

Product Evaluation – WaterSavr™

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APPENDIX A - NSF International Certification

Introduction

WaterSavr™ is a commercial product that is intended to reduce free water surface evaporation. A finely granulated powder, it is marketed as being suitable for applying to:

- Drinking water reservoirs (raw water supply)
- Potable water storage reservoirs
- Aqueducts and canals
- Agricultural irrigation canals and ditches
- Flood water crops (such as rice)
- Stock watering ponds
- Other water stands or runs without rapids that require evaporation reduction

Because this product is intended for use in drinking water sources, potable water storage, agriculture, and aquaculture, it (and its component constituents) should be evaluated for potential environmental, health, and ecological impacts.

At the request of Mr. Mike Stover, Director of Operations for WaterSavr Global Solutions, Inc., a Division of Flexible Solutions International Ltd., McGuire Environmental Consultants, Inc. (MEC) was contracted to:

1. Conduct a literature review of the chemical constituents comprising the product and determine possible associated health or environmental impacts/hazards.
2. Conduct a literature review of potential impacts of the WaterSavr™ product on various drinking water treatment processes.
3. Conduct a Flavor Profile Analysis of WaterSavr™ treated water to assess potential aesthetic impacts of the product on potable water sources.
4. Assay the potential environmental impact of the WaterSavr™ product on the ecosystem using both acute and chronic whole effluent toxicity (WET) tests employing vertebrate and invertebrate species.
5. Produce a written report describing the material, the methods of evaluation, and an opinion of its potential impacts.

This report is not intended to investigate the anti-evaporative properties, mechanisms, or efficacy of WaterSavr™.

The WaterSavr™ Product

WaterSavr™ is a patented hydrated lime powder containing hydroxy alkanes that is applied to the surface of the water. Ionic repulsion causes the hydroxy alkanes to self-spread resulting in a monomolecular film on the surface of the water, which reportedly retards evaporation by up to 50%. This same mechanism enables reforming of the film if integrity is lost due to wind or wave action.

With a nominal concentration of 83.3% by weight, its primary constituent is calcium hydroxide, which is also known as lime or slaked lime. Two hydroxy alkanes, stearyl alcohol and cetyl alcohol, are present at nominal concentrations of 4.6% each.

NSF International Certification

NSF International is a not-for-profit organization that evaluates bottled water, food equipment, water treatment chemicals and products, and plumbing components for potential human health impacts. The NSF Water Distribution Systems Program is responsible for certifying drinking water treatment chemicals and drinking water system components to ensure that these products do not contribute contaminants to drinking water that could cause adverse health effects. The applicable NSF Standard for the WaterSavr™ product is NSF/ANSI Standard 60: Drinking Water Treatment Chemicals – Health Effects, which is the nationally recognized health effects standard for chemicals used to treat drinking water.

WaterSavr™ is NSF/ANSI Standard 60 approved at a maximum stated application concentration of 0.3 mg/L. This means that at that dosage, NSF certifies that the product is appropriate for use in potable water systems – including raw and finished (treated) water reservoirs. See Appendix A for a copy of the NSF Certification document.

WaterSavr™ Constituents

Calcium Hydroxide

The primary constituent of WaterSavr™ is calcium hydroxide [Ca(OH)₂], also known as calcium hydrate, lime, or slaked lime. It is an inorganic chemical compound described in the Merck Index¹ as “crystals or soft, odorless, granules or powder [with a] slightly bitter alkaline taste” that is “slightly soluble in water” but readily soluble in a number of other compounds including acids. It has been issued a Chemical Abstracts Service (CAS) Registry number² of 1305-62-0.

Calcium hydroxide is a common chemical that is extensively used in a number of industrial processes and commercial products including mortar, plaster, cement, and other building/paving materials. It is also widely used in the drinking water industry to soften or reduce hardness-causing minerals in drinking water, a treatment process known as “lime softening”. In the WaterSavr™ product, calcium hydroxide acts as a solid diluent and carrier for the two hydroxy alkane compounds.

Calcium hydroxide is a relatively innocuous material with low acute toxicity; the Registry of Toxic Effects of Chemical Substances (RTECS)³ lists the LD50 (lethal dose – 50% kill) as 7,300 mg/kg (mouse) and 7,340 mg/kg (rat). It is not subject to registration as a pesticide by the US Environmental Protection Agency (US EPA) or other regulatory requirements under the Toxic Substances Control Act (TSCA). It is regulated in the workplace by the Occupational Safety and Health Administration (OSHA) to control airborne exposure; it is considered an eye and inhalation irritant. There are no oral or

¹ The Merck Index: An Encyclopedia of Chemicals, Drugs, and Biologicals, 11th Edition, Merck & Co., 1989

² A unique identifier assigned to individual chemical compounds to assure proper and accurate identification.

