagonistic to organic farming systems. The short period that it has had a field use label means that there is little experience with how the material fits into organic farming systems. There are a number of reasons to think that it is compatible with a system of sustainable agriculture. Given that the compound is made from and decomposes into acetic acid and water, it appears to have a similar compatibility to those parent substances.

TAP Reviewer Discussion

TAP Reviewer Comments

OMRI's information is enclosed in square brackets in italics. Where a reviewer corrected a technical point (e.g., the word should be "intravenous" rather than "subcutaneous"), these corrections were made in this document and are not listed here in the Reviewer Comments. The rest of the TAP Reviewer's comments are listed here minus any identifying comments and with corrections of typos.

Reviewer #1

[Organic farmer and research plant pathologist]

After reviewing the documentation on Peracetic Acid I recommend that the product should be listed as Synthetic, **Allowed** as a sanitizer for disinfecting surfaces of equipment, floors, walls, and indoor processing and packaging facilities, and as a post-harvest treatment of fruits and vegetable surfaces at the lowest effective dilution possible in the literature. All treated surfaces including vegetables and fruits should be rinsed with water following the treatment. I recommend it should be **Allowed with annotation** as a microbiocide for disinfecting seed and asexually propagated planting material (i.e., bulb, corm, tuber). I recommend that it should be **Prohibited** for soil (including soil mixes) or plant application.

Justification: Peracetic Acid appears to be an effective microbiocide for disinfecting equipment, seeds, plant materials, and as a post-harvest treatment of fruits and vegetables. However, Peracetic Acid is a hazardous substance to work with and therefore protective clothing, eye gear, and respiratory equipment is required (U.S. EPA, 2000). Peracetic acid breaks down to acetic acid, water, and oxygen that naturally occur in the agroecosystem (Alexander, 1991). It has the advantage over chlorination, which can seriously damage aquatic life and the formation of chlorinated hydrocarbons with mutagenic or carcinogenic properties (Arturo-Schaan, 1996). Additionally, the microbial activity of hypochlorite is reliant on environmental factors such as the pH, temperature, organic load, and ionic concentration of the solution and may not be an effective disinfectant if conditions are not monitored closely (Wright et al., 2000). The Guide to Minimize Microbial Food Safety Hazards for Fresh Fruits and Vegetables (U.S. Dept Health and Human Services and Food and Drug Adminstration, 1998) was published as a result of President Clinton's 1997 Food Safety Initiative ("Radio Address of the President to the Nation" January 25, 1997). The guide outlines steps to decrease the probability of contaminating food and food products with food pathogens. Organic growers need to have effective microbiocides available for use in their packaging and processing operations.

Peracetic Acid should be **Allowed with annotation** as a microbiocide for disinfecting seed and asexually propagated planting materiel (i.e., bulb, corm, tuber) used for planting crops. The annotation should be that it is allowed only in cases where there are documented plant or human pathogens or pests present that can not be eliminated by hot water or temperature treatments. Such treatments should be limited to an indoor environment with ventilation systems available and proper handling procedures followed.

Peracetic Acid should be **Prohibited** for soil (including soil mixes) or plant application including use for fireblight. Its broad-spectrum, non-specific mode of action makes it incompatible to organic farming systems. Additionally, its extremely hazardous classification with potential handling, reactivity, and human exposure dangers may have greater implications in situations where the product is sprayed in an outdoor, less controlled environment. There are effective organic alternatives to disinfecting materials used in soil mixes that include heat and steam. For fireblight control cultural practices, copper products and biological control (*Pseudomonas fluorescens*) options are available. Additionally, cultivars with better resistance to the pathogen should be employed. Antibiotics such as oxytetracycline and streptomycin are registered for fireblight and were also recommended by the NOSB to be added to the National List (Austin, 1995).

I recommend that production of the product be limited to the process of obtaining hydrogen peroxide by the electrolysis of water (Kirchner, 1981), and acetic acid by fermentation or distillation from plant sources. Obtaining acetic acid synthesized by hydrolysis of acetylene or oxidation of acetyladehyde (Budavari, 1996) should be prohibited.

Reviewer #2

[Research Entomologist]

Peracetic acid is a strong, oxidizing acid that is being reviewed for possible use in organic crop production because of its antimicrobial properties. It is probably more effective as a disinfectant in aqueous solutions (Greenspan and Margulies 1950) than on biofilms (Ntsama et al. 1997) or in organic waste slurries (Bohm et al. 1983). It may be a better biocide for viruses (Quiberoni et al. 1999) and bacteria (Meyer and Meltz 1999) than it is for fungi (Colgan and Johnson 1998). Some bacteria, such as spore formers, are more resistant (Lensing and Oei 1985).

Possible crop production uses include fireblight control (Hei 2000), bulb disinfestation (Hanks and Linfield 1999; Hanks et al. 1997), as a foliar spray to control greenhouse thrips (Gill et al. 1998), as a postharvest treatment to protect fruits against rot (Brown 1987; Mari et al. 1999; Colgan and Johnson 1998), and as a seed protectant (Wilson 1976). Since it is a synthetic, it would have to be added to the National List before it is used. Although current formulations have stabilizers added, concentrated solutions still pose a problem with fire and explosion. Exposure to aerosols can irritate skin and cause respiratory damage, as explained in the analysis.

As a postharvest treatment of apples and pears, it actually caused increased damage from fungal rots (Colgan and Johnson 1998). It might be more effective for control of brown rot (*Monilinia* sp.) on stone fruit (Mari et. al. 1999). As explained below, use in soil is prohibited by the EPA label and may be counter to the principles of sustainable agriculture. Concentrated solutions would probably be needed to disinfest potting soil, and questions of human and environmental safety would have to be answered. Organic methods are already available for this purpose and for thrips control. Though it might have use as a seed protectant, bleach is more effective (Wilson 1976). Though it effectively controlled *Fusarium* sp. and nematodes in vitro, field experiments conducted with treated narcissus bulbs showed that 1-1.5% solutions did not give adequate protection unless a fungicide was added (Hanks and Linfield 1999). Presumably, this would not be possible in organic agriculture. According to Hei (2000), sprays of peracetic acid are not effective for fireblight control. However, injections into trees were effective for this purpose.

Although injections for fireblight control are promising, more data on effectiveness is needed. My recommendation is that field application of this material does not appear to be warranted at this time. Evaluation under OFPA 2119 (m) and answers to specific questions are given below.

<u>Evaluation Under OFPA 2119 (m) Criteria</u>

1. It is a strong oxidizing acid. It would reaction with materials such as pyrethrins if sprayed onto foliage. It would react violently with potting soil mixtures containing organic material. It might be phytotoxic in concentrated solution. Other interactions in processing and livestock production are outside the scope of this review.

2. The LD50 orally in rats is about 315 mg/kg (Busch and Werner 1974). It is a severe skin and respiratory irritant. A solution of 1.5%, which is about half that of peroxide purchased at the drugstore, when applied to the skin of pigs produced "signs of distress, rapid breathing, struggling, lacrimation and coughing." Reddening of the skin occurred, and after 40 days fissures and scaly crusts began to develop.

The material is not persistent in the environment, and breakdown products are benign. None of the breakdown products are xenobiotics.

The mode of action is oxidation. Electrons are removed from living tissue causing chemical changes, and probably disruption of membranes.

3. Industrial production of this material is probably through oxidation of acetaldehyde using a cobalt acetate catalyst. Another way to produce concentrated solutions is reaction of acetic anhydride, hydrogen peroxide, and sulfuric acid. It can also be made by oxidizing acetic acid in a special generator (Hei 2000). The spent cobalt catalyst would have to be discharged into a toxic waste dump. The other materials could possibly be reacted and diluted with water and discharged into waste water with a special permit.

In processing operations, misuse could cause excessive bleaching of fruits. Concentrations greater than 3% when used in treatment of organic wastes leads to massive amounts of foaming (Bohm et al. 1983). If used without proper protection, lungs and eyes of workers could be damaged. Peracetic acid is unstable and degrades quickly in the environment into water, oxygen and acetic acid. The oxygen can increase the chance of fire, and acetic acid is itself a respiratory irritant. Otherwise, the active ingredient seems to pose no threat. Stablizers and chelating agents present in the formulations should be separately evaluated. It is possible they are all approved inerts.

4. The material irritates eyes, skin and the respiratory tract. Concentrated solutions are a severe explosion risk. Unstabilized peracetic acid could explode from the friction of being pumped from the container (New Jersey Hazardous Substance Fact Sheet).

Postharvest disinfection vats of produce being treated with dilute solutions could expose workers to low levels that could cause respiratory problems and depress their immune systems (Heinze et al. 1981).

When solutions are heated just to warm water temperatures (40-60°C), heavier than air fumes are released that are flammable in air. There is a danger of fire that releases toxic fumes. If the fire flashes back to the container, an explosion could result (New Jersey Hazardous Substance Fact Sheet). Explosion and fire hazard are more probable with concentrated solutions. Also formulations registered with the EPA have stablizers added that make explosion less likely (Hei 2000).

As pointed out by the review, it is also a possible co-carcinogen.

5. The TAP review does a good job of analysing effects on soil microorganisms. The analysis seems reasonable. There is not enough published information to make a good judgement of its effect on crops. However, according to Hanks and Linfield (1999), it is not effective enough as a disinfectant in horticultural crops, and would have to be used with a chemical fungicide. Presumably, this would not be possible in an organic operation. As a postharvest sterilant for apples and pears, it actually caused increased damage from fungi (Colgan and Johnson 1998). This was possibly because it killed microbials on the surface that were antagonistic to the pathogens. Effects on livestock are not part of this review.

6. Organic alternatives for postharvest handling include steam, hot water, and treatment with biocontrol microbials. As mentioned in the TAP review, cultural controls, biocontrol, and copper is available for fireblight. Possibly, antibiotics will be added to the National List.

7. Broad spectrum soil sterilants generally do not fit in the concept of sustainable agriculture. Composts, manure, and various soil amendments are added to achieve the proper microbial balance. Pathogens can be selectively destroyed by solarization.

There is not enough information to evaluate effects on sustainable agriculture when used as a foliar spray, a seed treatment, or as a solution for injection into trees.

How it fits into processing and organic livestock production is outside the scope of this review.

Answers to Specific Questions

1. The fireblight label is relatively recent. Is it too early to tell if it should be sprayed on trees? Is that regular (Section 3), Experimental Use Permit (Section 5) or Special Local Need (Section 24 c) registration.

According to Hei (2000), topical application of the material is not that effective for fireblight control. He may be somewhat biased, as his patent is for injection into the cambium layer of trees.

If it is sprayed on trees, workers and those in the way of drift would be at risk. Inhalation of aerosols could damage lungs. Eyes could be damaged. Workers would have to use respiratory protection, eye protection, and protective clothing.

