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12/17/01

PETITION FOR THE INCLUSION OF OZONE GAS USED FOR WEED CONTROL IN THE NATIONAL LIST

Submitted by SoilZone, Inc., 2736 Brentwood Pl., Davis, CA 95616
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ITEM A

This petition is for the inclusion of ozone gas used for weed control in the National List as a synthetic substance allowed for use in organic crop production.

ITEM B

1. **Common Name** - The substance's common name is ozone.

2. **Manufacturer's Name, Address and Telephone Number** - NA. Ozone is manufactured onsite with an ozone generator and immediately used (see No. 5 below). Ozone generators of the size sufficient to provide the quantities of ozone necessary for commercial applications as described herein are made by several dozen different manufacturers in the United States.

3. **Intended Use** - The intended use of the substance is for preplant weed control in conjunction with the use of plastic mulch. It is not intended for application once a crop is planted.

4. **Crop Activities and Rate and Method of Application** -

The preferred application method of the ozone gas is made through drip tape beneath plastic mulch laying on the surface of conventional row crop beds. The drip tape can subsequently be used for irrigation of the intended crop. The enclosed space between the soil surface and the plastic mulch into which the weeds grow after germination or sprouting thus becomes the treatment area in which the growing weeds are subsequently exposed to the ozone gases injected through the drip tape. Ozone oxidizes plant leaf surfaces thereby causing the weakening or premature death of the plant. This treatment is effective against all weed species

The technology is suitable for those crops currently utilizing plastic mulch such as strawberries and many winter vegetables in California, Arizona, and the southeast United States. Target weed species include nutsedges, grasses, and mallows among many others of concern to row crop farmers.

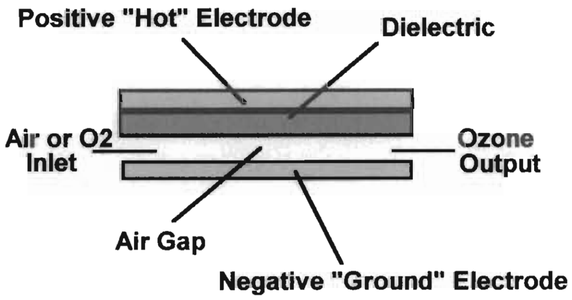
The technology would also work well in conjunction with solarization in an integrated weed control strategy. Preplant weed control under clear plastic mulch during solarization is often unpredictable due to the vagaries of climate and weather. Often, increases in temperature are sufficient to induce seed germination and tuber sprouting but insufficient to kill young, rapidly growing plants - thus exacerbating the problem. As an example, soil temperatures of 30° C. or higher stimulate sprouting of *Cyperus rotundus* (purple nutsedge) but it requires sustained temperatures in excess of 50° C to kill the tubers and sprouts. Control of nutsedge is particularly important in these cropping practices because the sharp points of new sprouts lance plastic mulch on the growing beds. The nutsedge is then able to grow up and through the plastic mulch destroying its integrity in the process. In the worst infestations, it can render the plastic mulch useless and require replacement prior to planting of the crop. The time period required for effective solarization (4-6 weeks prior to planting) coincides with the anticipated timing of the ozone application.

Application rates will vary depending on the particular weed species present. Grasses can be controlled with dosages of only 2 lbs/acre applied every 3rd or 4th day over a several week period. More persistent weeds such as nutsedges will require daily dosages of up to 2.0 lbs/acre over a 30-day period for effective control.

5. Description of Manufacturing Process -

Because of the short half-life due to the instability of ozone, it cannot be stored and transported but must instead be immediately consumed at the location of manufacture. Commercially, ozone is produced from ambient air and electricity by relatively simple pieces of equipment known as ozone generators through a process known as "corona discharge". A corona, the electrically energized field necessary for ozone production, is created by applying an electrical current to two metallic electrodes that are separated by a dielectric insulator and an air gap. As shown below, the electrical current will not arc between the electrodes because of the dielectric and the air gap. Instead, an energized corona develops in the interstitial air space. This is characterized by a deep blue or violet glow.

**TYPICAL CORONA DISCHARGE OZONE
GENERATOR ELECTRODE CONFIGURATION**



Ozone is produced by passing oxygen or air through this electrical field wherein a certain percentage of the oxygen molecules dissociate then recombine as ozone according to the following equation:

$3 O_2$ + energy ---> $2 O_3$ + heat and light

The four basic components of the process of ozone generation and application to soil water are electrical power supply, feed gas production and preparation, ozone generation, and ozone delivery.

6. Summary of Previous Reviews by State or Private Certification Programs or Organizations -

None for Weed Control. Ozone is currently on the National List as a Food Processing Aid.

7. Information Regarding Regulatory Authority Registrations - The requirements for use of ozone as a weed control agent in California parallel those now required for other ozone applications in California or by the US EPA. That is, the ozone generator itself must be registered as a biocidal device with the US EPA and that the establishment number so granted must be appropriately displayed on the ozone generator. As a result of obtaining the appropriate registration of the ozone generator itself, separate registration of the chemical "ozone" is not required. This is consistent with regulations covering the use of ozone as a biocide in many other applications such as potable water treatment, swimming pool ozonation, cooling water treatment, food processing, and its other myriad of uses as a biocide. Letters to and from the California Department of Pesticide Regulation regarding this matter are attached as Appendix A.

8. Chemical Abstract Service Number - 10028-15-6

9. Physical Properties and Chemical Mode of Action

Ozone (triatomic oxygen) is an unstable, bluish gas which has a molecular weight of 48.0, a gas density of 2.144 grams/liter at 0° Centigrade and atmospheric pressure, and a boiling point of minus 112°

Centigrade at atmospheric pressure. It is partially soluble in water (more than oxygen - see Table 1) and has a characteristic pungent odor detectable at concentrations as low as 0.01 - 0.05 ppm in ambient air.

TABLE 1 - SOLUBILITY OF OZONE AND OXYGEN IN WATER

Temperature (Degrees C)	Ozone Solubility in mg/l with 3% O_3 Gas Concentration	Oxygen (from air) Solubility in mg/l
0	20	6.9
20	8.9	4.3

Ozone is a powerful oxidant, having an oxidation potential of 2.07 volts in alkaline solutions. It is therefore capable of oxidizing many types of organic and inorganic material. By comparison, it is 52% greater than the oxidation potential of chlorine that is 1.35 volts. Low concentrations of ozone gas are produced for industrial or municipal applications by corona discharge ozone generators, generally at concentrations of 1-3% (w/w) from air and 2-12% (w/w) from oxygen. Ozone can be explosive if produced in concentrations in excess of 15%. This high of a concentration, however, cannot be produced with commercially available ozonation equipment. Ozone has a relatively unstable in aqueous solutions. It has a half-life in distilled water of 20-30 minutes at 20° Centigrade before reverting back to simple diatomic oxygen (O_2). If oxidant-demanding materials are in the water, the half-life is substantially less and is generally measured in seconds in organically laden water. In ambient air, it has a half-life of 12 hours but in confined spaces in which the ozone can come into intimate contact with organic materials (such as envisioned in this application), its half-life is measured in only minutes.

Ozone has been used historically for over 100 years as an extremely powerful but environmentally benign sanitizing agent for water. Due to its high oxidation potential, ozone has the ability to destroy a broad spectrum of microorganisms in water and to oxidize many organic and inorganic contaminants. Because ozone has a comparatively short half-life (measured in seconds to minutes in aqueous solutions and minutes to hours when in the gaseous phase) and because ozone's decomposition product is simple diatomic oxygen, ozone is increasingly viewed as a functionally efficient and environmentally benign alternative to the continued use of halogenated biocides and the associated toxicity and environmental persistence of their byproducts. Ozone is also now beginning to be used on a widespread basis for food processing wash waters as a result of its recent "Generally Recognized as Safe" ("GRAS") designation approved by the US FDA two years ago.

See Appendix B for chemical interactions with other substances and ozone's effects on soil organisms.

10. Safety Information -

Environmental Exposures - Ozone is ubiquitous to the environment and is found in varying concentrations throughout the atmosphere. It is formed naturally in the upper atmosphere from oxygen by ultraviolet light and by atmospheric electrical discharges such as or lightning or the aurora borealis. Ozone is also found in lower levels of the atmosphere primarily due to photochemical oxidation of hydrocarbons from automobile and industrial emissions. It is also coincidentally produced by a number of man made methods such as by photocopy instruments, electrical transformers, or other electrical devices. Human and plant exposure to ozone thus occurs at some concentrations on a continuous day-to-day basis.