³ <http://www.cdc.gov/niosh/rtecs/ew2ab980.html>

ingestion standards, and it is not listed in any of the potential carcinogen databases (*e.g.*, International Agency for Research on Cancer [IARC]).

Stearyl Alcohol

Stearyl alcohol [$\text{CH}_3(\text{CH}_2)_{16}\text{CH}_2\text{OH}$], also known as 1-octadecanol, is an oxygenated alkane (hydroxy alkane) that is commonly referred to as a fatty alcohol. An organic compound, it is described in the Merck Index⁴ as “unctuous white flakes or granules” that is insoluble in water, but soluble in other alcohols, ether, benzene, or acetone. Its CAS Registry number is 112-95-5 and has the following molecular diagram⁵:

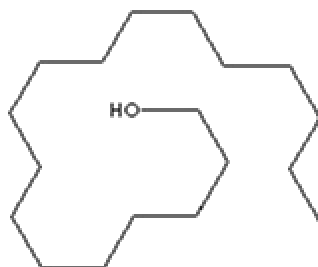


Figure 1 – Molecular Diagram of Stearyl Alcohol

Fatty alcohols are widely used as emulsifiers and emollients in cosmetics to make skin smoother and prevent moisture loss. Other applications include nonionic and anionic surfactants. Stearyl alcohol is used in pharmaceutical dispensing as an anti-foaming agent, lubricant, and chemical raw material. In the WaterSavr™ product, stearyl alcohol acts as an evaporation inhibitor.

Because it is a pharmaceutical dispensing and cosmetic ingredient, stearyl alcohol is a relatively non-toxic material. RTECS⁶ references an oral LD50 of 20,000 mg/kg (rat). It is not subject to registration as a pesticide by the US EPA or other regulatory requirements under TSCA. There are no oral or ingestion standards, and it is not listed in any of the potential carcinogen databases (*e.g.*, IARC).

Cetyl Alcohol

Cetyl alcohol [$\text{CH}_3(\text{CH}_2)_{15}\text{OH}$], also known as 1- or *n* (normal) – hexadecanol, is also a hydroxy alkane or fatty alcohol described in the Merck Index⁷ as “white crystals” that are “practically insoluble in water” but soluble in alcohol, chloroform, or ether. With a CAS Registry number of 36653-82-4, it has the following molecular diagram⁸:

⁴ The Merck Index, *op. cit.*

⁵ ChemLand21.com,

<http://www.chemicaland21.com/arokorhi/industrialchem/solalc/STEARYL%20ALCOHOL.htm>

⁶ <http://www.cdc.gov/niosh/rtecs/rg1eab90.html>

⁷ The Merck Index, *op. cit.*

⁸ ChemLand21.com,

<http://www.chemicaland21.com/arokorhi/industrialchem/solalc/CETYL%20ALCOHOL.htm>

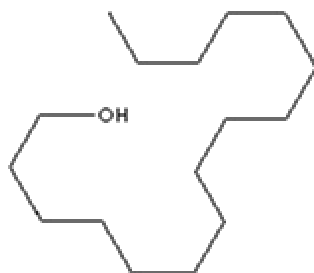


Figure 2 – Molecular Diagram of Cetyl Alcohol

Cetyl alcohol is used in many of the same cosmetic and pharmaceutical applications and chemical intermediates as stearyl alcohol; notably, it is immiscible (does not mix) in water. In the WaterSavr™ product, cetyl alcohol acts as an evaporation inhibitor.

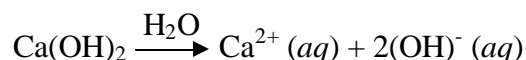
Like stearyl alcohol, cetyl alcohol is a relatively non-toxic material. RTECS⁹ references an oral LD50 of 3,200 mg/kg (mouse) and 5,000 mg/kg/kg (rat). It is not subject to registration as a pesticide by the US EPA or other regulatory requirements under TSCA. There are no oral or ingestion standards, and it is not listed in any of the potential carcinogen databases (*e.g.*, IARC).

Environmental Fate of WaterSavr™ Constituents

There are a number of chemical reactions and/or biological processes that can break down both inorganic and organic compounds in an aquatic environment. This section of the report will discuss possible decay mechanisms for the three constituents found in the WaterSavr™ product.