If a company wanted to register for fireblight control, it seems like the easiest thing to do would be to register with an experimental use permit, then conduct field trials to get the necessary data for a regular registration. I believe that Hei (2000) Larose and and Abbot (1998) and others conducted their experiments in greenhouses.

To register as a Special Local Need (24 c), I believe the State can apply to extend a registration for an additional use. To register there must be "an existing or imminent pest problem within a state for which the state lead agency, based upon satisfactory supporting information, has determined that an appropriate federally regisrered pesticide product is not sufficiently available." There are antibiotics already registered for fireblight control. The state must show that these are not effective before getting a 24c for this material. Also, tolerances must have already been established before this registration can be obtained. I don't know if this has been done.

For a company to register for this application, the experimental use permit followed by a regular registration would be the way to go.

It seems like it would be much easier to get a registration for injections into the trees. Then there would be less chance of environmental and health consequences.

2. It is not EPA labeled for soil application at this time. However, the label appears to allow use in potting media. Is this a correct interpretation? What should be the organic status of this use?
The label for Tsunami™ 100 does not mention disinfection of potting soil. It is labeled for dipping or spraying fruits and vegetables to disinfect them. Although I did not look at all the labels of the 21 currently registered products (EPA 2000), it seems most of them are registered for disinfection of equipment, surfaces, etc. I think the potting soil concept is a stretch. Because compost, peat, biosolids and other organic materials are present in potting soils, concentrated solutions would have to be used to be effective. Addition to potting soil would produce a violent exothermic reaction, foaming and fumes. There would be a possibility of fire.

As far as the organic status for potting soil, other alternatives such as steam and solarization are available. To use the material at all, it would have to be added to the National List. Also, it is not true that the material leaves no residue. Peracetic acid leaves no residue, but all the formulations have other material added to reduce the chance of explosion. Most of the registered formulations have surfactants added to make them more effective. Xenobiotics such as 1-hydroxethylidene-1,1-diphosphonic acid are common additives. Approved inerts would have to be used in the formulation.

3. It is not clear what applications are used by organic farmers. While there are several references to cleaning equipment— such as greenhouse and transplant tools, and irrigation installations—data and information on the OFPA criteria for use are not readily accessible in the literature.
I believe that disinfecting equipment, if done indoors, would be consistent with the EPA label and would not violate OFPA. However, I agree the published literature on this is sparse.

4. Should peracetic acid be allowed in organic crop production? Is there a need for an annotation? If so, for what? To clean equipment and for indoor uses? What about irrigation equipment? Should field uses be allowed?
I do not know if organic farmers and farmworkers can handle concentrated solutions of peracetic acid safely. If they are dealing with a more dilute, stabilized material such that fire and explosion risks are minimized, then it could be used as a replacement for bleach as a disinfectant of equipment. I believe the EPA label does not allow it to be discharged into outside irrigation lines.

It possibly has a use as a postharvest disinfectant of fruits and vegetables, but I believe that is covered in another TAP review. Similarly, uses in the organic dairy industry would probably be covered in another review.

I do not think that sprays of this material into tree foliage is a good idea. If it turns out that injection of dilute solutions into trees can stop fireblight, then it might be worth adding it to the National List for that purpose only.

I agree that field application of this material does not appear to be warranted at this time.

5. Peracetic acid does not appear on the EPA master list of inert ingredients, and is therefore List 3 by default. Should the NOSB consider its use as an inert ingredient? What about the stabilizers? Should these be considered in a separate TAP review or are they incidental when PAA is used as an inert? What about when it is used as an active.
I do not see any justification for considering the oxidizing, corrosive, flammable, and explosive PAA as an inert. It injures living material and is a biocide. What did you have in mind? I cannot think of any approved pesticide where this could be considered an inert material. The stabilizers and other additives should be evaluated as part of the approval process for this material.

[E-mail vote on these two sentences in "Suggested Annotation:" Allowed to disinfect seed and asexually propagated planting material (i.e., bulb, corm, tuber) used for planting crops. From hydrogen peroxide and fermented acetic acid sources only.] I support the position that peracetic acid should be obtained from fermented acetic acid sources and peroxide, if this is technically possible and is overall the most environmentally friendly production method. If approved for

organic production, it should be allowed for disinfecting seeds, bulbs, etc. Those who use it in this way, however, should be advised of its efficacy.

Reviewer #3

[Organic farmer and geologist with hazardous materials experience]
Production from petrochemical sources is against one of the core values of organic production, specifically the value of producing crops without dependence or reliance on the petrochemical industry. This is a farmer reaction to both the negative environmental consequences of oil production and the economic constraints of petrochemical based agricultural production. There is a viable alternative manufacturing method. Based on this information, I support Annotation #1 "manufactured from hydrogen peroxide and acetic acid sources only."

The dangerous effects are primarily to workers and NOT to consumers or the environment. Based on this information I support Annotation #2 "All organic personnel handling this material must be informed of its possible co-carcinogenic properties." As a farmer, this is the type of information I would like to have. One of its uses would be to reinforce the importance of handling the material according to specifications. I would also like to know the level of potential danger at concentrations likely to be used when to washing apples for juice or salad mix. I suggest that peracetic acid users be provided a summary of this finding (Bock, Meyers, and Fox, 1976). Any new work is done in this area that information be made available as well. This may be a responsibility put on certification agencies and or the manufacturers of the material as well as farmers.

I suggest that the statement on *[its compatibility with a system of sustainable agriculture]* could be strengthened. Given that the compound is made from and decomposes into acetic acid and water, it appears to have a similar compatibility as the parent substances, therefore PAA should be considered compatible with an organic system of sustainable agriculture.

It too early to tell if peracetic acid should be sprayed on trees. I believe it should be annotated as allowed with Experimental Use Permit after alternatives including biocontrols have been tried. (Annotation #3). Peracetic acid is not EPA labeled for soil application at this time. However the label appears to allow use in potting media. It should be allowed for use in certified indoor nurseries if needed for production of organic starts

Commercially formulated peracetic products are relatively new on the market and organic growers are only now becoming aware of them. The NOSB should consider what current applications used in organic production would the use of peracetic acid be an improvement over existing materials and practices. One area of improvement (in the sense of being more closely aligned with OFPA criteria) to look towards is its use as a method of cleaning irrigation systems, greenhouse sanitation, tools etc. Another area of improvement to consider is its use for foreseeable problems of post harvest sanitation, esp. salad mixes, fruits and root crop washes. Sanitation problems in these areas have already damaged organic markets. Part of the problem is the reluctance of organic farmers to use common sanitizers such as chlorine and ammonia, in part due to organic regulations. While there are several references to cleaning equipment such as greenhouse and transplant tools, and irrigation installations data and information on the OFPA criteria for such uses are not readily accessible in the literature.

My general understanding of applying OFPA criteria for these sanitizers is whatever is washed with a sanitizer, needs to be double or triple washed with water. In cases where the water source is not clean (which is common for ag water) this is counterproductive. In situations where food products are involved, the residual effect of the sanitizer is often needed for preservation. This material does not appear to require a wash before the surface comes into contact with organic food.

Other crops should be applied for on a crop by crop basis based on emergency crop needs. This area may need to be under the discretion of the certification agency. Peracetic acid does not appear on the EPA master list of inert ingredients, and is therefore List 3 by default. I am not aware of peracetic acid being used as an inert ingredient in any formulation. The NOSB should not consider its use as an inert ingredient. How can a material this reactive be truly inert in anything?

The stabilizers should be considered incidental. This question should stay open to new knowledge. Specifically, if a List 4 stabilizer becomes known and works well it should be allowed and products using List 3 stabilizers should be disallowed. Disinfecting washwater is very significant for organic products. It is one of the main reasons for allowing its use in organic production. Especially this section "5% acetic acid and peroxyacetic acid solutions were the most effective, causing reduction of 3.1 and 2.6 log units.respectively, without apparent sublethal injury (Wright et al., 2000)."

The conclusion that "PAA is effective, cheap, non-toxic to mammals and not harmful to the environment" places peracetic acid in the category or a synthetic that fits organic criteria. Any material that has these characteristics should be strongly considered for use in organic systems (Lagger, 1998).

Conclusion
While pre-planting, production aid, and post-harvest uses all appear consistent with OFPA and existing organic standards, field application of this material does not appear to be warranted at this time.

I believe the conclusion should include experimental use on fireblight after documented alternatives including biocontrols have been tried. The reasons for this include:

1) That this use is primarily on tree crops and fruit above the soil. It is likely to have some impact on the soil but not the same degree as a pre-planting soil drench or application to a field crop.
2) If it is permitted for post-harvest washing then why shouldn't it be allowed on the crop ten minutes earlier? If it is allowed ten minutes before eating a piece of fruit, then it should be allowed to be used two months earlier when it would be more effective at lower rates.
3) The main reason for not allowing field appliations is environmental damage to the soil. I am against allowing it as a field soil drench. There may be some value in allowing it as a drench for potted plants in certified nurseries. In many cases, especially in Hawaii and California, it may be necessary to pass agricultural regulations on transportation of soil bearing plant materials. Allowing its use in this situation could contribute to production of many more organic starts. Since the OFPA regulations call for growers to use organic starts when possible, this would increase the possibility of using organic starts instead of conventional ones for many large scale organic farms. The reasoning here is if organic starts can't be found then conventional ones are allowed for organic production, which may have much worse environmental consequences that allowing peracetic acid for this specific use.

Therefore I support Annotation #4 "Allowed for use in certified indoor nurseries if needed for production of organic starts."

The substance is SYNTHETIC
Summary Recommendation: ALLOWED
Suggested annotations:

1. Manufactured from hydrogen peroxide and acetic acid sources only
2. All organic personnel handling this material must be informed of its possible co-carcinogenic properties
3. Allowed for fireblight control with Experimental Use Permit with documentation that alternatives including biocontrols have been tried
4. Allowed for use in certified indoor nurseries if needed for production of organic starts.

Conclusion

While pre-planting, production aid, and post-harvest uses all appear consistent with OFPA and existing organic standards, field application of this material does not appear to be warranted at this time.

References

Alexander, M. 1991. *Introduction to Soil Microbiology*. Malabar, FL: Krieger Publishing Co.

Andrade, N.J., T.A. Bridgeman, and E.A. Zottola. 1998. Bacteriocidal activity of sanitizers against *Enterococcus faecium* attached to stainless steel as determined by plate count and impedance methods. *Journal of Food Protection* 61: 833-838.

Arturo-Schaan, M., F. Sauveger, C. Mamez, A. Gougeon, and M. Cormier. 1996. Use of peracetic acid as a disinfectant in a water-treatment plant: Effect on the plasmid contents of Escherichia coli strains. *Current Microbiology* 32: 43-47.

Blackistone, B., R. Chuyate, D. Kautter Jr., J. Charbonneau, and K. Suit. 1999. Efficacy of oxonia active against selected spore formers. *Journal of Food Protection* 62: 262-267. (from abstract)

Bock, F.G., H.K. Myers, And H.W. Fox 1975. Cocarcinogenic activity of peroxy compounds. *Journal of the National Cancer Institute* 55: 1359-1361.