Congested roadways and industrial areas have been typically associated with comparatively higher levels of ozone in the lower atmosphere. Levels up to 1.0 ppm have been found in some areas of Los Angeles in the past. Levels even exceeding these have been found in passenger cabins of some commercial aircraft. Workplace exposures of up to 9.0 ppm have been found in some gas shielded arc-welding applications. Measurable and sometimes excessive levels have also been found in many office environments containing electrical equipment such as X-ray apparatus, neon lamps, and copy machines or laser printers prompting promulgation of recent ventilation standards for such work environments. As discussed further below, some workers can be even exposed to ozone concentrations in excess of the recommended TLV-TWA and TLV-STEL in the absence of any commercial generation and use of ozone at the site because of high background ambient ozone levels.

Threshold Limit Values - The current Threshold Limit Value - Time Weighted Average (TLV-TWA) for ozone exposure in the workplace environment is 0.1 ppm as recommended by the American Conference of Governmental Industrial Hygienists (ACGIH) and allowed by the U.S. Occupational Safety and Health Administration (OSHA). This is the concentration to which healthy, nonsusceptible individuals can be repeatedly exposed for a normal 8 hour day / 40 hour workweek without adverse effects. The current Threshold Limit Value - Short Term Exposure Limit (TLV-STEL) is 0.3 ppm. This is the level to which healthy, nonsusceptible individuals can be exposed for a short term period of time without suffering from irritation or other acute effects providing that the TLV-TWA is not exceeded. A TLV-STEL is defined as a 15-minute time-weighted average exposure that should not be exceeded at any time during the workday even if the 8-hour time weighted average does not exceed the TLV-TWA. Exposures at the TLV-STEL should not be longer than 15 minutes and should not be repeated more then 4 times per day. There should be at least 1 hour between successive exposures at the TLV-STEL.

Ozone Toxicology - The acute and chronic effects of excessive exposure to ozone have been well investigated. Exposures to concentrations of ozone in excess of several tenths of a ppm sometimes cause reports of discomfort in a small susceptible portion of the population. This can be in the form of headaches or dryness of the throat and mucous membranes of the eyes and nose following exposures of short duration. Repeated exposure to ozone at such concentrations at 24-hour intervals, however, caused no further increase in airway irritability. In fact, after the first exposures, additional exposures to ozone had progressively lesser effects suggesting that tolerance may develop to these effects of ozone.

Ozone has been shown to be more injurious at concentrations exceeding 2.0 ppm over several hours such as experienced by gas shielded arc welders. The primary site of acute effects is the lung that is characterized by pulmonary congestion. This acute impact subsided in welders when exposures were reduced to less than 0.2 ppm. Based on animal studies, exposures over 10-20 ppm for an hour or less are believed to be lethal in humans although there has never been a single recorded fatality attributed to ozone overexposure in the greater than 100 years history of commercial use.

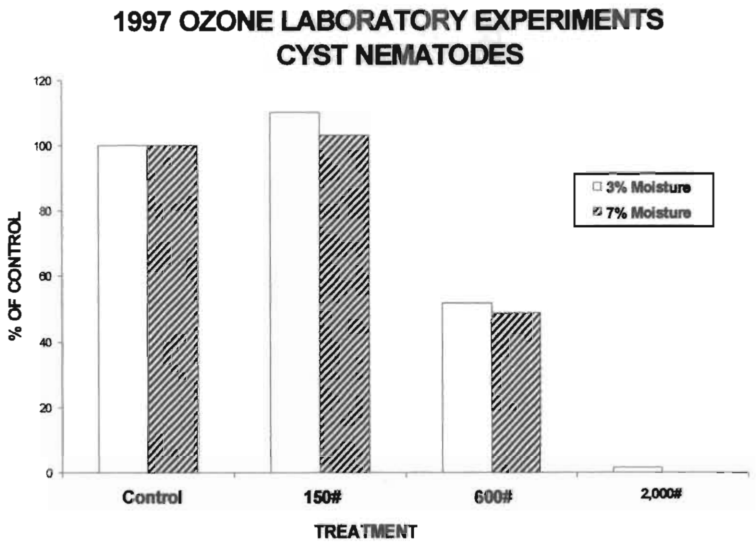
With respect to long term or chronic toxicity, ozone is a radiomimetic agent. That is, the effects of prolonged exposure to excessive ozone exhibits the same effects as excessive exposure to sunlight. These effects are drying of the dermal surfaces and general aging of exposed tissue. According to the ACGIH, ozone is not a confirmed or a suspected human carcinogen. Nor does it exhibit teratogenic or mutagenic properties.

Comparative Safety Aspects - In many applications, ozone is the gaseous oxidant of choice. This is due to the following properties of ozone or its manufacture:

a. Ozone is manufactured onsite, at relatively low concentrations and pressures (less than 15 psig), and is immediately consumed in the treatment process. It is not stored as a compressed gas. An uncontrolled, widespread, and immediate release of large quantities of ozone is thus not possible to the extent that the sudden releases of the entire contents of containers of other bulk stored, concentrated chemicals can occur upon an industrial accident or natural disaster.

b. Ozone has a comparatively short half-life; generally measured in minutes in the aqueous phase to hours in the gas phase. Any accidental releases of ozone will not persist in the environment as long compared to if more stable oxidizing agents were released.

FIGURE 7



Collaborator: Dr. Becky Westerdahl, Dept. of Nematology, UC Davis

Other tests were also conducted exposing *Phylloxera spp.* eggs to ozone treatment. The effects of ozone treatment were tested by placing fresh ripe mite eggs in a mesh envelope and inserted the envelope into the soil in the cylindrical chamber. The ozone treatment was applied several days before hatching to determine the effect on hatch rates. The hatch rate was subsequently determined to be nearly 100% indicating that ozonation had absolutely no detrimental effects even at the rate of over 500 lb./acre - again demonstrating that ozone is not a broad spectrum biocide.

3. Oxidation of Soil Compounds - Due to the high oxidation potential of ozone, many common soil components are readily oxidized by ozone. Following is a summary of the aqueous oxidation reactions:

- **Iron** - Soluble divalent ferrous iron is oxidized rapidly to trivalent ferric iron which hydrolyzes and precipitates out as ferric hydroxide. This insoluble form also adsorbs polar organics in the coagulation.

- **Manganese** - Divalent manganese is easily oxidized to the tetravalent species which hydrolyses to the insoluble manganese oxydihydroxide.

- **Nitrite** - Nitrite is quickly oxidized to nitrate.

- **Hydrogen Sulfide** - Odorous sulfide is quickly converted to elemental sulfur and more slowly to sulfate.

- **Organics** - The degree of oxidation of organics in water is quite varied due to the widely differing nature and reaction rates of the contaminants found. In general, however, ozone is effective at oxidizing aromatic and aliphatic compounds to some degree. Phenols are particularly susceptible to ozonation. Natural organics such as humic and fulvic acids are slowly oxidized as are the chlorinated hydrocarbon solvents and pesticides.

Due to the limited ozone contact times seen in soil treatment applications, complete mineralization of organics to CO_2 and H_2O rarely occurs. Instead, ozone oxidation generally results in the production of smaller, more polar organic compounds such as aldehydes and alchohols. These compounds play an important role in the normal biodegradative soil processes as they are readily assimilated by a variety of microorganisms and plant in the soil. Thus, ozonation enhances the biological digestion of organics due to the oxidation effect ozone has on the compounds. The oxygenated byproduct compounds are invariably smaller and more polar than their unozonated precursors. As a result, they are more biologically assimilable and digestible by endemic aerobic bacterial and fungal populations.

4. Soil Aeration - Through the continuos injection of ozone gas (produced in either air or oxygen) into the treatment space above the soil, substantial amounts of oxygen are directed down into the soil. In this manner, aerobic conditions are maintained in the upper soil zones that prevents septic conditions by inhibiting the proliferation of anaerobic bacteria. The aerobic digestion of organics is also stimulated due to the beneficial biological effects of the oxygenated environment.

APPENDIX C - OZONE MSDS, NTP CHEMICAL REPOSITORY REPORT, AND UNIFORM FIRE CODE REGULATIONS

MATERIAL SAFETY DATA SHEET

OZONE

SoilZone, Inc.
2736 Brentwood Place, Davis, CA 95616
530-758-5173

SECTION 1. MATERIAL IDENTIFICATION

MATERIAL NAME: OZONE

DESCRIPTION: (Origin/Uses): Obtained by passing air between two electrodes connected to an alternating current source of several thousand volts. Frequently generated by electronic equipment. Used as an air and water disinfectant and other industrial process water treatment.

OTHER DESIGNATIONS: Triatomic Oxygen; O_3; NIOSH RTECS #RS8225000; CAS #10028-15-6

COMMENTS: Ozone in high concentrations is a severe respiratory hazard.