Calcium Hydroxide

Calcium hydroxide is considered a moderately strong base and as such is likely to completely ionize in water according to the following reaction (Equation 1):



Equation 1 – Disassociation of Calcium Hydroxide in Water

The rate and extent of this reaction will depend primarily on the pH of the water and the presence of other inorganic ions. Calcium ions (the Ca^{2+} in the above equation) are one of the most common inorganic chemical species in natural surface waters with an average concentration of 20 mg/L in a typical surface water source¹⁰. The addition of approximately one-third kilogram (0.7 lb) of WaterSavr™ per surface acre of water is unlikely to significantly add to the naturally occurring calcium already present.

⁹ <http://www.cdc.gov/niosh/rtecs/mm36ee8.html>

¹⁰ L.W. Mays (editor), *Water Resources Handbook*, McGraw-Hill, 1996

The hydroxyl ion [(OH)⁻ in the above equation] will eventually interact with available hydrogen ions (H⁺) in the aqueous environment in a neutralizing reaction resulting in water molecules [H⁺ + (OH)⁻ → H₂O].

Stearyl Alcohol and Cetyl Alcohol

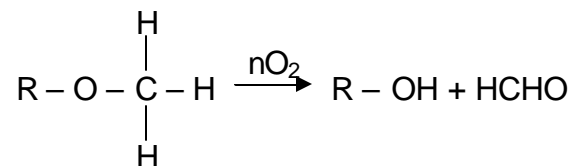
Organic compounds in an aquatic environment may be subject to both chemical decay and biodegradation. *Stearyl alcohol* and *cetyl alcohol* are likely to be degraded via both chemical degradation and microbial oxidation.

Biodegradation

Because the WaterSavr™ material will be applied at the water's surface, any biochemical reactions will occur in an aerobic environment – one that is rich in oxygen. Under such conditions, the most likely biochemical reaction will be biodegradation of the organic compounds via oxidation; a process that is accomplished by aerobic microbes.

“With their enormous variety, biochemical diversity, and rapid growth rates, microbes oxidize not only the detrital organic material produced by ecosystems, but also anthropogenic fuels, solvents, and other products. Low-molecular-weight and soluble organic compounds such as alcohols and organic acids are utilized particularly rapidly, perhaps because these classes of compounds also occur naturally in the environment and microorganisms have evolved to degrade them efficiently. The rate of microbial oxidation generally decreases for compounds of higher molecular weight, compounds having lower water solubilities, and compounds that possess aromatic rings, a large amount of branching, and/or halogen atoms (chlorine, fluorine, bromine, and iodine) in their chemical structure.”¹¹

Stearyl alcohol and cetyl alcohol are both higher molecular weight compounds with lower water solubilities; however they are not branched and contain no aromatic rings or halogenated species. As such, a moderate rate of biodegradation, consistent with a suggested reapplication rate of three days (*i.e.*, the alcohols are completely biodegraded in three days or less), is reasonable. It is likely that oxidative dealkylation (followed by β-oxidation) is occurring via the following reaction (Equation 2):



Equation 2 – Generic Oxidative Dealkylation Reaction

¹¹ Hemond, H.F. and Fechner, E.J., *Chemical Fate and Transport in the Environment*, Academic Press, 1994, pp 113-114

This process will continue with carbon atoms being removed in two-carbon fragments until the entire molecule is biodegraded into CO₂ and H₂O (or their constituent ions).

Chemical Degradation

Organic chemicals in an aquatic environment also are subject to abiotic chemical transformations. For the two subject hydroxy alkane compounds in a shallow (exposed to sunlight) oxygen-rich environment, the two most likely abiotic degradation mechanisms would be photodegradation and direct oxidation. Alcohols are generally resistant to aqueous environmental hydrolysis and this is not expected to be an important environmental fate process for stearyl or cetyl alcohol.

Photodegradation (or photolysis) results when light energy is transferred to chemicals. It is a common process with visible effects such as faded colors when dyed fabrics are exposed to the sun or the cracking and embrittlement of plastic objects left outdoors. Photodegradation of substances in surface waters will depend on both the intensity and wavelength of the light, with higher intensity and lower wavelength (*e.g.*, ultraviolet or UV) light producing faster and more intense reactions. Clearly, a thin monomolecular organic film at the surface of a water body would be amenable to this degradation process.

The presence of the (OH)[•] radical (produced by a variety of mechanisms) in surface water will also act as an effective oxidant, resulting in the degradation of many organic compounds including both stearyl and cetyl alcohol. Regardless of the specific degradation mechanism, the two compounds would be chemically degraded through a series of intermediate structures similar to those described in the previous section on biodegradation processes.