Bohm, R., E. Britzius and D. Strauch, eds. 1983. Disinfection of slurry with peracetic acid. *Hygienic Problems of Animal Manures*: 118-129. Stuttgart: Institut fur Tiermedizin. [CAB Abstracts].

Brown, G.E. 1987. Effect of experimental bacterial disinfectants applied to oranges on postharvest decay. 1987. *Proc. Fla. State Hort. Soc.* 100:20-22.

Budavari, S. 1996. Merck Index. 12th Ed. Whitehouse Station, NJ: Merck & Co.

Busch, A. and E. Werner. 1974. Zur problematik der tiervertraglichkeit von peressigsaure. I. Unersuchungsuergbnisse nach applikation von perssigsaurehalten losungen auf die haut von schweinen. [Aspects of the animal tolerance of peracetic acid. 1. Results of the cutaneous application of peracetic acid solution to pigs.] *Monatshefte fur Veterinarmedizin* 29: 494-498.

California Environmental Protection Agency. Department of Pesticide Regulation. 2000. USEPA/OPP Pesticide Related Database. http://www.cdpr.ca.gov/docs/epa/epamenu.htm

Colgan, R.J. and D.S. Johnson. 1998. The effects of postharvest application of surface sterilizing agents on the incidence of fungal rots in stored apples and pears. *Journal of Horticultural Science and Biotechnology* 73: 361-366.

Davies, D.M. and M.E. Deary. 1991. Kinetics of the hydrolysis and perhydrolysis of tetraacetylethylenediamine, a peroxide bleach activator. *J. Chem. Soc. Perkins Trans.* 2: 1549-1552.

Ecolab. 1998. Product Label, Technical Sheet, and Material Safety Data Sheet.

Farrell, B.L., A.B. Ronner, and A.C.L. Wong. 1998 Attachment of *Escherichia coli* O157:H7 in ground beef to meat grinders and survival after sanitation with chlorine and peroxyacetic acid. *Journal of Food Protection* 61: 817-822.

Gill, S.A., R. Reeser and M.J. Raupp. 1998. Battling thrips: five pesticides put to the test. *Grower Talks* 62(8):46-48.

Greenspan, F.P. and P.H. Margulies. 1950. Treatment of raw plant tissue. US Patent 2,512,640 (Assigned to Buffalo Electro-chemical Co.)

Hanks, G.R. and C.A. Linfield. 1999. Evaluation of a peroxyacetic acid disinfectant in hot-water treatment for the control of basal rot (Fusarium oxysporum f.sp. narcissi) and stem nematode (Ditylenchus dipsaci) in narcissus. *Journal of Phytopathology* 147: 271-279.

Hei, R.D.P. 2000. Method of protecting growing plants from the effects of plant pathogens. US Patent 6,024,986 (Assigned to Ecolab, Inc.).

Heinze, W., E. Werner and A.R. Fischer. 1981. [Effect and mode of action of peracetic acid aerosols on animals.] *Monatshefte fur Veterinarmedizin*. 36(9):343-349. [CAB Abstract]

Hilgren, J. 2000. Personal Communication. Ecolab, St. Paul MN.

Kirchner, J.R. 1981. Hydrogen peroxide. *Kirk-Othmer Encyclopedia of Chemical Technology* 3rd Ed. 13: 12-38.

Lagger, J.R. 1998. El acido peracetico (PAA), desinfectante-esterilizante en frio de equipos de ordeno y de plantas lacteas. [Peracetic acid (PAA) as a low-temperature disinfectant-sterilizer of milking and milk-processing equipment.] *Veterinaria Argentina*. 15: 719-726. [CAB Abstracts]

Lambert, R.J.W., M.D. Johnston, and E.A. Simons. 1999. A kinetic study of the effect of hydrogen peroxide and peracetic acid against *Staphylococcus aureus* and *Pseudomonas aeruginosa* using the Bioscreen disinfection method. *J. Applied Microbiology* 87: 782-786.

Larose, R.N. and M.N. Abbot. 1998. Method for control of horticulture diseases, and decontamination of plant tissue. US Patent 5,723,406.

Leaper, S. 1984. Synergistic killing of spores of Bacillus subtilis by peracetic acid and alcohol. *Journal of Food Technology* 19: 355-360.

Lensing, H.H. and H.L. Oei. 1985. [Investigation on the sporicidal and fungicidal activity of disinfectants.] *Zentralblatt Bakteriologie Mikrobiologie und Hygiene*. 181:487-495. [CAB Abstracts]

Lindsay, D. and A. Von-Holy. 1999. Different responses of planktonic and attached *Bacillus subtilis* and *Pseudomonas fluorescens* to sanitizer treatment. *Journal of Food Protection* 62: 368-379.

Mari, M., T. Cembali, E. Baraldi and L. Casalini. 1999. Peracetic acid and chlorine dioxide for postharvest control of *Monilinia laxa* in stone fruits. *Plant Disease* 83(8):773-776. [CAB Abstracts]

Meyer, B. and K.D. Meltz. 1999. Neues desinfektionsmittel P3-oxysan. [P3-oxysan, a new disinfectant.] *DMZ, Lebensmittelindustrie Milchwirtschaft* 120: 882-887. [CAB Abstracts]

Ntsama, C., S. Bouttier, M. Ramaldes, F.D.-Brissonnet and J. Fourniat. 1997. Resistance of E. coli growing as biofilms to disinfectants. *Veterinary Research* 28(4):353-363. [CAB Abstracts]

Mosteller, T.M. and J.R. Bishop. 1993. Sanitizer efficacy against attached bacteria in a milk biofilm. *Journal of Food Protection* 56: 34-41.

National Toxicology Program, National Institute of Environmental Health Studies (NTP). 2000. National Toxicology Program Profile: Peroxyacetic Acid. http://ntp-server.niehs.nih.gov/

New Jersey Department of Health and Senior Services. 1998. Peroxyacetic Acid Hazardous Substance Fact Sheet. Trenton, NJ: NJDHSS.

Pan, G.X., L. Spencer, L. and G.J. Leary. 1999. Reactivity of ferulic acid and its derivatives toward hydrogen peroxide and peracetic acid. *Journal of Agricultural and Food Chemistry* 47: 3325-3331.

Park, C.M. and L.R. Beuchat. 1999. Evaluation of sanitizers for killing *Escherichia coli* O157: H7, Salmonella, and naturally occurring microorganisms on cantaloupes, honeydew melons, and asparagus. *Dairy, Food, and Environmental Sanitation* 19: 842-847.

Quiberoni, A., V.B. Suarez and J.A. Reinheimer. 1999. Inactivation of *Lactobacillus helveticus* bacteriophages by thermal and chemical treatments. *Journal of Food Protection* 62: 894-898. [CAB Abstracts]

Restaino, L. E.W. Frampton, R.L. Bluestein, J.B. Hemphill and R.R. Regutti. 1994. Antimicrobial efficacy of a new organic acid anionic surfactant against various bacterial strains. *Journal of Food Protection* 57: 496-501

Sax, N.I. 1979. *Dangerous Properties of Industrial Materials*. 5th Ed. New York: Van Nostrand Reinhold.

US Environmental Protection Agency. Office of Pesticide Programs. 1993. Peroxy compounds--Reregistration Eligibility Decision Factsheet. Washington, DC: US EPA.

US Environmental Protection Agency. 2000. Hazardous substances data bank. www.epa.gov/

U.S. EPA. 2000. Registered formulations of peracetic acid, www.cdpr.ca.gov/docs/epa/epamenu.htm

Wilson, D.O. 1976. Evaluation of chemical seed coat sterilants. *Plant and Soil* 44: 703-707. [CAB Abstracts]

Wright, J.R., S.S. Sumner, C.R. Hackney, M.D.Pierson,and B.W. Zoecklein,-B.W. 2000. Reduction of Escherichia coli O157:H7 on apples using wash and chemical sanitizer treatments. *Dairy, Food, and Environmental Sanitation* 20: 120-126.

Zeiger, E., B. Anderson B., S. Haworth, T. Lawlor, and K. Mortelmans. 1988. Salmonella mutagenicity tests. IV. Results from the testing of 300 chemicals. *Environ. Molec. Mutagen.* 11: 1-158. *[Cited by NIEHS/NTP]*

Peracetic Acid

Livestock

Identification

Chemical Name(s):
peroxyacetic acid
ethaneperoxic acid

Other Names:
PAA, per acid, periacetic acid

CAS Number:
79-21-0

Other Codes:
NIOSH Registry Number: SD8750000
TRI Chemical ID: 000079210
UN/ID Number: UN3105

Summary Recommendation

Synthetic / Non-Synthetic:	Allowed or Prohibited:	Suggested Annotation:
Synthetic (consensus)	*Allowed (consensus)*	For facility and processing equipment sanitation (barns, milking parlors, processing areas). Direct application to animals may be made only in the event of documented injuries or illnesses, under the direct supervision of a licensed veterinarian. *(consensus)* From hydrogen peroxide and fermented acetic acid sources only. *(Not discussed by livestock reviewers–see discussion of source under Crops PAA TAP review.)*

Characterization

Composition:
$C_2H_4O_3$. Peracetic acid is a mixture of acetic acid (CH_3COOH) and hydrogen peroxide (H_2O_2) in an aqueous solution. Acetic acid is the principle component of vinegar. Hydrogen peroxide has been previously recommended by the NOSB for the National List in processing (synthetic, allowed at Austin, 1995).

Properties:
It is a very strong oxidizing agent and has stronger oxidation potential than chlorine or chlorine dioxide. It is liquid, clear, and colorless with no foaming capability. It has a strong pungent acetic acid odor, pH is acid (2.8). Its specific gravity is 1.114 and weighs 9.28 pounds per gallon. Stable upon transport.

How Made:
Peracetic acid (PAA) is produced by reacting acetic acid and hydrogen peroxide. The reaction is allowed to continue for up to ten days in order to achieve high yields of product according to the following equation.

$$\underset{\text{acetic acid}}{CH_3\text{-}C(=O)\text{-}OH} + \underset{\text{hydrogen peroxide}}{H_2O_2} \longrightarrow \underset{\text{peroxyacetic acid}}{CH_3C(=O)\text{-}O\text{-}OH} + H_2O$$

Due to reaction limitations, PAA generation can be up to 15% with residual levels of hydrogen peroxide (up to 25%) and acetic acid (up to 35%) with water up to 25%. Additional methods of preparation involve the oxidation of acetaldehyde or alternatively as an end product of the reaction of acetic anhydride, hydrogen peroxide, and sulfuric acid.

Additional methods of preparation involve the oxidation of acetaldehyde (Budavari, 1996). Another method involves the reaction of tetraacetylethylenediamine (TAED) in the presence of an alkaline hydrogen peroxide solution (Davies and Deary, 1991). These sources appear to be used more frequently in pulp, paper, and textile manufacture (Pan, Spencer, and Leary, 1999).