SECTION 2. INGREDIENTS AND HAZARDS

INGREDIENTS:Ozone, CAS #100028-15-6; NIOSH RTECS #RS8225000

PERCENTAGE:Up to 3% (w/w) in air and up to 12% (w/w) in oxygen

HAZARD DATA:

ACGIH VALUES:

TLV-TWA: 0.1 ppm, 0.2 mg/m^3*
TLV-STEL: 0.3 ppm, 0.6 mg/m3

OSHA PEL 1986 (29 CFR 1910, Subpart Z)

8-hour TWA-TLV*: 0.1 ppm, 0.2 mg/m^3
IDLH** Level: 10 ppm

TOXICITY DATA:

Human, Inhalation, TC_{Lo}: 600 ppb/2 Hrs
Human, Inhalation, TC_{Lo}: 0.2 ppm/3 Hrs
Human, Inhalation, TC_{Lo}: 100 ppm/1 Min
Men, Inhalation, TC_{Lo}: 1860 ppb/75 Min

* This TLV-TWA is set to prevent ostensible or manifest injury; yet, sufficiently prolonged continual daily repeated eight-hour exposures may result in premature aging in a manner similar to that from exposure to ionizing radiation.

** Immediately dangerous to life or health.

Boiling Point...	-169.42°F (-111.9°C)
Vapor Pressure...	>1 atm
Water Solubility...	Negligible
Density of Gas (Air = 1)	1.6
Melting Point...	-315.4°F (-193°C)

% Volatile by Volume... 100
Molecular Weight... 48 Grams/Mole
pH... Not Listed
Critical Temperature... 10.22°F (-12.1°C)

APPEARANCE AND ODOR: Blue-colored gas or liquid; characteristic odor often associated with electrical sparks or lightning in concentrations of less than 2 ppm.

COMMENTS: The pungent characteristic odor of ozone is detectable above 0.01 ppm and becomes disagreeable (sulfurlike) above 0.2 - 0.5 ppm.

CAUTION: Olfactory fatigue develops rapidly, so do not use odor as a preventative warning device.

SECTION 4. FIRE AND EXPLOSION DATA

Flash Point and Method: Not Available
Auto-ignition Temperature: Not Available
Flammability Limits in Air: % by Volume
 Lower: Not Listed
 Upper: Not Listed

EXTINGUISHING MEDIA: Use large amounts of water spray or fog to put out fires involving ozone. This material at high concentrations increases the intensity of combustion as compared to the burning or exploding of material in air or with a comparable amount of oxygen gas. Use appropriate fire-fighting techniques to deal with the surrounding material.

SPECIAL FIRE-FIGHTING PROCEDURES: Wear self-contained breathing apparatus with full facepieces operated in a pressure-demand or other positive-pressure mode.

SECTION 5. REACTIVITY DATA

Ozone is not stable. Potentially hazardous polymerization cannot occur.

CHEMICAL INCOMPATIBILITIES: Ozone is chemically incompatible with all oxidizable materials, both organic and inorganic.

CONDITION TO AVOID: Avoid ignition sources such as heat, sparks, and open flame. Ozone is unstable at ordinary temperatures because it spontaneously decomposes to oxygen gas. Keep it away from heat, flame, strong reducing agents, and combustible materials such as grease, oils, and fats.

PRODUCTS OF DECOMPOSITION: Ozone spontaneously decomposes to oxygen gas even at ordinary room temperatures.

SECTION 6. HEALTH HAZARD INFORMATION

CARCINOGENICITY: Ozone is not listed as a carcinogen by the NTP, IARC, or OSHA.

SUMMARY OF RISKS: High concentrations of ozone may cause severe irritation of the eyes and respiratory tract. Exposure above 0.1 ppm causes the mucous membranes of the mouth, nose, and throat to dry. A short exposure at 1 to 2 ppm causes headache as well as irritation to the respiratory tract, but these symptoms subside when the exposure ends. High concentrations and/or repeated or prolonged exposures above the ACGIH/OSHA exposure limits produce nausea, chest pain, coughing, dyspnea, fatigue, reduce visual acuity, and pulmonary edema.

CAUTION: Inhalation of >20 ppm for at least 1 hour (or 30 ppm for at least 1/2 hours) may be fatal. Symptoms of pulmonary edema may be significantly delayed (one or more hours) from the time of initial exposure. Toxic effects reported include eye, skin, and CNS effects.

TARGET ORGANS: Respiratory system, eyes. PRIMARY ENTRY: Inhalation.

ACUTE EFFECTS: The acute damage from ozone appears to be the result of its oxidizing effect upon contact with tissue. The acute effects of ozone inhalation include eye irritation, mucous membrane irritation, and pulmonary edema.

CHRONIC EFFECTS: Respiratory disease. Deleterious (ozone inhalation) effects on the lungs and acceleration of tumors have been reported as chronic effects on exposure to ozone.

MEDICAL CONDITIONS AGGRAVATED BY LONG-TERM EXPOSURE: Workers with a history of heart or lung problems must be prevented from industrial exposure to ozone. Individual susceptibility to injuries from ozone varies significantly. Because of a certain enzyme deficiency, particular persons may become ill from ozone exposures that are readily endured by workers without this condition.

FIRST AID

EYE CONTACT: Flush eyes, including under the eyelids, promptly and gently with plenty of running water for 15 minutes. Get medical help.

INHALATION: Remove victim to fresh air; restore and/or support his breathing as needed. If breating is extremely labored, provide victim with a 100% oxygenated atmosphere. Get medical help. Observe victim carefully for delayed onset of pulmonary edema. Keep him warm, quiet and still.

INGESTION: As a gas, ozone is unlikely to be ingested.

SPILL AND DISPOSAL PROCEDURES

SPILL/LEAK: Before using ozone, it is essential that proper emergency procedures be established and made known to all personnel involved in handling it. Use approved NIOSH respirators in emergency/IDLH conditions. Ozone leaks may be detected by ozone meters using UV spectrophotometry, by exposing paper impregnated with dried 4% potassium iodide to the suspected leak (i.e. if the paper turns brown, it is an indication that ozone is present), or by employing various other commercially available methods. The smell of ozone can also be detected to levels as low as 0.005 ppm.

DISPOSAL: Provide ventilation to dilute and disperse small amounts of ozone into the outside atmosphere. Follow Federal, state, and local regulations.

Ozone is not designated as a hazardous substance by the EPA (40 CFR 116).
Ozone is reported in the 1980 EPA TSCA Inventory.
EPA Hazardous Waste Number (40 CFR 261): Not Listed
EPA Reportable Quantity: Not Listed
Ozone is an OSHA Air Contaminant (29 CFR 1910.1000, Subpart Z, Table Z-1).

SECTION 8. SPECIAL PROTECTION INFORMATION

RESPIRATOR: For IDLH/unknown concentrations, use a self-contained breathing apparatus with a full facepiece operated in a pressure-demand or other positive-pressure modes.

VENTILATION: Provide general and local exhaust ventilation to meet ACGIH exposure values. Provide ventilation to dilute and disperse small amounts of ozone into the outside atmosphere. Ozone is highly toxic, and properly maintained engineering ventilation systems are crucial to safe work environment.

SAFETY STATIONS: Make eyewash stations, washing facilities, and safety showers available in areas of use and handling. Contact lenses pose a special hazard; soft lenses may absorb irritants, and all lenses concentrate them.

SECTION 9. SPECIAL PRECAUTIONS AND COMMENTS

STORAGE SEGREGATION: Prevent ozone from coming into direct physical contact with strong acids or bases or with strong oxidizing/reducing agents.

ENGINEERING CONTROLS: Install ventilation systems that are able to maintain ozone use concentrations below the ACGIH/OSHA exposure limits (see sect. 2). Minimize or eliminate all sources of ignition such as open flame or sparks when oxygen is used as a feed gas.

OTHER PRECAUTIONS: Where ozone is generated using oxygen as a feed gas, explosion hazards exist and must be avoided by proper planning, equipment, engineering systems, training, and work practices. Use only equipment in compliance with the Uniform Fire Code.

Judgments as to the suitability of information herein for User's purposes are necessarily purchaser's responsibility. Therefore, although reasonable care has been taken in the preparation of such information, SoilZone, Inc. extends no warranties, makes no representations and assumes no responsibility as to the accuracy or suitability of such information for application to purchases; intended purposes or for consequences of its use.