Potential Impacts of WaterSavr™ on Drinking Water Treatment Processes

While the primary emphasis of this report is evaluating the potential health and/or environmental impacts of the WaterSavr™ product, utilities must also be concerned with the product's possible impacts on various drinking water treatment technologies. It should be noted that stearyl alcohol and cetyl alcohol are immiscible and insoluble; thus following application, they will only be found on the water surface and most raw water intakes, regardless of the source, are submerged. Therefore, their presence in water destined for the treatment train is unlikely.

However, it would be prudent to examine a number of traditional and emerging drinking water treatment technologies, and evaluate the potential impacts of WaterSavr™ use upon them. Unless otherwise specified, the drinking water treatment process descriptions and chemicals referenced in this section were adapted from *Water Quality Treatment & Technology*¹² or *Water Treatment*¹³.

Natural surface waters will exhibit an entire suite of physical and chemical water quality parameters: temperature, pH, alkalinity, dissolved solids, and turbidity, among others. Unless the source water displays extraordinarily low alkalinity or low pH, applying WaterSavr™ is unlikely to alter the existing ambient conditions. If such sensitive source water conditions exist, MEC recommends that jar tests be conducted to determine WaterSavr's™ potential impact on the coagulation/flocculation/sedimentation processes.

Pretreatment Processes & Coagulation/Flocculation/Sedimentation

Pretreatment processes are used when a surface water source may contain large quantities of organic matter (leaves, twigs), gritty substances, or unusually heavy concentrations of sediment. Screens, settling impoundments, sand traps, and other passive mechanical settling devices are often employed as pretreatment technologies. Given the nature of its components and the recommended application rate of 0.31 kg/surface acre (0.7 lb/surface acre) for the WaterSavr™ product, water utilities would not 1) have to install additional pretreatment processes to accommodate WaterSavr™ or 2) expect to see interference with existing pretreatment processes when using WaterSavr™.

While larger particulates in source water may settle out in impoundments, smaller, non-settleable solids will not. Typically these materials consist of biological organisms, pathogens, organic matter, and inorganic matter, all of which are known as turbidity. One means of removing turbidity is through coagulation, followed by flocculation and sedimentation, the first step in what is termed conventional treatment. The process consists of:

1. *Coagulation* – chemical coagulants are added to the raw water and mixed.
2. *Flocculation* – the chemicals continue in a slow mix allowing particles to form a floc.

¹² Letterman, R.D. (Editor), *Water Quality and Treatment*, Fifth Edition, McGraw-Hill, Inc., 1999

¹³ Von Huben, H. (Editor), *Water Treatment*, Second Edition, AWWA, 1995

3. *Sedimentation* – the floc settles from the water in sedimentation basins removing a great deal of the turbidity.

A number of chemical and physical factors can impact the effectiveness of the preceding processes including mixing conditions, pH, alkalinity, turbidity levels, temperature, and coagulant employed. Many inorganic chemicals are used as coagulants (aluminum sulfate, ferric chloride) or coagulant aids (activated silica, polyelectrolytes); lime is often used in conjunction with the coagulant as a softening agent or to add alkalinity.

While the exact amount of coagulant added is highly dependent on the source water quality, typical coagulant doses are considerably less than 100 mg/L; when lime is used in conjunction with a coagulant, it is routinely added at a 3:1 to 4:1 ratio (3 or 4 parts aluminum sulfate or ferric chloride to 1 part lime). Even at the NSF maximum use concentration of 0.3 mg/L for WaterSavr™ (and assuming a worst-case condition of essentially no degradation), such an addition would be unlikely to impact the coagulation effectiveness. As noted earlier, utilities with atypical source waters or sensitive treatment processes should confirm this evaluation through jar tests.

In addition to the more traditional sedimentation basins, other processes are used to remove smaller particulates from water including dissolved air flotation (DAF) or microsand ballasted rapid sedimentation (such as Actiflo®). DAF is an extremely robust process that is often applied to challenging source waters; as such, the addition of a few tenths of a milligram per liter (again, at worst case assuming no prior biological or chemical degradation) would cause no impacts. However, the process chemistries associated with the rapid sedimentation process can be quite sensitive. While *highly unlikely to impact such processes*, MEC recommends pilot testing or jar tests if a utility plans to initiate WaterSavr™ use in conjunction with rapid sedimentation.

Conventional Filtration

The remaining suspended materials formed during the coagulation and flocculation phases (that do not settle during sedimentation) are filtered from the water as it passes through beds containing granular materials called filter media. Single or multiple filter media may be employed; common media include sand, anthracite (a type of coal), granular activated carbon, or garnet sand. There are a variety of filter sub-types, but all essentially work the same way.