Specific Uses:

Peracetic acid is primarily used to clean equipment, milking parlors, barns, stalls, and veterinary facilities. It is used as a topical disinfectant on animals, for example, to treat papillomatous digital dermatitis (Hernandex, Shearer, and Elliot, 1999). Peracetic acid is also used in the handling and processing of livestock products as a dairy equipment sanitizer, as a meat and poultry disinfectant (Kurschner and Diken, 1997), and as an egg wash.

Action:
The primary mode of action is oxidation. PAA disinfects by oxidizing the outer cell membrane of vegetative bacterial cells, endospores, yeast, and mold spores. (See Question 2 under OFPA criteria for more information).

Combinations:
Peracetic acid usually occurs with hydrogen peroxide and acetic acid in an aqueous solution. Stock commercial preparations usually contain a synthetic stabilizer, such as 1-hydroxyethylidene-1,1-diphosphonic acid (HEDP) or 2,6-pyridinedicarboxylic (dipicolinic) acid to slow the rate of oxidation or decomposition (Kurschner and Diken, 1997).

Status

OFPA
Falls under Production Aid and Medication (7 USC 6517(b)(1)(C)(i)).

Regulatory
External / topical use as an antimicrobial covered under EPA regular section 3 registration (40 CFR 152.25(a)). Not included separately in 21CFR for feed use, but co-products acetic acid (21 CFR 582.1005) and hydrogen peroxide (21 CFR 582.1366) are listed as FDA GRAS in animal feeds.

EPA/NIEHS/Other Appropriate Sources
OFPA 6518 (l)(1) states. "In establishing the National List or proposed amendments to the National List, the Board shall review available information from the Environmental Protection Agency, the National Institute of Environmental Health Studies, and such other sources as appropriate, concerning the potential for adverse human and environmental effects of substances considered for inclusion in the proposed National List."

EPA: It is on EPA's Extremely Hazardous Substances list (US EPA, 2000).

NIEHS: See National Institute of Environmental Health (NIEHS) attachment.

Other sources: See New Jersey Department of Health and Senior Services attachment.

Status Among U.S. Certifiers
Variable. Some appear to allow all livestock facility cleaners, equipment disinfectants, and/or animals drugs with restrictions. Others have a list of allowed materials. No standards examined explicitly allow PAA for livestock use.

Historic Use
Acetic acid and hydrogen peroxide both have a longer history of use in livestock production than commercial preparations of peracetic acid, but the substance has, in effect, been used by farmers who combine vinegar and peroxide in a cleaning solution. Peracetic acid is a relatively recent development, but has been used to clean stalls and to disinfect livestock, particularly dairy cattle.

International
Codex Alimentarius allows chemical allopathic veterinary drugs or antibiotics to be used "under the responsibility of a veterinarian" if the use of alternative methods are "unlikely to be effective in combating illness or injury." Withholding periods are required to be double of those required by law with a minimum of 48 hours (Codex, 2000). The European Union has a similar standard (EC 1999). European Commission Regulation (EC) No. 1433/96 amended Annex II of EC 2377/90 to establish maximum residue limits of peracetic acid in foodstuffs of animal origin. IFOAM allows conventional medicines "when no other justifiable alternative is available" (IFOAM, 2000).

OFPA 2119(m) Criteria

1. *The potential of such substances for detrimental chemical interactions with other materials used in organic farming systems.*
   This material is a strong oxidizing agent. It can react violently with acetic acid anhydride, olefins (e.g., mineral oil), and organic matter (NTP, 2000). PAA works synergistically with hydrogen peroxide, decreasing the amount of

hydrogen peroxide needed to reduce microorganisms (Lambert et al., 1999).

2. *The toxicity and mode of action of the substance and of its breakdown products or any contaminants, and their persistence and areas of concentration in the environment.*
Toxicity high via oral for guinea pigs; moderate via oral and dermal routes for rats and rabbits (Sax, 1979). Skin and Eye Irritation Data: skin-rabbit 500 mg open SEV; eye-rabbit 1 mg SEV (NTP, 2000). An experimental neoplastinogen (tumor-causing agent) via dermal route (NTP, 2000). It is on EPA's Extremely Hazardous Substances list (US EPA, 2000).

Peracetic acid is an irritant of the skin, eyes, mucous membranes, and respiratory tract (NTP, 2000; Budavari, 1996; Lenga, 1985). When heated to decomposition it emits acrid smoke and toxic fumes of carbon monoxide and carbon dioxide. The vapor is heavier than air and can travel a considerable distance to a source of ignition and flash back (NTP, 2000). Breakdown products are acetic acid (same acid found in vinegar at 5% level) and hydrogen peroxide that breads down to O_2 and H_2O.

The primary mode of action is oxidation. The mechanism of oxidation is the transfer of electrons, therefore the stronger the oxidizer, the faster electrons are transferred to the microorganism and the faster the microorganism is inactivated or killed.

Table 1
Oxidation Capacity of Selected Sanitizers

Sanitizer	eV*
Ozone	2.07
Peracetic Acid	1.81
Chlorine dioxide	1.57
Sodium hypochlorite (chlorine bleach)	1.36

*electron-Volts

Therefore PAA has a higher oxidation potential than chlorine sanitizers but less than ozone.

3. *The probability of environmental contamination during manufacture, use, misuse, or disposal of such substance.*
Production from hydrogen peroxide and acetic acid would depend on the process used. Hydrogen peroxide is commonly produced by the electrolysis of water (Kirchner, 1981). Acetic acid may be produced by fermentation (vinegar) or distillation from plant sources. However, acetic acid may also be synthesized by hydrolysis of acetylene or oxidation of acetylaldehyde (Budavari, 1996). Acetylene and acetaldehyde are generally produced from petrochemical sources. The environmental consequences of petroleum production and refining are beyond the scope of this TAP review.

Misuse at the processing level would cause a bleaching out effect on the color of meat and poultry, resulting in loss of quality that could be visually detected. Under normal use and disposal conditions, PAA decomposes into acetic acid, oxygen, and water.

4. *The effect of the substance on human health.*
Peracetic acid is an irritant of the skin, eyes, mucous membranes and respiratory tract (NTP, 2000; Budavari, 1996; Lenga, 1985). When heated to decomposition it emits acrid smoke and toxic fumes of carbon monoxide and carbon dioxide. The vapor is heavier than air and can travel a considerable distance to a source of ignition and flash back (NTP, 2000).

The product is registered for use as a hospital disinfectant and to clean kidney dialysis machines (EPA, 2000).

5. *The effects of the substance on biological and chemical interactions in the agroecosystem, including the physiological effects of the substance on soil organisms (including the salt index and solubility of the soil), crops and livestock.*
The substance is used *because* of its biological and chemical interactions and its physiological effects on microorganisms, including many that are naturally found in a soil environment. Among the model organisms that show significant reductions in populations after exposure to PAA are *Bacillus cereus* (Blackiston et al., 1999); *B. subtilis* (Leaper, 1984; Blackiston et al., 1999; Lindsay and von Holy, 1999); *B. stearothermophilus* (Blackiston et al., 1999); *Clostridium botulinum* (Blackiston et al., 1999); *C. butyricum* (Blackiston et al., 1999); *C. sporogenes* (Blackiston et al., 1999); *Ditylenchus dipsaci* (Hanks and Linfield, 1999); *Enterococcus faecium* (Andrade et al., 1998); *Escherichia coli* (Arturo-Schaan et al., 1996), including *E. coli* O157:H7 (Farrell et al., 1998). *Fusarium oxysporum* (Hanks and Linfield, 1999);

Gluconobacter oxydans (Winniczuk and Parish, 1997), *Lactobacillus plantarum* (Winniczuk and Parish, 1997), *L. thermophilus* (Langeveld and Montfort-Quasig, 1996); *Leuconostoc mesenteroides* (Winniczuk and Parish, 1997); *Listeria monocytogenes* (Mosteller and Bishop, 1993; Restaino et al., 1994); *Pseudomonas aeruginosa* (Restaino et al., 1994; Lambert et al., 1999); *P. fluorescens* (Mosteller and Bishop, 1993; Lindsay and von Holy, 1999); *Saccharomyces cerevisiae*(Winniczuk and Parish, 1997); *Salmonella typhimurium* (Restaino et al., 1994); *Staphylococcus aureus* (Restaino et al., 1994; Lambert et al., 1999); *Streptococcus delbreuckii* subsp *bulgaricus* (Langeveld and Montfort-Quasig, 1996); and *Yersinia enterocolitica* (Mosteller and Bishop, 1993).

The immediate effect against soil organisms would be broad-spectrum and, if mishandled, potentially violent. The toxic effects would be short-lived, and somewhat selective, favoring acid-tolerant and aerobic bacteria. For example, experimental evidence indicates that *Bacillus* spp. would likely be less affected and would recover more quickly than *Clostridium* spp. (Blackiston et al., 1999). However, at least one study indicates no difference in the susceptibility between plasmid-containing *E. coli* strains and those strains that do not contain plasmids (Arturo-Schaan, 1996). The breakdown products--oxygen, water, and acetic acid--are all part of the agroecosystem. Acetic acid is produced in nature as a function of acetobacter species of microorganism found in soil, and is part of the natural carbon cycle (Alexander, 1991).

It may be of benefit to livestock health in certain applications (Hernandez et al., 1999).

Salt Index: The salt index has not been calculated for this substance.

Solubility: Water: 100mg/ml at 19°C. (freely soluble). Also soluble in alcohol.

6. *The alternatives to using the substance in terms of practices or other available materials.*
For teat dips and udder washes, the NOSB has recommended iodine (Orlando, 1995), glycerin, chlorhexidine, and lanolin (D.C., 1999) be on the National List for livestock uses.

For cleaning stables and stalls, there is water, hydrogen peroxide, chlorine solutions, and iodine solutions.

For topical disinfection, copper compounds, hydrated lime, and iodine-based compounds can be used. PAA itself may be an alternative to topical antibiotics (Hernandez et al., 1999).

The TAP and NOSB have reviewed a number of items for crop and/or processing that are commonly used in cleaning livestock facilities. These have not been considered for livestock facilities, including soap, hydrogen peroxide, sodium carbonate, and sodium phosphates (specifically trisodium phosphate). Detergents for crops use were tabled.

7. *Its compatibility with a system of sustainable agriculture.*
Broad-spectrum synthetic biocides are generally considered incompatible with sustainable agriculture. However, proper farm sanitation and the protection of the public health from food-borne pathogens merits special consideration. Substances are needed to clean milking machines and keep livestock facilities from harboring food-borne pathogens. While sustainable systems should minimize the use of such substances, they should not be eliminated unless and until suitable alternatives are found.