NTP CHEMICAL REPOSITORY (RADIAN CORPORATION, AUGUST 29, 1991)

OZONE

-IDENTIFIERS
===========

*CATALOG ID NUMBER: 002199

*CAS NUMBER: 10028-15-6

*BASE CHEMICAL NAME: OZONE

*PRIMARY NAME: OZONE

*CHEMICAL FORMULA: O_3

*STRUCTURAL FORMULA: OOO

*WLN: Not available

*SYNONYMS:
TRIATOMIC OXYGEN
TRIOXYGEN

-PHYSICAL CHEMICAL DATA
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*PHYSICAL DESCRIPTION: LITERATURE: Colorless gas or dark blue liquid
REPOSITORY: Not available

*MOLECULAR WEIGHT: 48.00

*SPECIFIC GRAVITY: Not available

*DENSITY: 1.614 g/mL @ -195.4 C [017,031,042,421]

*MP (DEG C): -193 C [031,042,421,430]

*BP (DEG C): -111.9 C [017,031,042,421]

*SOLUBILITIES:
WATER : 0.00003 g/100 g @ 20 C [102]

DMSO : Not available

95% ETHANOL : Not available

METHANOL : Not available

ACETONE : Not available

TOLUENE : Not available

OTHER SOLVENTS:
Alkaline solutions: Soluble [017]
Oil: Soluble [017]

*VOLATILITY:
Vapor pressure: 1 mm Hg @ -180.4 C; 20 mm Hg @ -157.2 C [038]
Vapor density : 1.6

*FLAMMABILITY(FLASH POINT):
This compound will accelerate combustion. Flash point data for this chemical are not available. Fires involving this material can be controlled with a dry chemical, carbon dioxide or Halon extinguisher.

*UEL: Not available LEL: Not available

*REACTIVITY:
This compound is a powerful oxidizing agent [031]. It is incompatible with rubber, dicyanogen, dinitrogen tetraoxide, 4-hydroxy-4-methyl-1,6-heptadiene, NCl3, stibine and tetrafluorohydrazine. It is also incompatible with powerful reducing agents. It may present a dangerous fire hazard by chemical reaction with aniline, (diallyl methyl carbinol + acetic acid), diethyl ether, N2O5, ethylene, HI, NO2, NO, NCl3, NI3, nitroglycerin, organic liquids, organic matter and Sb [042]. It is also incompatible with acetylene, alkyl metals, PI, citronellic acid, trans-2,3-dichloro-2-butene, (ethylene + formyl fluoride), 1,1-difluoroethylene, fluoroethylene, hydrogen, 2-methyl-1,3-butadiene, nitrogen and tetramethyl ammonium chloride [066]. It reacts with alkenes to form peroxides which are often explosive. Gelatinous explosive oxonides formed with benzene, aniline and other aromatic compounds. It may also react with bromine, N2O4 and HBr. Mixtures of this compound with C2H4 at low pressure explodes @ -150 C. Mixtures with isopropylidene compounds give explosive acetone peroxide [036].

*STABILITY:
This compound is unstable [031,042,062]. Solutions containing this compound may explode on warming [031,421]. Although the stability of this compound in aqueous solutions decreases as alkalinity rises, this effect is reversed at high concentrations; the half-life of this material is 2 min. in 1N NaOH and is increased to 83 hours in 20N NaOH [031].

*OTHER PHYSICAL DATA:
Pleasant odor in concentrations of less than 2 ppm; pungent odor at higher concentrations
Critical temperature: -12.1 C
Critical pressure: 53.8 atm
Heat of formation: 34.4 kcal/mole @ 25 C
Freezing point: -192 C
Refractive index (liquid): 1.2226
Density (gas): 2.144 g/L @ 0 C [017,031,042]

-TOXICITY
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*NIOSH REGISTRY NUMBER: RS8225000

*TOXICITY:

typ. dose	mode	specie	amount	units	other
LC50	ihl	cat	34500	ppb/3H	
LC50	ihl	gpg	24800	ppb/3H	
LC50	ihl	ham	10500	ppb/4H	
LCLo	ihl	hmn	50	ppm/30M	
TCLo	ihl	hmn	100	ppm/1M	
TCLo	ihl	hmn	1	ppm	
TCLo	ihl	hmn	200	ppb/3H	
TCLo	ihl	hmn	600	ppb/2H	
TCLo	ihl	man	1860	ppb/75M	
LC50	ihl	mus	12600	ppb/3H	
LC50	ihl	rat	4800	ppb/4H	
LC50	ihl	rbt	36	ppm/3H	

*AQTX/TLM96: Not available

*SAX TOXICITY EVALUATION:

THR: High irritant via inhalation and to skin, eyes and mucous membranes. An experimental neoplastigen via inhalation. Affects the central nervous system. Mutation data.

*CARCINOGENICITY:

Tumorigenic Data:

TCLo: ihl-mus 5 ppm/2H/75D-I

TC : ihl-mus 608 ug/m3/24W-I

*MUTATION DATA:

test	lowest dose	test	lowest dose
cyt-ckn:fbr	1 ug/L/30M	cyt-ham-ihl	200 ppb/5H
cyt-hmn-ihl	500 ppb/6H	cyt-hmn:leu	7230 ppb/1H
cyt-hmn:oth	8 ppm/5M-C	cyt-rat-ihl	28 mg/m3/5D-C
dnd-esc	500 ug/L	dnd-mmo	70 pph
dni-ham:lng	2 ppm/1H	dnr-esc	50 ppm/30/M
dlt-oin-ihl	30 ppm/3H-C	mmo-esc	100 ppb/20/M
otr-ham-emb	5 ppm	otr-mus:fbr	5 ppm
sce-hmn:lng	250 ppb/1H-C		

*TERATOGENICITY:

Reproductive Effects Data:

TCLo: ihl-rat 1040 ppb/24H (6-9D preg)

TCLo: ihl-rat 1500 ppb/24H (17-20D preg)

*STANDARDS, REGULATIONS & RECOMMENDATIONS:

OSHA: Federal Register (1/19/89) and 29 CFR 1910.1000 Subpart Z
Transitional Limit: PEL-TWA 0.1 ppm [610]
Final Limit: PEL-TWA 0.1 ppm; STEL 0.3 ppm [610]

ACGIH: TLV-Ceiling Limit 0.1 ppm [610]

NIOSH Criteria Document: None

NFPA Hazard Rating: Health (H): None
Flammability (F): None
Reactivity (R): None

*OTHER TOXICITY DATA:
Skin and Eye Irritation Data:
eye-rbt 2 ppm/4H
Review: Toxicology Review-4
Status: EPA Genetox Program 1986, Negative:In vivo cytogenetics-nonhuman bone marrow
EPA Genetox Program 1986, Negative: In vivo SCE-nonhuman
EPA Genetox Program 1986, Inconclusive: In vivo cytogenetics-nonhuman lymphocyte
EPA Genetox Program 1986, Inconclusive: In vitro cytogenetics-human lymphocyte
EPA Genetox Program 1986, Inconclusive: In vivo cytogenetics-human lymphocyte
EPA Genetox Program 1986, Inconclusive: Cytogenetics-male germ cell
EPA TSCA Chemical Inventory, 1986
EPA TSCA Test Submission (TSCATS) Data Base, June 1987
Meets criteria for proposed OSHA Medical Records Rule
IDLH Level: 10 ppm

-OTHER DATA (Regulatory)

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*PROPER SHIPPING NAME (IATA): Liquefied gases, toxic, n.o.s.
(Ozone)

*UN/ID NUMBER: UN1955

*HAZARD CLASS: 2 SUBSIDIARY RISK: 6.1 PACKING GROUP:

*LABELS REQUIRED:

*PACKAGING: PASSENGER: PKG. INSTR.: Forbidden MAXIMUM QUANTITY: Forbidden
CARGO : PKG. INSTR.: Forbidden MAXIMUM QUANTITY: Forbidden

*SPECIAL PROVISIONS: A2

*USES:
Purification of drinking water; industrial waste treatment; deodorization of air and sewage gases; bleaching waxes, oils, wet paper and textiles; production of peroxides; bactericide; oxidizing agent in several chemical processes (acids, aldehydes, ketones from unsaturated fatty acids); steroid hormones; removal of chlorine from nitric acid; and oxidation of phenols and cyanides.

*COMMENTS:
This compound is found in the atmosphere in varying proportions since it is produced continuously in the outer layers of the atmosphere by the action of solar UV radiation on the oxygen of the air. It is formed locally in the air from lightning. It inhibits penetration of UV radiation. It also occurs in automobile engines and by electrolysis of alkaline perchlorate solutions.

-HANDLING PROCEDURES

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*ACUTE/CHRONIC HAZARDS:
This compound is irritating and injurious at concentrations >1 ppm [102]. It may cause severe irritation of the respiratory tract and eyes [031,042,102].

*MINIMUM PROTECTIVE CLOTHING:
If Tyvek-type disposable protective clothing is not worn during handling of this chemical, wear disposable Tyvek-type sleeves taped to your gloves.