It is unlikely that “recognizable” constituents of WaterSavr™ would be present at this point in the treatment process, the last (calcium) probably being removed during the coagulation/flocculation/sedimentation process. However, even if any fraction were present, it would not interfere or inhibit with conventional treatment processes.

Membrane Filtration

There are two basic classes of membranes: low pressure membranes operating between 10 and 30 psi (microfiltration [MF] and ultrafiltration [UF]) and high pressure

membranes operating between 75 and 250 psi (nanofiltration [NF] and reverse osmosis [RO]). They provide a barrier to both organic and inorganic contaminants. While extremely effective treatment technologies, low pressure membranes are ineffective for removing dissolved organic matter, thus taste and odor (T&O) and color causing materials will pass. High pressure membranes remove these and many other low molecular weight contaminants including DBPs. Often membranes are used in conjunction with more conventional treatment technologies.

Many membrane systems are extremely sensitive to specific constituents in source waters and extensive pretreatment is often practiced; widely varying qualities in source waters may also be problematic. However, despite this recognized sensitivity, it is unlikely that using WaterSavr™ at its NSF-maximum concentration of 0.3 mg/L would interfere with membrane performance. Any nominal pretreatment process used upstream of the membrane unit (dictated by source water quality) would provide acceptable performance.

Disinfection Processes

Disinfection is the treatment process used to destroy or inactivate disease-causing organisms such as bacteria, viruses, and protozoa. Several chemical oxidants and one non-chemical irradiating process are used. Chemical oxidants include chlorine, chlorine dioxide, chloramines, ozone, and potassium permanganate with chlorine the most widely used. The disinfectant properties of ultraviolet (UV) irradiation have long been known and this technology has been used in both the U.S. and Europe since the 1950s. However, these applications have typically been on a smaller scale and validation issues, source water constraints, and maintenance issues have prevented further market inroads until recently.

Effective disinfection can occur only if the disinfectant (say chlorine) can contact the pathogens to be killed. Excess turbidity in the water can interfere with this process. Similarly, because UV radiation is readily absorbed or scattered, excessive particulates could interfere with its efficacy.

Disinfectants are typically applied after the coagulation / flocculation / sedimentation and filtration processes. As previously noted, by this point in the treatment process it is extremely unlikely that any significant component of the applied WaterSavr™ remains in the drinking water. As such, there is little likelihood that the product would interfere with the disinfection process or reduce its ability to destroy pathogens.

Other Treatment/Post-Treatment Processes

As drinking water regulations become more numerous and more restrictive, additional treatment technologies are developed and introduced to produce drinking water including ion exchange (IX) processes to remove inorganic contaminants. Both continuous and fixed-bed column processes are undergoing research and development. WaterSavr's™ impact would depend on where the IX process was located in the treatment train. While *highly unlikely*, it is possible that an IX process could be impacted by the presence of

additional calcium ions in its influent. Vendor discussions and/or pilot tests should be conducted to confirm that WaterSavr™ does not impact this process.

Many other chemicals are added to drinking water once it leaves the treatment plant and is pumped throughout the distribution system. Typically, these are applied to alter water chemistry and control corrosion and deposition. Chemical additives include those for pH adjustment and orthophosphate (among others) for corrosion inhibitors. WaterSavr™ should exhibit no effect on any of these additives or their efficacy.

Additional chlorine is often added in the distribution system to maintain an appropriate residual disinfectant level. Again, it is extremely unlikely that WaterSavr™ would interfere with this process or accelerate residual disinfectant decay.

WaterSavr™ Field Tests

The toxicological and chemical information on the various WaterSavr™ components presented above was obtained from literature references. In an effort to obtain more empirical data about its characteristics, a defined field trial of the product was conducted with the assistance of Denver Water staff. This field trial was not designed to assess issues of drinking water regulatory compliance or impacts on downstream treatment processes. The toxicological tests results should not be interpreted as an endorsement of product safety; rather, the data serve to provide an indication of potential localized impacts that could be manifest under limited applications of the compound.

Using a small, hand-operated cyclical spreader, WaterSavr™ was applied to Lower Long Lake, a non-potable reservoir located just north of Golden, Colorado (see Figure 3). Product was applied at and near the southeast shoreline at the nominal recommended application dose of 0.31 kg/surface acre (0.7 lb/surface acre); the actual application may have slightly exceeded this figure due to application constraints and windy conditions.