TAP Reviewer Discussion

TAP Reviewer Comments

OMRI's information is enclosed in square brackets in italics. Where a reviewer corrected a technical point (e.g., the word should be "intravenous" rather than "subcutaneous"), these corrections were made in this document and are not listed here in the Reviewer Comments. The rest of the TAP Reviewer's comments are listed here minus any identifying comments and with corrections of typos.

Reviewer #1
[Analytical chemist with animal production experience.]
What is animal drug status of PAA?
Listed uses that I've been able to find so far include all aspects of sterilizing equipment and buildings in processing for all manner of produce, dairy, hog operations, etc. and, many listings for fruit, grain and vegetable dips. There are several references to PAA as a sterilant for both processing and livestock byproducts, including manures. Uses on animals

include a variety of internal uses, mostly dealing with uterine infections. So far, I haven't seen a listing for udder wash specifically, although there are several commercial products on the market that include PAA.

EPA defines PAA as an "anti-microbial pesticide" (CFR June 24, 1998). It clearly has more uses than strictly topical, so I don't think it can be defined entirely in that manner. In fact, I can see the need for listings for equipment/barn washes, topical uses, and internal uses.

From the CFR June 24, 1998, EPA declares PAA exempt from the requirement of a tolerance up to 100ppm (EPA. 1998).

[Where do we draw the line between the farm and the processor in dairies?]
With animal operations that include "byproducts" (eggs, milk), it is difficult to define where the farm stops and the processor starts. Maybe the easiest way of doing so is to define the processing as beginning "downstream" of contact with the animal. In other words, milk collection from the cows would be considered "farm", and everything downstream of that would be considered "processing". Certainly the sanitation problems change significantly at that point.

On the farm side, one deals with excreta, feed, animal disease, the animal as pathogen incubator. Once the milk is collected and removed from the presence of the animal, sanitation problems becomes more clearly that of processing (thermophyllic bacteria, mesophyllic bacteria, machine molds, lurking spores, the microherd residing in the product being processed).

The interface in dairy is less clear than in most operations, because of the processing-type equipment used in the milking parlor. However, a pretty clear line can be drawn, if the animal-containing environment is used to define "farm."

Other situations where farm/processor lines are blurred: on-farm washing operations (i.e., dirt off of carrots, stripping cabbage or lettuce and packing for shipping). On-farm drying, cooking, or other preparing operations are far more clearly on-farm processing, and the line is pretty clear between the two.

Further, the processing-type machinery in the milking parlor should be treated as processing equipment, except where it comes in contact with the cow. For instance, cleaning solutions in the teat cups should be compatible with skin contact. Again, this is the animal interface. It would seem appropriate that the rest of the equipment be cleaned by whatever approved processing cleaners necessary.

[What is the appropriate overall approach to cleaning agents on farms?]
I think that the animal contact question might be a good yes/no for farm/livestock use. In most cases, this tends to test out. There are some situations where harsher cleansers might be appropriate (for instance, broiler/layer operations where the chickens are removed and the entire building is sterilized, or periodic cleaning of milking parlors from the bottom up), because the animals are not present. In these cases, there would need to be some certainty that there'd be no residues that would come in contact with the animals when they were returned to the facility.

Areas such as processing sheds, bunkers, storage areas, barns, that come in contact with crops and/or livestock may need periodic rigorous cleanings. It would seem that more aggressive cleaning solutions could be employed during these periodic cleanings as long as all contact with produce or livestock is avoided. However, there should be either no trace cleaner residue, or the cleaner should be listed as OK for direct contact with produce/livestock.

I would agree that the currently approved materials for crops and processors (soaps and peroxide) should generally be OK for livestock. However, anything, including currently approved crops/processing materials should be looked at individually before any specific listing for livestock, due to the possibility of residues of general cleaning or from direct applications; could at the very least cause dermatitis.

[Regarding the OFPA criteria]
1. Potential of explosive reactions with organic and basic materials. Very strong irritant, will burn to third degree on contact. However, solutions are generally sold as pretty dilute solutions. I didn't actually see strong dilutions in any of the livestock products that I perused. The strong oxidizing reaction is the desirable component of this compound; this is what fries the little buggies.

2. Concentrated solution is very toxic in terms of contact, ingestion and inhalation. Irritant and burns. This would be true of undiluted cleaning solutions. There would be some hazard during the dilution process, requiring protective clothing. However, concentrations during actual use are generally very dilute.

Mode of action is strong oxidation.

3. Byproducts are water and acetic acid. Acetic acid is a "weak" acid, and occurs naturally in a variety of situations. The product is moderately unstable, and will break down pretty quickly if a stabilizer isn't included.

Direct consequences of misuse of concentrated solutions could be catastrophic; explosions, serious burns, etc. Indirect consequences are minimal, as breakdown into acetic acid and water happens rapidly.

Proper use should have minimum consequences, due to the dilute nature of the solutions, although the possibility of irritation of mucous membranes and skin is possible. Therefore, good chemical practices should be followed when using PAA.

Manufacture: Acetic acid is a "weak" organic acid; therefore, the potential for harm is significantly lower than the inorganic acids. Fermentation and distillation seem to have low environmental impacts. Hydrogen peroxide mfr seems to be moderately low impact as well. However, acetic acid from petroleum sources may be problematic. Do we need to know from which source the acetic acid comes?

4. Direct: burns, inhalation and ingestion injuries.
Indirect: breakdown products: acetic acid is an irritant, and can cause burns as well.
Minimal secondary effects, as the breakdown products are pretty benign. EPA exempts this product from requiring a tolerance up to 100 ppm.

5. Initially, a strong oxidizer. It's what it's used for. Spills could have nasty initial consequences, until oxidation reactions are complete. All microorganisms, and many "macroorganisms" would be killed outright. Organic matter would be oxidized. After that, there would be some acidification that may need neutralizing, and that would be it.
Acetic acid does occur naturally, just not at those concentrations.

6. Facility and equipment cleaning: High-pressure water, steam, mechanical removal (brushing of residues), chlorine, detergents, TSP. PAA stacks up well in terms of environmental consequences, efficacy.

Udder wash and teat dip: It looks like there are a number of organic acid (lactic, succinic)/sodium salt/glycerine products on the market that might be considered OK for organic use. Iodine and chlorhexadine alone would also be potential irritants. I don't know how they stack up in speed of kill to PAA, but PAA seems to stack up favorably with other products on the market.

Topical sanitation: hydrated lime??? This would seem to me to be really irritating! Don't use along with PAA! Seems a good alternative here, too.

7. In places where thorough sanitation is required, PAA seems to be fairly low impact. It does its job, then breaks down into pretty harmless components. Unlike many other synthetics, it doesn't leave much in the way of footprints. Its biocidal properties are "mechanical," that is, they interfere with cell wall components, rather than metabolization. There are places where broad-spectrum biocides are required, sustainable ag or not. Therefore I think that used properly, PAA can be compatible with sustainable ag.

CONCLUSION:
Peroxyacetic acid appears to be compatible with organic agriculture livestock systems including the following uses:
1. Facility sanitation (barns, milking parlors, processing areas).
2. Processing equipment sanitation (milking machines, transfer tubing, fermentation tanks, milk tanks).
3. Topical antiseptic.
4. Udder wash.
5. As a veterinarian-prescribed uterine wash for various uterine infections.
6. As an ingredient in multiple ingredient solutions for the above purposes, assuming that all of the other ingredients are approved for organic production.

Reviewer #2
[Professor of food science.]
A review of the available literature indicates that peracetic acid is a broad-spectrum biocide that appears to have efficacy as an external parasiticide with anti microbial properties. It is capable of bacteriophage in activation on dairy equipment during processing of cheese whey. Therefore, since peracetic acid is considered as a broad-spectrum disinfectant, it may be used for a number of both on farm and process sanitation-disinfecting operations.

I feel food safety is critically important both at the farm and process level. Recent outbreaks of E. coli 0157:H7 in muscle foods as well as salmonella in milk have elevated the concern of both consumers and government regulatory agencies. Therefore one must take a holistic view of both farm and process sanitizing operations. Since peracetic acid breaks down rapidly to acetic acid, hydrogen peroxide and eventually to O_2 and H_20, overall risk to organic integrity may be minimal when compared to NOSB recommendations of iodine and chlorohexidine that do not break down readily. Therefore use and application of peracetic acid may be more compatible with sustainable agriculture. The overall approach to cleaning and sanitizing agents on farms should be no different than for processors. Risk reduction of food born illness must be a priority, with a focus on maintaining organic integrity. From a sustainability issue, chlorine, phenols, quats, and chloramines pose a much greater risk to organic integrity and to the environment. For example, it is well known that chlorine sanitizers have been shown to form trihalomethane pre-carcinogens and are not used for this reason in many municipal water treatment systems in favor of ozonation. Other sanitizers such as quats, and to a certain degree iodine compounds, are residual and do not break down or are easily removed after application.

Therefore I would like to make the following recommendations:

1. Peracetic acid be approved for on farm sanitizing operations of milking machines, pipes, pumps as well as tanker trucks that haul milk from farm to processor in accordance with CFR title 21.
2. Peracetic acid be approved for direct food contact surfaces in accordance with CFR Title 21 for dairy, livestock facilities, and poultry farms.
3. Peracetic acid should be regulated or used only under the responsibility of a veterinarian to treat external microbiological infections of animals designated for slaughter or for milk producing cows.

SUMMARY

Peracetic acid appears to offer outstanding sanitizing functionality at both the farm and process level. It appears to be compatible with sustainable agriculture and may pose less of a risk to organic integrity when compared to other available sanitizers. It may be used for all on farm and process sanitizing operations in accordance with CFR title 21. Therefore I recommend an allowed (A) status.

For direct treatment of external infections of farm animals (include cows, beef cattle, poultry) its use should be restricted (R) and used only under the direct supervision of a veterinarian as per Codex Alimentarius recommendations.

Reviewer #3

[Veterinarian with substantial ovine (sheep) experience and no direct interest in the product.]

Peracetic acid is a synthetic product, is caustic topically, but is extremely germicidal due to its oxidation action. I would call it bactericidal and virucidal rather than a parasiticide.

I recommend its use as a cleaning agent in barns and in milking facilities and equipment. It appears that this compound breaks down quickly in the environment, so shouldn't be a concern even if it is expelled outdoors in the wastewater. The food safety issue is an important and since the residue appears to be minimal, I don't think there needs to be any distinction with this product whether it is used in barns or on milking equipment; whether these uses are considered farm use or processing use.

I have more of a problem with it as an animal antimicrobial. I am not sure of effectiveness, based on some of the research given. Also, if peracetic acid were to be used at a stronger level than these articles state, the irritation might be greater than the benefits of using it. NOSB has recommended several compounds for teat dips and udder washes that there is more known regarding level of irritation and toxicity. Since there isn't as much known about peracetic acid's use on animals, I have a much harder time recommending it be allowed for use on animals. If there were fewer products recommended, I would be willing to consider its use. Until there is more information about the amount of irritation when being used in farm animals, I'd recommend that it be prohibited.