*RECOMMENDED GLOVE MATERIALS:
Recommended Glove Type For Use With Neat (Undiluted) Chemical:
Recommendations based on permeation test results are made for handling the neat (undiluted) chemical. If this chemical makes direct contact with your glove, or if a tear, puncture or hole develops, replace them at once.

Suggested Glove Type(s) (RAD): No information available

*RECOMMENDED RESPIRATOR:
When working with this chemical, wear a NIOSH-approved full face positive pressure supplied-air respirator or a self-contained breathing apparatus (SCBA). [651]

*OTHER: Not available

*STORAGE PRECAUTIONS:
You should store this material under ambient temperatures.

*SPILLS AND LEAKAGE:
This chemical should be used in a fume hood. If a leak occurs, FIRST REMOVE ALL SOURCES OF IGNITION, then the main valve of the gas cylinder should be turned off and all personnel evacuated. Do not reenter the contaminated area until the Safety Officer (or other responsible person) has verified that the area has been properly ventilated.

*DISPOSAL AND WASTE TREATMENT: Not available

-EMERGENCY PROCEDURES
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*SKIN CONTACT:
CAUTION: Exposure of skin to compressed gases may result in freezing of the skin. Treatment for frostbite may be necessary.

Remove the victim from the source of contamination. IMMEDIATELY wash affected areas gently with COLD water (and soap, if necessary) while removing and isolating all contaminated clothing. Dry carefully with clean, soft towels.

If symptoms such as inflammation or irritation develop, IMMEDIATELY call a physician or go to a hospital for treatment.

*INHALATION:
IMMEDIATELY leave the contaminated area; take deep breaths of fresh air. IMMEDIATELY call a physician and be prepared to transport the victim to a hospital even if no symptoms (such as wheezing, coughing, shortness of breath,

or burning in the mouth, throat, or chest) develop.

Provide proper respiratory protection to rescuers entering an unknown atmosphere. Whenever possible, Self-Contained Breathing Apparatus (SCBA) should be used; if not available, use a level of protection greater than or equal to that advised under Respirator Recommendation.

*EYE CONTACT:

First check the victim for contact lenses and remove if present. Flush victim's eyes with water or normal saline solution for 20 to 30 minutes while simultaneously calling a hospital or poison control center.

Do not put any ointments, oils, or medication in the victim's eyes without specific instructions from a physician.

IMMEDIATELY transport the victim after flushing eyes to a hospital even if no symptoms (such as redness or irritation) develop.

*INGESTION:

This compound is a gas, therefore inhalation is the first route of exposure.

*SYMPTOMS:

Exposure to a 1 ppm concentration of this compound may result in headache and irritation of the eyes and upper respiratory tract. Symptoms disappear after leaving the exposure [042]. Other symptoms include dryness of the nose, upset stomach or vomiting, pain in the chest, tiredness and lung damage [102]. This compound is a lung irritant capable of causing death from pulmonary edema (gross pulmonary edema is evident in mice exposed to concentrations >2 ppm). Long-term exposure may cause thickening of the terminal respiratory bronchioles. Chronic bronchitis, fibrosis and emphysematous changes are observed at concentrations slightly above 1 ppm. At concentrations of 0.25-0.75 ppm, exposure may cause shallow, rapid breathing, decrease in pulmonary compliance, cough, tightness of the chest and dryness of the throat. It also increases sensitivity of the lung to bronchoconstrictors such as histamine, acetylcholine and allergens [406]. People with obstructive lung diseases showed increased breathing resistance, increased oxygen consumption and decreased arterial oxygen concentration when exposed to this compound. Other symptoms include reduced visual acuity, increased peripheral vision, decreased night vision and altered balance of muscles controlling the position of the eye [301]. Exposure has also caused dyspnea, dermatitis, lacrimation and somnolence [015].

-SOURCES

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UNIFORM FIRE CODE APPENDIX II-I
OZONE GAS GENERATION EQUIPMENT

1. SCOPE

Equipment having a maximum ozone-generating capacity of 1/2 pound or more over a 24-hour period shall be in accordance with this appendix.

EXCEPTION: Ozone-generation equipment used in Group R, Division 3 Occupancies.

2. DEFINITIONS

For the purpose of this appendix, certain terms are defined as follows:

OZONE GENERATOR is equipment which causes the production of ozone.

3. STANDARDS

The following standards are intended for use as a guide in the design, fabrication, testing and use of equipment regulated by this appendix:

Standard 250, Enclosures for Electrical Equipment - National Electric Manufacturers Ass.
2101 L. Street, N.W., Suite 300
Washington, DC 20037

4. LOCATION

(a) General. Ozone generators shall be located in approved cabinets or ozone generator rooms in accordance with this section.

EXCEPTION: A generator within an approved pressure vessel need not be in a cabinet or ozone generator room when located outside of buildings.

(b) Cabinets. Ozone cabinets shall be constructed of approved materials compatible with ozone in accordance with nationally recognized standards. Cabinets shall display an approved sign stating, OZONE GAS GENERATOR - HIGHLY TOXIC - OXIDIZER. See section 2.304(b).

Cabinets shall be braced for seismic activity in accordance with the Building Code.

Cabinets shall be mechanically ventilated with a minimum of six air changes per hour. Exhausted air shall be directed to a treatment system designed to reduce the discharge concentration of the gas to one half of the IDLH value at the point of discharge to the atmosphere.

The average velocity of ventilation at makeup air openings with cabinet doors closed shall be not less than 200 feet per minute.

(c) Ozone Generator Rooms. Ozone generator rooms shall be mechanically ventilated with a minimum of six air changes per hour. Exhausted air shall be directed to a treatment system designed to reduce the discharge concentration of gas to one half of the IDLH value at the point of discharge. Alternately, the ozone generator room shall be equipped with a continuous gas-detection system which will shut off the generator and sound a local alarm when concentrations above the permissible exposure limit occur.

Ozone generator rooms shall not be normally occupied, and such rooms shall be kept free of combustible and hazardous material storage. Rooms access doors shall display an approved sign stating, OZONE GAS GENERATOR - HIGHLY TOXIC - OXIDIZER.

5. PIPING AND FITTINGS

(a) General. Piping, valves, fitting and related components used to convey ozone shall be in accordance with this section.

(b) Secondary Containment. Secondary containment, such as double-walled piping or exhausted enclosures, shall be provided for piping valves, fittings and related components. Secondary containment shall be capable of directing a sudden release to an approved treatment system.

EXCEPTION: Welded stainless steel piping and tubing.

(c) Materials. Materials shall be compatible with ozone and shall be rated for the design operating pressures.

(d) Identification. Piping shall be identified "Ozone Gas--Highly Toxic--Oxidizer."

6. AUTOMATIC SHUTDOWN

Ozone generators shall be designed to automatically shut down under the following conditions:

(a) When the dissolved ozone concentration in the water being treated is above saturation when measured at the point where the water is exposed to the atmosphere.

(b) When the process using generated ozone is shut down.

(c) Failure of the ventilation system for the cabinet or ozone-generator room.

(d) Failure of the gas-detection system.

7. MANUAL SHUTDOWN

Manual shutdown controls shall be provided at the generator and, if in a room, within 10 feet of the main exit door.

APPENDIX D - LABORATORY AND FIELD TRIAL RESULTS USING OZONE FOR WEED CONTROL

FIELD TRIAL CONTROL OF *CYPERUS ROTUNDUS* (PURPLE NUTSEDGE) WITH OZONE AND AMMONIA GAS

Collaborators: Alan Pryor, SoilZone, Inc., Dave Bayer, UC Davis-Weed Sci.

BACKGROUND

Methyl bromide very effectively controls weed seed germination and sprouting from nutsedge tubers. Proposed alternative fungicides and nematicides (primarily metam sodium and Telone) have little to no beneficial effect on weeds in general and nutsedge in particular. Preplant weed control under clear plastic mulch during solarization is also unpredictable due to the vagaries of climate and weather. Often, increases in temperature are sufficient to induce seed germination and tuber sprouting but insufficient to kill young, rapidly growing plants - thus exacerbating the problem. As an example, soil temperatures of 30 ° C. or higher stimulate sprouting of *Cyperus rotundus* (purple nutsedge) but it requires sustained temperatures in excess of 50 ° C to kill the tubers and sprouts. Control of nutsedge is particularly important in these cropping practices because the sharp points of new sprouts lance plastic mulch on the growing beds. The nutsedge is then able to grow up and through the plastic mulch destroying its integrity in the process. In the worst infestations, it can render the plastic mulch useless and require replacement prior to planting.