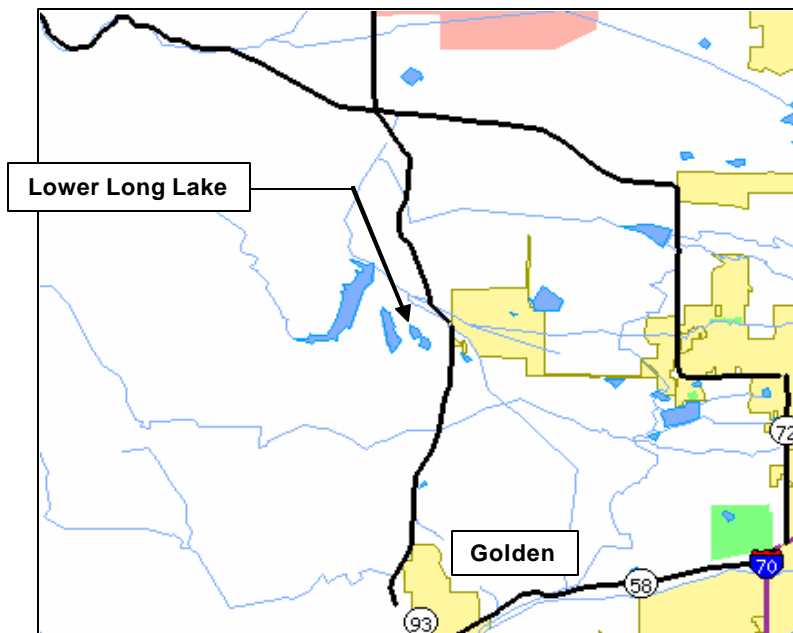


Image Courtesy: US Census

Figure 3 – Lower Long Lake, CO

Table 1 details the field conditions, application schedule, and sampling schedule for the field trials. Samples were obtained to conduct the Flavor Profile Analysis and Whole Effluent Toxicity test described in the following sections.

WaterSavr™ Sampling & Testing Schedule								
Day	1	1	2	3	4	5	6	
Date	Monday 11/08/2004	Monday 11/08/2005	Tuesday 11/09/2004	Wednesday 11/10/2004	Thursday 11/11/2004	Friday 11/12/2004	Saturday 11/13/2004	
Conditions	Clear, dry, (~65F), no wind	Clear, dry, (~65F), no wind	Cool, dry, (~55F), no wind	Cool, w/intermittent rain and wind, (~45F)	Cold, clear, (~35F), snow last night, light wind	Cold, clear (~35F), no wind	Cool, clear, (~40F), no wind	
Application Cycle	0	1	2	3	1	2	3	
Analysis	Baseline	First Application			Second Application			
Flavor Profile Analysis	X	X	X	X	X	X	X	
WET Acute Test								
<i>Pimephales promelus</i>	X	X			X			
<i>Ceriodaphnia dubia</i>	X	X			X			
WET Chronic Test								
<i>Pimephales promelus</i>	X	X			X		X	
<i>Ceriodaphnia dubia</i>	X	X			X		X	

X - sample taken for analysis as indicated

Field Observations:
11/8 - area where product applied differs in appearance; noticeable film or sheen.
11/9-11/10 - no observable difference in appearance in area where product applied.
Same observations from second application of product.

Table 1 – Sampling and Testing Schedule

WaterSavr™ Flavor Profile Analysis

Flavor Profile Analysis (FPA) is an analytical method that evaluates the sensory characteristics of water, and is referenced as Standard Method 2170¹⁴. FPA determines the strength or intensity of each perceived taste or odor without dilution or treatment of sample. Flavor characteristics are determined by taking water samples into the mouth; odor characteristics are determined by sniffing the sample.

FPA is used to assist in the detection, control, and understanding of off-flavors in drinking water. Off-flavor problems in drinking water are usually indicators of system problems including the disinfection process, distribution system, treatment plant processes, and algae growth in reservoirs or lakes. FPA has been applied to drinking water sources, finished drinking water, sampling points within the drinking water treatment train, bottled water, and for investigating consumer complaints.

Samples were obtained from Lower Long Lake according to the schedule in Table 1. These were refrigerated and shipped on ice via Federal Express to MEC's Santa Monica, California office for testing by a trained, FPA panel. Because the samples were raw water, *no taste analysis was conducted*. FPA results are presented in Table 2.

¹⁴ Standard Methods for the Examination of Water and Wastewater, 20th Edition, 1998, published jointly by the American Public Works Association, American Water Works Association, and Water Environment Federation.