[OMRI e-mailed this reviewer to ask if there is agreement on the second sentence in the suggested annotation: "Direct application to animals may be made only in the event of documented injuries or illnesses, under the direct supervision of a licensed veterinarian."] This is a GREAT annotation. I felt that to say prohibited was too strong, but wasn't sure what else I could say.

Conclusion

While organic farming is not a food safety claim, it must meet laws and standards to protect the public from risks arising from both microbiological and chemical exposures. The OFPA recognizes the need to exempt synthetic substances to clean equipment. This is an undefined area between production and handling, but is usually thought of as part of the farm by farmers, certifiers, and inspectors. As such, it would fall under the livestock standards. The NOSB has reviewed few materials for use in barns, stalls, stables, and milking parlors, leaving relatively few options for producers. While these are synthetic biocides, there are public health and safety benefits from their use that need tobe considered. Physical methods, such as steam and heat, might be more appropriate, but have their disadvantages. Peracetic acid, while synthetic, might serve a role in cleaning and disinfecting livestock facilities and equipment.

While its use as a topical disinfectant is relatively new, external use appears to have promise to alleviate animal suffering.

References

Aiello, S.E. 1998. *Merck Veterinary Manual.* 8th Ed. Whitehouse Station. NJ: Merck & Co.

Alexander, M. 1991. *Introduction to Soil Microbiology.* Malabar, FL: Krieger Publishing Co.

Andrade, N.J., T.A. Bridgeman, and E.A. Zottola. 1998. Bacteriocidal activity of sanitizers against *Enterococcus faecium* attached to stainless steel as determined by plate count and impedance methods. *Journal of Food Protection.* 61: 833-838.

Arturo-Schaan, M., F. Sauveger, C. Mamez, A. Gougeon. and M. Cormier. 1996. Use of peracetic acid as a disinfectant in a water-treatment plant: Effect on the plasmid contents of Escherichia coli strains. *Current Microbiology* 32: 43-47.

Blackistone, B.,R. Chuyate, D. Kautter Jr., J. Charbonneau, and K. Suit. 1999. Efficacy of oxonia active against selected spore formers. *Journal of Food Protection.* 62: 262-267. (from abstract)

Block, S.S. 1991. *Disinfection, Sterilization, and Preservation* 4th Ed. Philadelphia: Lea & Febiger.
Budavari, S. 1996. Merck Index 12th Ed. Whitehouse Station. NJ: Merck & Co.

Bohm, R.,E. Britzius and D. Strauch, eds. 1983. Disinfection of slurry with peracetic acid. *Hygienic Problems of Animal Manures*: 118-129. Stuttgart, Germany: Institut fur Tiermedizin. [CAB Abstracts]

Clansky, K.B., Ed. *Suspect Chemicals Sourcebook: A Guide to Industrial Chemicals Covered Under Major Federal Regulatory and Advisory Programs.* Roytech Publications, Inc. Burlingame, CA. 1990.

Clayton, G.D. and F.E. Clayton, eds. 1981. *Patty's Industrial Hygiene and Toxicology.* 3rd Ed. New York: John Wiley & Sons.

Davies, D.M. and M.E. Deary. 1991. Kinetics of the hydrolysis and perhydrolysis of tetraacetylethylenediamine, a peroxide bleach activator. *J. Chem. Soc. Perkins Trans.* 2: 1549-1552.

Ecolab. 1998. Product Label, Technical Sheet, and Material Safety Data Sheet.

Environmental Protection Agency. June 24, 1998 pp. 34302-34303. Peroxyacetic Acid; Exemption From the Requirement of a Tolerance; Correction. 40 CFR Part 180.

Farrell, B.L., A.B. Ronner, and A.C.L. Wong. 1998 Attachment of *Escherichia coli* O157:H7 in ground beef to meat grinders and survival after sanitation with chlorine and peroxyacetic acid. *Journal of Food Protection.* 61: 817-822.

Gosselin, R.E., H.C. Hodge, R.P. Smith and M.N. Gleason. 1976. *Clinical Toxicology of Commercial Products.* 4th Ed. Baltimore: Williams and Wilkins, Co.

Hanks, G.R. and C.A. Linfield. 1999. Evaluation of a peroxyacetic acid disinfectant in hot-water treatment for the control of basal rot (Fusarium oxysporum f.sp. narcissi) and stem nematode (Ditylenchus dipsaci) in narcissus. *Journal of Phytopathology* 147: 271-279.

Hawley, G.G., Ed. 1981. *Condensed Chemical Dictionary.* 10th Ed. New York: Van Nostrand Reinhold.

Heinze, W., E. Werner and A.R. Fischer. 1981. [Effect and mode of action of peracetic acid aerosols on animals.] *Monatshefte fur Veterinarmedizin.* 36: 343-349. [CAB Abstract]

Hernandez, J., J.K. Shearer, and J.B. Elliott. 1999. Comparison of topical application of oxytetracycline and four nonantibiotic solutions for treatment of papillomatous digital dermatitis in dairy cows. *Journal of the American Veterinary Medical Association* 214: 688-690.

Hilgren, J. 2000. Personal Communication. Ecolab, St. Paul MN.

Jones, M.V., Wood, M.A., and T.M.Herd. 1992. Comparative sensitivity of *Vibrio cholerae* 01 El Tor and *Escherichia coli* in disinfectants. Letters in Applied Microbiology. Volume 14. P 51-53.

Jones-MV; Johnson-MD; Herd-TM. 1991. Sensitivity of yeast vegetative cells and ascospores to biocides and environmental stress. Letters-in-Applied-Microbiology. Volume 12, No. 6. P. 254-257.

Kirchner, J.R. 1981. Hydrogen peroxide. *Kirk-Othmer Encyclopedia of Chemical Technology* Third Ed. 13: 12-38.

Kurschner, L.M. and G.M. Diken. 1997. Use of peracetic acid to sanitize processed fowl. US Patent 5,632,676 (assigned to FMC Corporation).

Lambert, R.J.W., M.D. Johnston, and E.A. Simons. 1999. A kinetic study of the effect of hydrogen peroxide and peracetic acid against *Staphylococcus aureus* and *Pseudomonas aeruginosa* using the Bioscreen disinfection method. *Journal of Applied Microbiology* 87: 782-786.

Langeveld, L.P.M. and R.M.G.E. van Montfort-Quasig. 1996. Bacteriophage inactivation and starter-inhibiting properties of a peracetic acid disinfectant. *J. Dairy Res.* 63: 649-654.

Leaper, S. 1984. Synergistic killing of spores of Bacillus subtilis by peracetic acid and alcohol. *Journal of Food Technology*. 19: 355-360.

Lenga, Robert E. 1985. *The Sigma Aldrich Library of Chemical Safety Data*. 1st Ed. Milwaukee, WI. Sigma-Aldrich Corporation.

Lindsay, D. and A. Von-Holy. 1999. Different responses of planktonic and attached *Bacillus subtilis* and *Pseudomonas fluorescens* to sanitizer treatment. *J. Food Prot* 62: 368-379.

Marriot, N *Principles of Food Plant Sanitation*. 4th Edition, 1999. Aspen Publishers, Gaithersberg, Maryland.

Mosteller, T.M. and J.R. Bishop. 1993. Sanitizer efficacy against attached bacteria in a milk biofilm. *Jornal of Food Protection*. 56: 34-41.

National Toxicology Program, National Institute of Environmental Health (NTP). 2000. National Toxicology Program Profile: Peroxyacetic Acid. http://ntp-server.niehs.nih.gov/.

New Jersey Department of Health and Senior Services. 1998. Peroxyacetic Acid Hazardous Substance Fact Sheet. Trenton, NJ: NJDHSS.

Pan, G.X., L. Spencer, L. and G.J. Leary. 1999. Reactivity of ferulic acid and its derivatives toward hydrogen peroxide and peracetic acid. *J. Agric. Food Chem.* 47: 3325-3331.

Park, C.M. and L.R. Beuchat. 1999. Evaluation of sanitizers for killing *Escherichia coli* O157: H7, Salmonella, and naturally occurring microorganisms on cantaloupes, honeydew melons, and asparagus. *Dairy, Food, and Environmental Sanitation*. 19: 842-847

Sax, N.I. 1979. *Dangerous Properties of Industrial Materials*. 5th Ed. New York: Van Nostrand Reinhold.

Taylor, D.M. 1991. Resistance of the ME7 scrapie agent to peracetic acid. *Veterinary Microbiology*. March. pp.19-24 (abstract).

US Environmental Protection Agency. 2000. Hazardous substances data bank. www.epa.gov/

US Environmental Protection Agency. Office of Pesticide Programs. 1993. Peroxy compounds--Reregistration Eligibility Decision Factsheet. Washington, DC: US EPA.

Zeiger, E., B. Anderson B., S. Haworth. T. Lawlor, and K. Mortelmans. 1988. Salmonella mutagenicity tests. IV. Results from the testing of 300 chemicals. *Environ. Molec. Mutagen.* 11: 1-158 [cited by NTP/NIEHS].

Peracetic Acid

Processing

Identification

Chemical Name(s):
peroxyacetic acid, ethaneperoxic acid

CAS Number:
79-21-0

Other Names:
per acid, periacetic acid, PAA

Other Codes:
NIOSH Registry Number: SD8750000
TRI Chemical ID: 000079210
UN/ID Number: UN3105

Summary Recommendation

Synthetic / Non-Synthetic:	Allowed or Prohibited:	Suggested Annotation:
Synthetic (consensus)	*Allowed (consensus)*	Allowed only for direct food contact for use in wash water. Allowed as a sanitizer on surfaces in contact with organic food. *(consensus)* From hydrogen peroxide and fermented acetic acid sources only. *(Not discussed by processing reviewers--see discussion of source under Crops PAA TAP review.)*

Characterization

Composition:
$C_2H_4O_3$. Peracetic acid is a mixture of acetic acid (CH_3COOH) and hydrogen peroxide (H_2O_2) in an aqueous solution. Acetic acid is the principle component of vinegar. Hydrogen peroxide has been previously recommended by the NOSB for the National List in processing (synthetic, allowed at Austin, 1995).

Properties:
It is a very strong oxidizing agent and has stronger oxidation potential than chlorine or chlorine dioxide. Liquid, clear, and colorless with no foaming capability. It has a strong pungent acetic acid odor, and the pH is acid (2.8). Specific gravity is 1.114 and weighs 9.28 pounds per gallon. Stable upon transport.