Previous testing using ozone as a soil treatment agent during the growing season demonstrated the potential phytotoxicity of ozone leaking from the soil to leaves of growing crop plants. Laboratory experiments were subsequently performed showing that growth of purple nutsedge could be controlled in the vegetative, growing stage if exposed to repeated, small daily doses over a 3 to 4 week period. This weed test species was chosen because it is the most persistent weed facing warm weather vegetable growers and is arguably the most difficult to control in US agriculture.

EXPERIMENTAL DESIGN

The experiment was designed to test the effects of either ammonia or ozone gas on purple nutsedge in the post-sprouting, vegetative stage in a manner consistent with current cropping practices. Growers using plastic mulch on beds in conjunction with either conventional fumigants or solarization typically have a minimum 30-day time period required after laying down the plastic mulch before planting can commence. This minimum amount of time is required to give fumigants time to disperse through the soil to less than phytotoxic concentrations or to allow for sufficient days of solarization to achieve the desired soil temperatures and duration. The treatment period for this experiment was thus set at 30 days. The application of the phytotoxic gas was made through drip tape beneath plastic mulch laying on the surface of conventional row crop beds. The enclosed space between the soil surface and the plastic mulch into which the weeds grow thus becomes the treatment area in which the plants are exposed to the phytotoxic gases injected through the drip tape.

Newly harvested purple nutsedge tubers were planted approximately 2" deep in an approximate checkerboard pattern (6" boxes) in 30 ft. long x 36" wide beds on 52" centers and covered with soil. The soil in the field was sandy loam that had lay fallow for 2 years. The presence of nutsedge had never been noted in the field. The field was thoroughly irrigated prior to ground preparation and soil moisture at planting was approximately 10%. Two lengths of Toro AquaTrax drip tubing (8 mil walls, 0.5 gph emitters on 12" spacing) were placed 18" apart on the bed surface along the length of the beds. One end of each length of drip tape was sealed and the other end fitted with a connector. Clear polyethylene plastic mulch (4 mil) was then immediately placed over the beds by hand, drawn tight, and sealed at the edges with dirt.

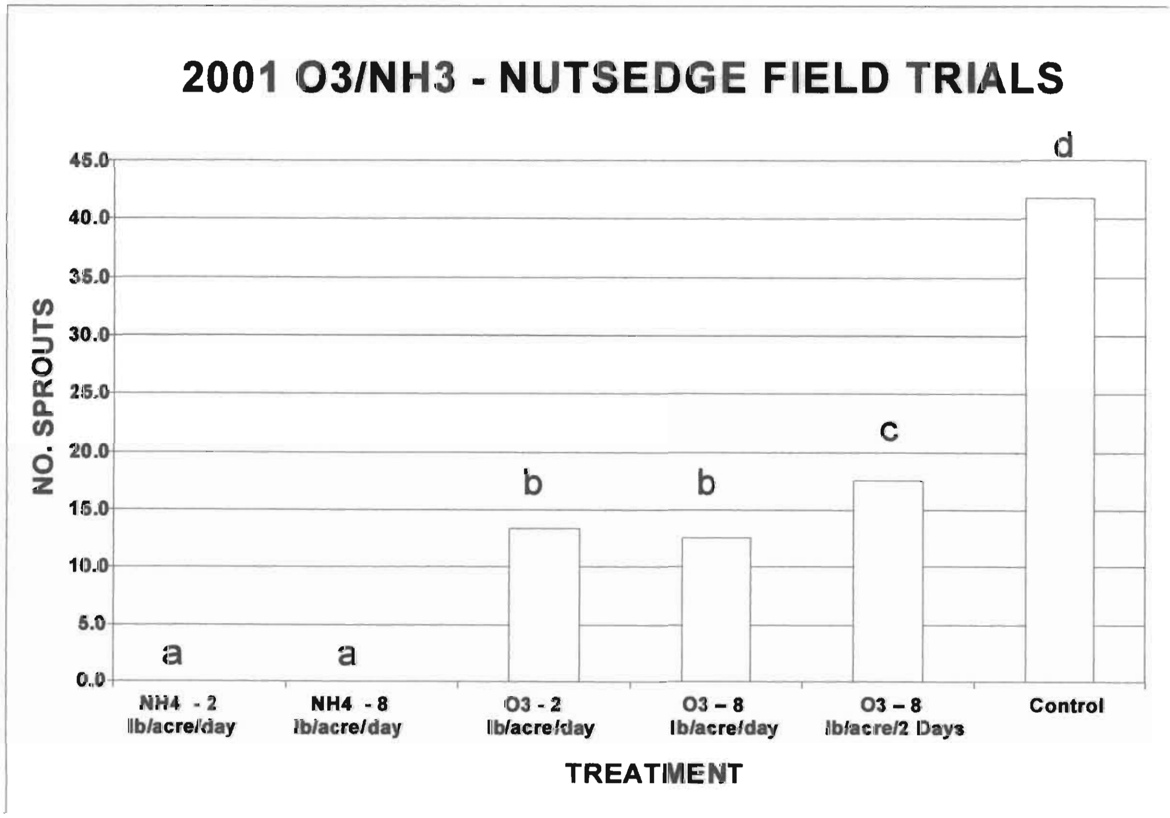
After 4 days, gas exposure treatments were begun with the largest sprouts at about 1" in height. Gas mixtures were injected under low pressure (7.5 psig) into the drip tape through the connector and forced out into the treatment space through the drip tape emitters. Ozone gas was injected at a concentration of 1% (w/w) in air and a flow rate of 40 scfh @ 7.5 psig into each bed. Treatment times were 10 minutes or

40 minutes per day or 40 minutes every other day. Ammonia gas was delivered into each bed at a flow rate of 1.0 l/min at 7.5 psig along with an air carrier gas at a flow rate of 40 scfh at 7.5 psig. Treatment times were 3 minutes or 12 minutes per day. Total equivalent dosages of both ozone and ammonia were either 2.0 lbs/acre/day or 8.0 lbs/acre/day. Replicate dosages of each gas treatment were applied simultaneously to each of three plots on a daily or every other day basis depending on the specified treatment. After 30 days of treatment, plots were allowed to sit for an additional 7 days and plastic mulch was removed. Three 12" diameter areas were evaluated in each 30 ft. plot at 7.5 ft., 15 ft., and 22.5 ft. along the centerline of the plot. All plants were removed from the identified circular areas and the numbers of nutsedge, grass, mallow, mustard, and lambs quarters sprouts were counted. After removing any attached mother tubers, the nutsedge sprouts from each circular area were then washed (to remove dirt), dried and weighed.

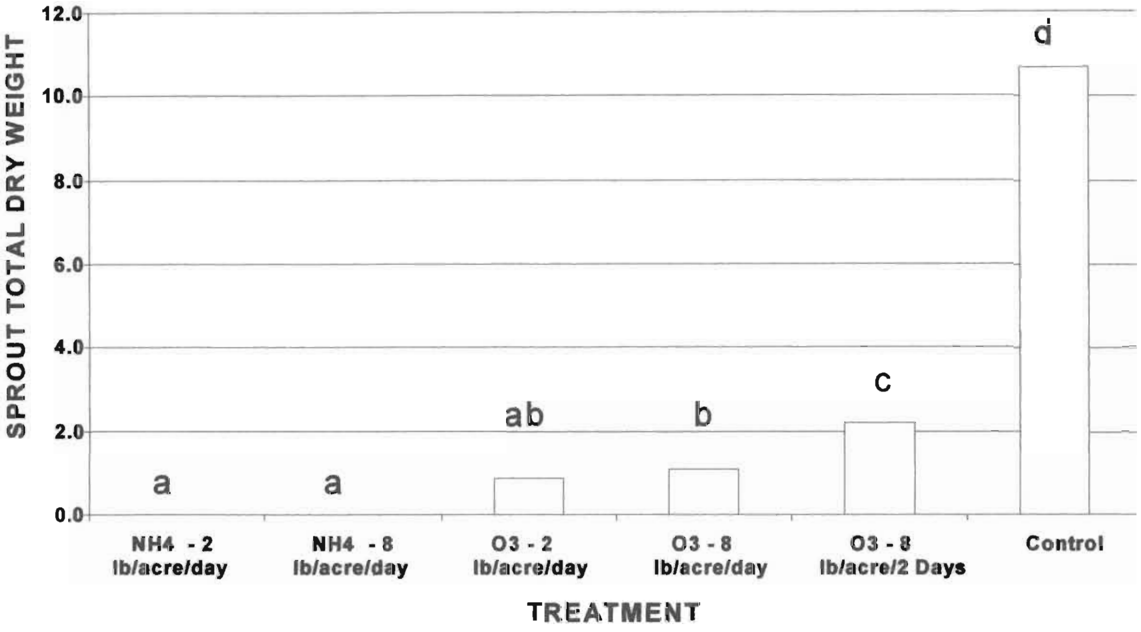
TREATMENT RESULTS - The following results were obtained 37 days after commencement of treatment and 7 days after completion of treatment. Estimated equivalent costs per acre are based on a net cost of ozone of $4.00/lb and of ammonia at $0.35/lb (costs include estimated associated labor costs for application). Note: See Discussion of Treatment Results for information on leakage of ammonia into the treatment space during the treatment periods that may have impacted final results.