WaterSavr™ Flavor Profile Analysis Results					
Sample ID	Date Sampled	Time Sampled	Odor Characteristics and Intensities	Flavor Characteristics and Intensities	Date Analyzed
Day 0	11/8/2004	9:30	Decaying Vegetation 1.5	N/A	11/11/2004
Day 1	11/8/2004	10:00	Decaying Vegetation 2.0	N/A	11/11/2004
Day 2	11/9/2004	11:15	Grassy 1.0 Notes: earthy, stagnant water	N/A	11/11/2004
Day 3	11/10/2004	10:00	Algae 1.5 Notes: musty, adhesive	N/A	11/12/2004
Day 4	11/11/2004	10:00	Algae 1.5 Notes: musty, decaying vegetation	N/A	11/12/2004
Day 5	11/12/2004	10:00	Grassy/Marshy 1.5 Notes: decaying vegetation, septic, musty	N/A	11/15/2004
Day 6	11/13/2004	9:00	Decaying vegetation 1.5 Note: musty	N/A	11/15/2004
N/A - Non-potable sample, flavor not analyzed.					

Table 2 – Flavor Profile Analysis Results

The musty, algae, grassy/marshy, and decaying vegetation odors are all fairly typical of surface waters, especially an untreated raw water source such as Lower Long Lake. The intensities, which range from 1 to 2 (out of a maximum of 12) are noticeable to trained panelists. They would probably also be detected by untrained individuals. In any case, they are considered relatively weak (<2). The presence of WaterSavr™ did not appear to have any impact on the baseline odor.

WaterSavr™ Whole Effluent Toxicity Tests

Toxicological data for individual WaterSavr™ constituents were presented above; all of these (calcium hydroxide, cetyl alcohol, and stearyl alcohol) exhibit reasonably low toxicity. However, there are no data that describe their collective impact on the environment when applied as the WaterSavr™ product. One means of determining such an impact is through a Whole Effluent Toxicity or WET test.

WET testing was conceived as a means of monitoring what happens when a discharge (or in this case a product) is introduced into the environment. This test can provide a good indication of how the material will impact living organisms in the environment. It is designed as an alternative approach to testing or analyzing all the individual components of a discharge. WET procedures can be used as an accurate and cost-effective means of

quickly determining if a substance has the potential to adversely impact the environment. WET testing takes into account both acute (rapid or immediate) and chronic (long-term) effects. WET tests typically use an invertebrate species, *Ceriodaphnia dubia*, and the minnow *Pimephales promelas*.

Ceriodaphnia dubia belongs to a group of freshwater microcrustaceans, commonly referred to as water fleas. These invertebrates are a major component of the freshwater zooplankton found in lakes, streams, ponds, and rivers throughout North America (in fact, native microcrustaceans had to be filtered from the Lower Long Lake water before it was used in the WET tests). Using *Ceriodaphnia* for toxicity testing is appropriate for a number of reasons:

- They are broadly distributed in fresh water and are present throughout a wide range of habitat,
- They are an important link in aquatic food chains and are a significant source of food for small fish,
- They have a short lifecycle and are easy to culture in the laboratory,
- They are sensitive to a broad range of aquatic contaminants and
- Their small size requires small volumes of test water leading to ease of sampling.

Fathead minnows, *Pimephales promelas*, belong to the fish family *Cyprinidae*, or carps and minnows, the dominant freshwater family in terms of number of species. Fathead minnows are native to North America and thrive in ponds, lakes, ditches, and slow muddy streams. Fathead minnows are easy to culture in the laboratory, adapting well to the dry commercial fish food and brine shrimp necessary for culturing in the laboratory.

These species have been used for acute and chronic tests for many years. Their lifecycles allow for tests which run from two to seven days, thus reducing testing costs and sample volumes considerably.

Toxicity Test Results

The objective of an *acute WET test* is to determine the concentration of a water sample that causes an adverse effect, such as death, during short term exposure. LC50 is a lethal concentration that causes 50% mortality. For this experiment, 48-hour acute toxicity tests were performed on fathead minnows and *Ceriodaphnia dubia*.

The objective of a *chronic WET test* is to determine the concentration of a water sample that causes a non-lethal biological effect, such as reduced reproduction or growth. During a chronic test, several life stages of the organism are continuously exposed to various concentrations of the sample. IC25 is a statistical calculation used to estimate the concentration of toxicant that would cause a 25% reduction in growth or average young per female. For this experiment, *Ceriodaphnia* survival and reproduction tests and 7-day larval fish growth and survival tests were performed.

Results of the chronic and acute WET tests are summarized in Table 3. These results show that at the recommended WaterSavr™ application rate, the LC50 and IC25 were >100% for all samples. This means that more than 0.31 kg/surface acre (0.7 lb/surface acre) of WaterSavr™ would have to be applied to result in 50% mortality or a 25% reduction in growth or reproduction of the species tested (this test, however, does *not* define what that higher value is).