How Made:
Peracetic acid (PAA) is produced by reacting acetic acid and hydrogen peroxide. The reaction is allowed to continue for up to ten days in order to achieve high yields of product according to the following equation.

$$CH_3\text{-}C(=O)\text{-}OH + H_2O_2 \rightarrow CH_3C(=O)\text{-}O\text{-}OH + H_2O$$

acetic acid + hydrogen peroxide → peroxyacetic acid

Due to reaction limitations, PAA generation can be up to 15% with residual levels of hydrogen peroxide (up to 25%) and acetic acid (up to 35%) with water up to 25%. Additional methods of preparation involve the oxidation of acetaldehyde or alternatively as an end product of the reaction of acetic anhydride, hydrogen peroxide, and sulfuric acid.

Additional methods of preparation involve the oxidation of acetaldehyde (Budavari, 1996). Another method involves the reaction of tetraacerylethylenediamine (TAED) in the presence of an alkaline hydrogen peroxide solution (Davies and Deary, 1991). These sources appear to be used more frequently in pulp, paper, and textile manufacture (Pan, Spencer, and Leary, 1999).

Specific Uses:
Peracetic acid's primary use in food processing and handling is as a sanitizer for food contact surfaces and as a disinfectant for fruits, vegetables, meat, and eggs (Evans, 2000). PAA can also be used to disinfect recirculated flume water (Lokkesmoe and Olson, 1993). Other uses of PAA include removing deposits, suppressing odor, and stripping biofilms from food contact surfaces (Block, 1991; Mosteller and Bishop, 1993; Marriot, 1999; Fatemi and Frank 1999). It is also

used to modify food starch by mild oxidation and is used as a bleach (Food Chemicals Codex, 1996).

Action:
The primary mode of action is oxidation. PAA disinfects by oxidizing of the outer cell membrane of vegetative bacterial cells, endospores, yeast, and mold spores. The mechanism of oxidation is the transfer of electrons, therefore the stronger the oxidizer, the faster electrons are transferred to the microorganism and the faster the microorganism is inactivated or killed.

Table 1
Oxidation Capacity of Selected Sanitizers

Sanitizer	eV*
Ozone	2.07
Peracetic Acid	1.81
Chlorine dioxide	1.57
Sodium hypochlorite (chlorine bleach)	1.36

*electron-Volts

Therefore PAA has a higher oxidation potential than chlorine sanitizers but less than ozone.

PAA also inactivates enzymes that are responsible for discoloration and degradation, such as peroxidase in the browning of potatoes (Greenspan and Margulies, 1950).

Combinations:
Peracetic acid usually occurs with hydrogen peroxide and acetic acid in an aqueous solution. Stock commercial preparations usually contain a synthetic stabilizer such as 1-hydroxyethylidene-1,1-diphosphonic acid (HEDP) or 2,6-pyridinedicarboxylic (dipicolinic) acid to slow the rate of oxidation or decomposition (Kurschner and Diken, 1997). According to FDA regulations, HEDP may be used with PAA at a level not to exceed 4.8 ppm in water used to wash fresh fruits and vegetables (21 CFR 173.315(a)(5)).

Sanitizing combinations approved by 21CFR 178.1010 to be used with PAA under (b)(38) include: hydrogen peroxide; acetic acid; sulfuric acid; and 2,6-pyridinedicarboxylic (dipicolinic) acid. Under (b)(45) they include: hydrogen peroxide; acetic acid; octanoic acid; peroxyoctanoic acid; sodium 1-octanesulfonate; and 1-hydroxyethylidene-1,1-diphosphonic acid.

These stabilizers, surfactants, and synergists are not evaluated in this TAP review. Some are specifically mentioned in the context of the OFPA criteria.

Status

OFPA 7 USC 6517(b)(1)(C)(i) is listed as an equipment cleaner.

Regulatory
FDA approved it for direct food contact for use in wash water or to assist in the peeling of fruits and vegetables (21CFR 173.315). Also approved as sanitizer on food contact surfaces (21 CFR 178.1010). Registered as an EPA Section 3 pesticide (40 CFR 152.25(a)--regular registration).

Status among U.S. Certifiers
Variable. Most allow it with a fresh water rinse. Some may require continuous testing of rinse water by on-line meter. Some may allow direct food contact use at present, but many will not allow for direct food contact unless the NOSB recommends that it be included on the National List.

Historic Use
Peracetic acid was patented in 1950 to treat fruits and vegetables to reduce spoilage from bacteria and fungi destined for processing (Greenspan and Margulies, 1950). It has since been used in systems to disinfect recirculated wash water used to handle fresh produce (Lokkesmoe and Olson, 1995). Research as an alternative to chlorine and irradiation as a disinfectant for meat and poultry is relatively recent.

International
Does not appear on the IFOAM Basic Standards Appendix IV or EU 2092/91 Annex VI. It is not clear if those standards require that disinfectants need to apper: these lists are "positive" lists.

Criteria from the February 10, 1999 NOSB Meeting

A PROCESSING AID OR ADJUVANT may be used if;

1. *It cannot be produced from a natural source and has no organic ingredients as substitutes.*
   Alternatives include: fresh, clean water; rapid cooling; and reducing the time between harvest and consumption. Physical methods such as heat and steam can also be used in some situations. Other alternatives previously reviewed by the NOSB include hydrogen peroxide (synthetic, allowed at Austin 1995), chlorine bleach (synthetic, allowed at Austin 1995 and includes calcium hypochlorite, sodium hypochlorite, and chlorine dioxide), phosphoric acid (synthetic and allowed with annotation "for cleaning food contact surfaces and equipment" at D.C. 1999), and sodium hydroxide (synthetic and allowed with annotation "Prohibited for use in lye peeling of fruits and vegetables and where natural sodium bicarbonate is an acceptable substitute" at Orlando 1995). Peracetic acid is superior to hydrogen peroxide in antimicrobial activity (Evans, 2000).

2. *Its manufacture, use, and disposal do not have adverse effects on the environment and are done in a manner compatible with organic handling as described in section 6513 of the OFPA.*
   Impacts of manufacture depends on processes used. Various methods of manufacturing involve the use of acetaldehyde. Breakdown products are acetic acid (same acid found in vinegar at 5% level) and hydrogen peroxide that breads down to O_2 and H_2O. Disposal in municipal sewer system may have a positive effect due to oxidation capabilities (Arturo-Schaan et al., 1996). It is more persistant than chlorine-based disinfectants, but less so than quaternary ammonium compounds (Evans, 2000). It can have a longer residual activity than chlorine (Gruetzmacher and Bradley, 1999).

3. *If the nutritional quality of the food is maintained and the material itself or its breakdown products do not have adverse effects on human health as defined by applicable Federal regulations.*
   Limited studies have shown no significant loss of water soluble vitamins as a function of direct food contact (asserted, but not backed up by any reference journal studies). It may inhibit various dairy cultures, but this effect is short-lived (Langeveld and van Montfort-Quasig, 1996). Peracetic acid is an irritant of the skin, eyes, mucous membranes, and respiratory tract (NTP, 2000; Budavari, 1996; Lenga, 1985). When heated to decomposition it emits acrid smoke and toxic fumes of carbon monoxide and carbon dioxide. The vapor is heavier than air and can travel a considerable distance to a source of ignition and flash back (NTP, 2000).

4. *Its primary purpose is not as a preservative or used only to recreate/improve flavors, colors, textures, or nutritive value lost during processing except in the latter case as required by law.*
   Peracetic acid is approved by the FDA for sanitizing and disinfection (21 CFR 178.1005-1010). Proper disinfection of equipment and facilities can reduce the need for synthetic preservatives contained in food products (Bundgaard-Nielsen and Nielsen, 1995).

   Peracetic acid may be used with hydrogen peroxide as a bleach and to produce artificial flavors (Pan, Spencer, and Leary, 1999). For example, when used to disinfect chicken chillwater, some bleaching is observed (Kurschner and Diken, 1997). PAA is also used to modify food starch through mild oxidation (21 CFR 172.892 and Food Chemicals Codex, 1996).

5. *Is Generally Recognized as Safe (GRAS) by FDA when used in accordance with Good Manufacturing Practices (GMP), and contains no residues of heavy metals or other contaminants in excess of FDA tolerances.*
   Peracetic acid is not explicitly listed as GRAS by FDA. However, PAA arguably benefits human health by controlling food-borne pathogens (Cherry, 1999). The maximum residues for washwater used for fruits and vegetables is 80 ppm (21 CFR 173.315). The maximum residues allowed on a food contact surface are 200 ppm (21 CFR 178.1010).

6. *Its use is compatible with the principles of organic handling.*
   In comparison to other most-used sanitizers in the food industry, peracetic acid may be more compatible with organic handling than the use of halogen-based sanitizers and disinfectants such as chlorine bleach, iodine-phosphorous (iodophors), or quaternary ammonia products (quats). For example, chlorination can seriously damage aquatic life and form chlorinated hydrocarbons with carcinogenic and mutagenic properties (Arturo-Schaan et al., 1996). Quats have the longest residual activity (Block, 1991). PAA degrades rapidly, leaves little residue, and decomposes into relatively harmless naturally-occurring substances (Evans, 2000).

7. *There is no other way to produce a similar product without its use and it is used in the minimum quantity required to achieve the process.*

While there are other disinfectants and sanitizers, these are also synthetic. The efficient (minimal) use of peracetic acid as a disinfectant in a HACCP program requires constant monitoring but is technically feasible (Schultz, 1992). Minimum levels for allowed for sanitizing food contacts surfaces are established by FDA (21 CFR 178.1010(c)).

TAP Reviewer Discussion

TAP Reviewer Comments

OMRI's information is enclosed in square brackets in italics. Where a reviewer corrected a technical point (e.g., the word should be "intravenous" rather than "subcutaneous"), these corrections were made in this document and are not listed here in the Reviewer Comments. The rest of the TAP Reviewer's comments are listed here minus any identifying comments and with corrections of typos.

Reviewer #1
[Food Scientist in a research laboratory.]
Synthetic/Non: It is synthetic.

Allow or prohibit: Allowed with annotations.

Annotations:
Allow as an equipment sanitizer where organic food contacts the equipment.

Allow for direct food contact use in wash water (with a concentration limitation of maybe 100 ppm). Must be followed by a fresh water rinse.

Notes: the only concern that I have is with the added stabilizers. Are we approving peracetic acid ONLY if it doesn't contain any stabilizers? Do we need to evaluate the potential stabilizers? I was unable to find any pertinent information about the various stabilizers listed in the packet.

Annotations should be written to NOT allow use for peeling or starch modification if these are not implicitly prohibited. The notes about rinsing (when used as an equipment sanitizer) or not are still up for debate. I tend to NOT want to see sanitizer rinsed off (preferring to allow time for it to volatilize off), but I know that *[other experts want]* to see them rinsed off. I can go either way on this.

Reviewer #2
[Facility pest management expert]
Thank-you for the opportunity to participate in the Technical Advisory Panel (TAP) Review of peracetic acid. This subject is especially important because in my fieldwork in both food safety and organic certification of food products; the area of sanitizers and disinfectants is a difficult issue. Organic consumers, producers, and handlers are not only faced with concerns of appropriate materials selection for the handling and processing of organic commodities, but are responsible for controlling the incidence of potentially harmful pathogens in food products.