Effect of Treatments on Purple Nutsedge - Average per 12" Diameter Circle

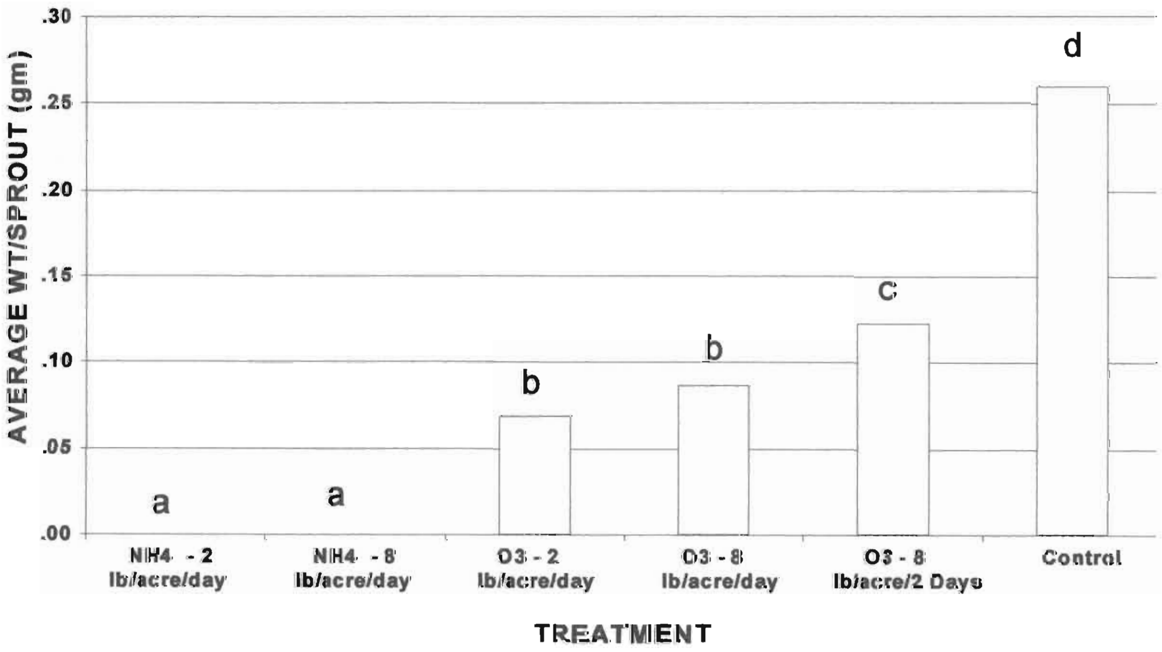
Treatments	No. Sprouts	Dry Wt	Dry Wt /Sprout	Total Equivalent Application Dose (lb aia)	Estimated Treatment Costs ($/Acre)
NH3 - 2 lb/acre/day	0.0	0.00	0.000	60	$21
NH3 - 8 lb/acre/day	0.0	0.00	0.000	240	$84
O3 - 2 lb/acre/day	13.3	0.88	0.069	60	$240
O3 - 8 lb/acre/day	12.6	1.07	0.087	240	$960
O3 - 8 lb/acre/2 days	17.6	2.21	0.123	120	$480
Untreated Control	41.8	10.70	0.260	0	$0


2001 O3/NH3 - NUTSEDGE FIELD TRIALS

2001 O3/NH3 - NUTSEDGE FIELD TRIALS



2001 O3/NH3 - NUTSEDGE FIELD TRIALS



Effect of Treatments on Other Plants - Average per 12" Diameter Circle

Treatments	Grasses	Mallow	Mustard	Lambs Quarters
NH3 - 2 lb/acre/day	0 -a	0 -a	0 -a	0 -a
NH3 - 8 lb/acre/day	0 -a	0 -a	0 -a	0 -a
O3 - 2 lb/acre/day	0 -a	0 -a	0 -a	0 -a
O3 - 8 lb/acre/day	0 -a	0 -a	0 -a	0 -a
O3 - 8 lb/acre/2 days	0 -a	0 -a	0 -a	0 -a
Untreated Control	5.3 - b	0.3 - b	0.6 - b	0.9 - b

DISCUSSION OF TREATMENT RESULTS

Ozone - The daily doses (2.0 lb and 8.0 lb/acre) ozone treatment provided the best overall weed control of the three ozone treatments. These treatment reduced the number of nutsedge sprouts by about 70% and the overall nutsedge biomass by about 90% compared to untreated controls. Both reductions were statistically significant at the 95% confidence level. The 8 lb/acre treatment dosage applied every other day reduced the number of sprouts by 58% and the overall nutsedge biomass by 80% compared to untreated controls. These values were statistically less than the number of sprouts and total nutsedge biomass of the untreated control and statistically increased compared to the other two ozone treatments. Complete control of all other plant growth was achieved in the ozone treated plots except for a few small (< 6" diameter), stunted patches of bermuda grass on the edge of one of the plots treated with ozone every other day.

The most important field parameter determining the amount of ozone or ammonia required to effectively control nutsedge or other weeds under plastic is the volume of air space between the plastic and soil. This is because the depth of this air gap directly determines volume of the enclosed treatment space and thus the ultimate concentration of an injected gas upon dilution. Because the plastic mulch was applied by hand for this experiment, a certain amount of looseness was present as the mulch lay over the surface of the beds. This increased the volume of the treatment space compared to if plastic were laid down very tightly with a mechanical device, as is the conventional practice. If a 0.25 " gap is otherwise acheived compared to the estimated 0.5" gap maintained during the course of this experiment, the treatment space volume would be reduced by half and the amount of applied ozone necessary to achieve the desired concentration would also be reduced by half.

Ammonia - The ammonia treatments provided 100% control of all plant growth. These results may be erroneous, however, due to valve leakage possibly resulting in excess ammonia exposure on 3 days of the treatment process. The ammonia gas used for treatment was delivered from a pressurized tank equipped with a manual shutoff valve provided as part of the equipment by the supplier. To minimize leakage into the external environment necessitated by changing hoses during the treatment process, all hoses connecting the tank to the drip tape beneath the plastic on the beds was continuously connected. Through day 15 of the treatment process, no leakage was detected from the valve into the tubing (and thus into the treatment space). On day 18, however, it was observed that the shutoff valve was not tightly sealing upon closing and indeterminate amounts of ammonia were leaking into the treatment space. The problem was fixed and no subsequent leakage occurred. Although the overall effect this leakage had on the growth of nutsedge cannot be determined, little nutsedge growth was observed prior to when this leakage may have occurred.

Although ammonia is utilized in many agricultural applications directly as a fertilizer (either shanked into soil or added to irrigation water), excess levels in the soil are phytotoxic to all plants. The soil in the ammonia treated plots had a noticeable smell of ammonia after the plastic had been removed possibly indicating phytotoxic concentrations. Although very positive and encouraging, the nutsedge control results obtained with ammonia obtained in this field trial need to be replicated before they can be viewed conclusively. Further, the effects of the treatment on subsequent plant growth needs to be determined. If excess ammonia does accumulate in the upper soil surfaces during the treatment process, seeding the soil prior to application with relatively inexpensive ammonia oxidizing bacteria that are commercially available should speed the conversion of excess ammonia to nitrate that can then be utilized as a rapid uptake fertilizer.

POTENTIAL APPLICIBILITY AND INTEGRATION INTO CURRENT CROPPING PRACTICES

This technology will lend itself well toward winter vegetable growers in the southeast US and California and Florida strawberry growers. Both types of growers routinely use plastic mulch covering raised beds in conjunction with surface drip tape. As such, with the exception of the ozone generating equipment or a tank of pressurized ammonia gas, no additional materials would be required for the in-field delivery system on a farm. The technology would also work very well with solarization or conventional fumigants because the duration of time required for successful solarization (6-10 weeks during late summer/early fall) or following fumigation would allow the ozone to be applied repeatedly without cutting in to a farmer's normal planting and harvesting cycles. As more and more farmers are forced to switch from methyl bromide fumigation, nutsedge control in winter vegetables and volunteer regrowth from the prior year's roots in strawberry fields will become increasingly problematic. The use of ozone or ammonia holds good potential for providing a functionally effective, economically viable, and environmentally benign alternative.