	Units	Baseline	Day 1	Day 4	Day 6
Hardness as CaCO ₃	mg/L	220	210	210	210
Total Alkalinity	mg/L	160	160	160	160
Ammonia as N	mg/L	0.037	0.059	0.034	0.011
Ceriodaphnia nubia LC50	%	>100	>100	>100	
Fathead minnow LC50	%	>100	>100	>100	
Ceriodaphnia nubia IC25	%	>100	>100	>100	>100
Fathead minnow IC25	%	>100	>100	>100	>100

Table 3 – Acute (LC50) and Chronic (IC25) WET Test Results

Table 4 summarizes the results of the acute toxicity tests on *Ceriodaphnia*. The lowest survival (80%) was observed in the undiluted water sample collected on Day 4. However, with the limited number of samples it is impossible to say if this survival rate was significantly different than the 90% survival observed in the control.

	Dilution (%)						
	0	6.25	12.5	25	50	75	100
Baseline	100	100	100	100	100	100	95
Day 1	100	100	100	100	95	100	100
Day 4	90	95	90	100	95	90	80

Table 4 – Percent Survival for the *Ceriodaphnia* Acute Toxicity Tests

Data from only two toxicity tests is not sufficient to determine whether or not WaterSavr™ results in increased mortality of *Ceriodaphnia*; however, based on test fish survival, WaterSavr would not be considered acutely toxic. For example, California NPDES permits consider effluents to be acutely toxic when there is 1) less than 90% survival of fish 70% of the time or 2) less than 70% survival of fish 100% of the time. Using the California criteria to analyze the data obtained in this experiment, acute toxicity was not observed when WaterSavr™ was applied as recommended because fathead minnow survival was 100% in all tests.

In this study, the WaterSavr™ concentration used did not result in noticeable acute or chronic toxicity to *Ceriodaphnia* or fathead minnows. However, *Ceriodaphnia* and minnows are not the only aquatic organisms that could potentially be exposed to the product. But, because WaterSavr™ forms a film on the surface of the water, it is most likely that aquatic organisms would have little if any exposure to it. Therefore, even at higher concentrations, WaterSavr™ would probably have minimal impact on an aquatic ecosystem. Thus under the conditions of this limited study, the initial toxicity testing conducted at Lower Long Lake suggests that WaterSavr™, when applied as recommended, does not exhibit either acute or chronic toxicity.

Conclusions

WaterSavr™ is intended for use in drinking water systems, agriculture, and aquaculture. Because of its potential to impact both the aquatic environment and human health, due diligence mandates that it be evaluated for potential environmental, health, and ecological impacts. This study performed the following:

1. *Conducted a literature review of the chemical constituents comprising the product to determine possible associated health or environmental impacts/hazards.* – WaterSavr™ is NSF/ANSI Standard 60 approved at a maximum stated application concentration of 0.3 mg/L. Additional literature review revealed that all constituents exhibit extremely low toxicity characteristics. Further, the environmental fate of the individual constituents was expected to be benign and occur fairly rapidly (within 3 days).
2. *Conducted a literature review of potential impacts of the WaterSavr™ product on various drinking water treatment processes.* – It appears that the components will demonstrate little to no impact on a conventional water treatment processes. While it is impossible to comment on the product's impact on all new or innovative treatment processes, it is assumed to be minimal.
3. *Conducted a Flavor Profile Analysis of WaterSavr™ treated water to assess potential aesthetic impacts of the product on potable water sources.* - The presence of WaterSavr™ did not appear to have any impact on the baseline odor.
4. *Assayed the potential environmental impact of the WaterSavr™ product on the ecosystem by conducting acute and chronic WET tests employing vertebrate and invertebrate species.* - The WaterSavr™ concentration used (approximating the 0.31 kg/surface acre [0.7 lb/surface acre] recommended dose) did not result in noticeable acute or chronic toxicity to *Ceriodaphnia dubia* or *Pimephales promelas* (fathead minnows). Based on the test results, it was also surmised that even at higher concentrations, WaterSavr™ would probably have minimal impact on an aquatic ecosystem.

Based on this evaluation, it appears that when used as recommended by the manufacturer and within NSF International guidelines, WaterSavr™ exhibits extremely low environmental and aquatic toxicity, imparts no objectionable odors, and is compatible with most raw waters and conventional drinking water treatment technologies. Utilities with extraordinary raw water chemistries or considering exotic treatment technologies should evaluate WaterSavr™ to simulate their specific circumstances.