Opinions:

1. In the assessment of the resource materials provided and based upon personal experience in the food industry, it is the opinion of this reviewer that peracetic acid (PAA) is [by definition of the Organic Foods Production Act of 1990] a *synthetic* substance.
2. Under provision of the Organic Food Production Act of 1990, it is the opinion of this reviewer that the material PAA should be listed as an *allowed synthetic* substance with the following annotations:
    a. From hydrogen peroxide and acetic acid sources only.
    b. Allowed only for direct food contact for use in wash water. (Which should be understood to mean for use in recirculating flume water.)
    c. Allowed as a sanitizer on food contact surfaces (not requiring a rinse step after application).
3. Without additional background materials and discussions on the use of PAA in the assistance in the peeling of fruits and vegetables, this reviewer believes that this use pattern should be prohibited in organic handling practices.
4. This reviewer does not believe that the use of PAA for bleaching of food is consistent with organic handling practices.
5. Without additional background and discussion, this reviewer believes that the modification of starches with PAA should at least be temporarily prohibited.
6. This reviewer found no additional information regarding the use of PAA for the bleaching of organic cotton and has no comments on the topic at this time.

Discussion

With the implementation of the OFPA, the organic certification industry will be in an increasingly difficult position with regard to acceptable materials for food borne pathogen control. The organic industry has traditionally prohibited synthetic materials for the handling and processing of certified organic products, but has made certain allowances depending on circumstances. Under a strict rule, the available options for sanitizing are narrow and can be costly.

As stated in the materials provided by OMRI for this TAP review, there has traditionally been a mixed view amongst organic certifiers in the use of various sanitizers and disinfectants. The range of materials available does not provide a completely "perfect" organic solution. We are faced with the dilemma of allowing potential residues of synthetic sanitizers on organic products, or the use of fresh water rinses after sanitizing—which is problematic because potentially harmful pathogens can be reintroduced to food or food preparation surfaces during this step.

The use of Hazard Analysis and Critical Control Points (HACCP) as a food hazard identification and control tool requires that certain steps routinely occur to control potentially harmful conditions from occurring. Chemical sanitizers and disinfectants are critical to this management program.

It is the opinion of this reviewer that while this material is synthetic under definition of the OFPA, a reasonable and responsible position can be taken by allowing PAA in the handling and processing of certified organic commodities. This allowance is justifiable and should be provided under the auspices of food safety.

Please be advised that the original conflict of interest statement provided by this reviewer to OMRI is still applicable in all respects for this review process. I have no commercial alliances or monetary affiliations that have influenced this position.

Reviewer #3

[Consultant to organic food processors]

I agree with the summary recommendation put together by OMRI. The product is Synthetic, should be Allowed and the suggested annotations are as follows: from hydrogen peroxide and acetic acid sources only. Allowed for direct food contact for use in wash water. Allowed on surfaces in contact with organic food.

Peracetic acid seems to be a much more acceptable sanitizer than chlorine, in that it is a stronger oxidizing agent, but is less detrimental to the environment. It is an irritant in concentrated form, but appears to be relatively easy to handle in its diluted state.

A search of the literature did not turn up any information on the impact of peracetic acid on nutritional quality. I found only one reference to treatment of rice straw (Tamiguchi et al 1982).

My recommendation would be not to approve for peeling of fruits and vegetables or for bleaching of organic cotton. Those uses should be petitioned separately as this review is primarily for its disinfectant properties in food establishments and I believe we need more complete analysis of the literature and feasibility of its use for these purposes.

One concern is a reference to it ability to corrode steel, unless anti-corrosive agents are present (Boulange-Peterman et al, 1997). Would these be included in the inert ingredients in *[brand name products]*? I did not see a reference to anti-corrosion in *[a company's]* literature.

In conclusion, I agree with most of the analysis contained in the current TAP review document.

Conclusion

Organic farmers, handlers, and consumers face a dilemma with the disinfection of wash water used to handle organic food as well as to clean food contact surfaces. On the one hand, organic standards prohibit the use of synthetic biocides. On the other hand, the presence of food-borne pathogens is a concern. While organic farmers and handlers have a number of materials and methods that they can use instead of peracetic acid, these are limited in their ability to disinfect and sanitize certain types of food, equipment, and surfaces. Both acetic acid and hydrogen peroxide are produced in nature as a function of natural processes.

PAA has broad-spectrum impacts on microorganisms, is an irritant, and may cause other health problems if handled improperly. However, if proper safety precautions are taken, then PAA is no worse than the principle alternative chemical sanitizers and disinfectants previously recommended to be included on the National List.

Some bleaching or discoloration may occur as a part of the normal disinfection application. However, the use of PAA to intentionally bleach food would not be compatible with organic principles.

References

Anonymous. 1999. Alternatives to chlorine. *Food Review*. 26: 36ff.

Arturo-Schaan, M., F. Sauveger, C. Mamez, A. Gougeon, and M. Cormier. 1996. Use of peracetic acid as a disinfectant in a water-treatment plant: Effect on the plasmid contents of Escherichia coli strains. *Current Microbiology* 32: 43-47.

Block, S.S. 1991. *Disinfection, Sterilization, and Preservation* 4th Ed. Philadelphia: Lea & Febiger.

Boulange-Petermann, L., I. Tireau, F. Bourion, and B. Baroux. 1997. Corrosiveness of cleaning products on stainless steel: peracetic acid and quaternary ammonium chloride. *Industries Alimentaires et Agricoles*. December, 114 (12), 838-843 (24 ref.).

Budavari, S. 1996. *Merck Index*. Whitehouse Station, NJ: Merck and Co.

Bundgaard-Nielsen, K. and P.V. Nielsen. 1995. Fungicidal effect of 15 disinfectants against 25 fungal contaminants commonly found in bread and cheese manufacturing. *Journal of Food Protection*. 59: 268-275.

Cherry, J.P. 1999. Improving the safety of fresh produce with antimicrobials. *Food Technology*. 53: 54ff.

Colgan, R.J. and D.S. Johnson. 1998. The effects of postharvest application of surface sterilizing agents on the incidence of fungal rots in stored apples and pears. *Journal of Horticultural Science and Biotechnology*. 73: 361-366.

Davies, D.M. and M.E. Deary. 1991. Kinetics of the hydrolysis and perhydrolysis of tetraacetylethylenediamine, a peroxide bleach activator. *J. Chem. Soc. Perkins Trans.* 2: 1549-1552.

Ecolab. 1998. Product Label, Technical Sheet, and Material Safety Data Sheet.

Evans, D.A. 2000. Disinfectants. *Wiley Encyclopedia of Food Science and Technology* 1: 501-509.

Fatemi, P. and J.F. Frank. 1999. Inactivation of *Listeria monocytogenes/ Pseudomonas* biofilms by peracid sanitizers. *Journal of Food Protection*. 62: 761-765.

Greenspan, F.P. and P.H. Margulies. 1950. Treatment of raw plant tissue. US Patent 2,512,640 (Assigned to Buffalo Electro-chemical Co.)

Gruetzmacher, T.J. and R.L. Bradley, Jr. 1999. Identification and control of processing variables that affect the quality and safety of fluid milk. *Journal of Food Protection*. 62: 625-631.

Katsuyama, A.M. 1993. *Principles of Food Processing Sanitation*. Washington, DC: Food Processors Institute.

Kurschner, L.M. and G.M. Diken. 1997. Use of peracetic acid to sanitize processed fowl. US Patent 5,632,676 (assigned to FMC Corporation).

Lambert, R.J.W., M.D. Johnston, and E.A. Simons. 1999. A kinetic study of the effect of hydrogen peroxide and peracetic acid against *Staphylococcus aureus* and *Pseudomonas aeruginosa* using the Bioscreen disinfection method. *Journal of Applied Microbiology* 87: 782-786.

Langeveld, L.P.M. and R.M.G.E. van Montfort-Quasig. 1996. Bacteriophage inactivation and starter-inhibiting properties of a peracetic acid disinfectant. *Journal of Dairy Research.* 63: 649-654.

Lenga, Robert E. 1985. *The Sigma-Aldrich Library of Chemical Safety Data.* 1st Ed. Milwaukee, WI. Sigma-Aldrich Corporation.

Lokkesmoe, K. and K. Olson. 1993. Process for inhibition of microbial growth in aqueous transport streams. US Patent 5,409,713 (Assigned to Ecolab, Inc.)

Marriot, N. *Principles of Food Plant Sanitation*, 4th Edition, 1999. Aspen Publishers, Gaithersberg, Maryland.

Meyer, B. 2000. A modern approach to disinfection in food establishments. German journal article abstract.

Meyer, B. and T. Thyborski. 1999. New disinfection materials for use in the food industry. German journal article abstract.

Mosteller, T.M. and J.R. Bishop. 1993. Sanitizer efficacy against attached bacteria in a milk biofilm. *Journal of Food Protection.* 56: 34-41.

National Academy of Sciences. 1996. *Food Chemicals Codex.* 4th Ed. Washington, DC: National Academy Press.

National Toxicology Program. 2000.

New Jersey Department of Health and Senior Services. 1998. Peroxyacetic Acid Hazardous Substance Fact Sheet. Trenton, NJ: NJDHSS.

Pan, G.X., L. Spencer, L. and G.J. Leary. 1999. Reactivity of ferulic acid and its derivatives toward hydrogen peroxide and peracetic acid. *Journal of Agricultural Food Chemicals.* 47: 3325-3331.

Restaino, L. E.W. Frampton, R.L. Bluestein, J.B. Hemphill and R.R. Regutti. 1994. Antimicrobial efficacy of a new organic acid anionic surfactant against various bacterial strains. *Journal of Food Protection.* 57: 496-501.

Sax, N.I. 1979. *Dangerous Properties of Industrial Materials.* 5th Ed. New York: Van Nostrand Reinhold.

Schultz, G. 1992. Kemikalier for rengöring och desinfektion. [Chemical compounds for cleaning and disinfection--Swedish]. *Livsmedelsteknik* 34(11) 18-19.

Tamiguchi, M., M. Tanka, R. Matsuno, and T. Kamikubo. 1982. Evaluation of Chemical Pre-treatment for Enzymatic Solubilization of Rice Straw. *Journal of Applied Microbiological Biotechnology.* Vol. 14 Number 1, pp. 35-39.

Wisniewsky, M.A., B.A. Glatz, M.L. Gleason, and C.A. 2000. Reitmeier. Reduction of Escherichia coli O157:H7 counts on whole fresh apples by treatment with sanitizers. *Journal of Food Protection.* Volume 63, Number 6, pp. 703-708.

Zeiger, E., B. Anderson B., S. Haworth, T. Lawlor, and K. Mortelmans. 1988. Salmonella mutagenicity tests. IV. Results from the testing of 300 chemicals. *Environ. Molec. Mutagen.* 11: 1-158.