LABORATORY CONTROL OF *CYPERUS ROTUNDUS* (PURPLE NUTSEDGE) WITH OZONE GAS

Collaborators: Alan Pryor, SoilZone, Inc., Dave Bayer, UC Davis-Weed Sci.

BACKGROUND

Previous testing using ozone as a soil treatment agent during the growing season demonstrated the potential phytotoxicity of ozone to growing crop plants. Experiments were designed to determine if ozone treatments could be used to specifically control undesirable weed growth. The test species, *Cyperus rotundus* (purple nutsedge), is the most persistent weed facing warm weather vegetable growers and is arguably the most difficult to control in US agriculture. For growers using plastic mulch, the sharp points of new sprouts lance plastic mulch on the growing beds. The nutsedge is then able to grow up and through the plastic destroying its integrity in the process. Although solarization can control many pests in soil, its effectiveness against purple nutsedge has been very sporadic. This is because soil temperatures of 30° F. or higher stimulate sprouting of purple nutsedge but it requires sustained temperatures in excess of 35° F to kill the tubers and sprouts. The following laboratory tests were performed to determine the effectiveness of ozone gas in controlling young nutsedge sprouts when injected into an enclosed space.

EXPERIMENTAL DESIGN

Newly harvested nutsedge tubers were planted approximately 1" deep in 6" pots. Tubers were placed in a square pattern with an additional tuber in the center for a total of 5 tubers per pot. Plants were placed in a greenhouse maintained at approximately 90° F during daylight hours and 70° F during night hours. After 4 days treatments were begun with the largest sprouts at about 1 - 2" in height.

Ozone exposure was accomplished by placing 300 ml plastic containers in an inverted manner on the top of the 6" pots. In this manner a tight seal between the pot and container was maintained. Ozone was injected at the rate of 200 ml per minute into the enclosed space thus formed through a bulkhead inlet situated on the top of the inverted container. Replicate dosages were applied to each of three plants at 1% or 5% O3 for 5 minutes or 20 minutes on a daily or every other day basis. Upon completion of each daily ozone application, the containers were immediately removed and the pots returned to the greenhouse until the next application the following day.

After 15 days and again after 30 days, treatment of one of the 3 replicated treatments was terminated for continued observation. The last of the three replicated treatments were terminated after 45 days for continued observation.

RESULTS AFTER 60 DAYS

The following measurements were made 60 days after commencement of ozonation.

15-Day Treatments

Treatments	Frequency	No. of Sprouts	Avg. Sprout Height
Untreated Control	None	23 Avg.	6 - 10"
1% O3 - 5 Minutes	Every Other Day	9	4 - 6"
1% O3 - 20 Minutes	Every Other Day	10	4 - 6"
5% O3 - 5 Minutes	Every Other Day	10	4 - 6"
5% O3 - 20 Minutes	Every Other Day	7	4 - 6"
1% O3 - 5 Minutes	Daily	10	4 - 6"
1% O3 - 20 Minutes	Daily	9	4 - 6"
5% O3 - 5 Minutes	Daily	6	4 - 6"
5% O3 - 20 Minutes	Daily	6	4 - 6"

30-Day Treatments

Treatments	Frequency	No. of Sprouts	Avg. Sprout Height
Untreated Control	None	23 Avg.	6 - 10"
1% O3 - 5 Minutes	Every Other Day	9	2 - 5"
1% O3 - 20 Minutes	Every Other Day	2	1 - 4"
5% O3 - 5 Minutes	Every Other Day	0	0
5% O3 - 20 Minutes	Every Other Day	0	0
1% O3 - 5 Minutes	Daily	0	0
1% O3 - 20 Minutes	Daily	0	0
5% O3 - 5 Minutes	Daily	0	0
5% O3 - 20 Minutes	Daily	0	0

45-Day Treatments

Treatments	Frequency	No. of Sprouts	Avg. Sprout Height
Untreated Control	None	23 Avg.	6 - 10"
1% O3 - 5 Minutes	Every Other Day	0	0
1% O3 - 20 Minutes	Every Other Day	0	0
5% O3 - 5 Minutes	Every Other Day	0	0
5% O3 - 20 Minutes	Every Other Day	0	0
1% O3 - 5 Minutes	Daily	0	0
1% O3 - 20 Minutes	Daily	0	0
5% O3 - 5 Minutes	Daily	0	0
5% O3 - 20 Minutes	Daily	0	0

CONCLUSIONS

All of the treated plants from the 15-day cycle showed significant leaf oxidation damage upon termination of ozone application. However, within 1 week all of the treated pots showed renewed growth, albeit at a substantially reduced rate compared to untreated controls.

Following completion of the 30-day ozonation cycle, only the two treatments using 1% ozone every other day showed renewed sprouting within several weeks of termination of treatments. All other treatment showed complete control with no new sprouting within the 60-day monitoring period. All of the 45-day treatment cycle plants similarly showed 100% control with no sprouting within the 2-week period (day 60) following termination of treatment.

POTENTIAL ECONOMICS

The important field parameters determining the amount of ozone required to effectively control nutsedge or other weeds under plastic is the volume of air space between the plastic and soil and the turnover rate of air necessary to build and hold the desired concentration of ozone for the desired time. We assumed a 0.25" gap between the soil and plastic and that we needed 10 volume turnovers per hour to build and hold the desired concentrations.

If these assumptions are correct, the total cumulative amount of ozone applied per acre for each treatment for the 15-, 30-, and 45-day cycles are shown in top of the following spreadsheet. On the bottom is the price per acre a farmer could expect to pay if their total cost per pound is $4.00. This is a broad assumption. The electricity required to make a pound of ozone is about 12 kwh/lb which would cost $1.20 at $.10/kwh. The remaining costs of $2.80/lb would include equipment amortization and labor to operate the equipment as well as maintenance and repair.

There are a number of the 30-day cycle treatments that can be applied for less than $200/acre that have not shown any regrowth to date. Thus we believe there is a strong potential for functional control and economic viability.

POTENTIAL INTEGRATION INTO CURRENT CROPPING PRACTICES

This technology lends itself well toward winter vegetable growers in the southeast US and California and Florida strawberry growers. Both types of growers routinely use plastic mulch covering raised beds in conjunction with surface drip tape. As such, with the exception of the ozone generating equipment, no additional materials would be required for the in-field delivery system on a farm. The technology would also work very well with solarization because the time of year and duration required for successful solarization (6-10 weeks during late summer/early fall) would allow the ozone to be applied repeatedly without cutting in to a farmer's normal planting and harvesting cycles. As more and more farmers are forced to switch from methyl bromide fumigation, nutsedge control in winter vegetables and volunteer regrowth from the prior year's roots in strawberry fields will become increasingly problematic. The use of ozone holds good potential for providing a functionally effective, economically viable, and environmentally benign alternative.

NUTSEDGE CONTROL WITH OZONE - ESTIMATED DOSAGE & COSTS

Total Dosage - Lbs. O3 / Acre

Treatment	Lbs. O3 / Application	15 Day		30 Day		45 Day		Treatment Length
		Every Day	Every Other Day	Every Day	Every Other Day	Every Day	Every Other Day	Treatment Frequency
		15	8	30	15	45	23	Number of Applicatio
1% for 5 Minutes	0.4	6	3.2	***12***	6	***18***	***9.2***	
1% for 20 Minutes	1.6	24	12.8	***48***	24	72	***36.8***	
5% for 5 Minutes	2	30	16	60	***30***	90	***46***	
5% for 20 Minutes	8	120	64	240	120	360	184	

Total Cost Range ($) / Acre **Assumed Cost/Lb. O3 - $ 4.00**

Treatment	Lbs. O3 / Application	15 Day		30 Day		45 Day		Treatment Length
		Every Day	Every Other Day	Every Day	Every Other Day	Every Day	Every Other Day	Treatment Frequency
		15	8	30	15	45	23	Number of Applicatio
1% for 5 Minutes	0.4	$ 24.00	$ 12.80	***$ 48.00***	$ 24.00	***$ 72.00***	***$ 36.80***	
1% for 20 Minutes	1.6	$ 96.00	$ 51.20	***$ 192.00***	$ 96.00	$ 288.00	***$ 147.20***	
5% for 5 Minutes	2	$ 120.00	$ 64.00	$ 240.00	***$ 120.00***	$ 360.00	***$ 184.00***	
5% for 20 Minutes	8	$ 480.00	$ 256.00	$ 960.00	$ 480.00	$ 1,440.00	$ 736.00	

Bold-Italics represents treatments that can be applied for less than $200/acre and showed 100% control