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April 29, 2013

Laura Quakenbush, Ph.D.
Pesticide Registration Coordinator
Colorado Department of Agriculture
700 Kipling Street, Suite 4000
Lakewood, Colorado 80215

RE: Submission of Risk Assessment for Ozone Exposures Associated With the Use of the EOI Sanitizing Spray Bottle, SB-100-Industrial

Dear Laura:

As part of the documentation required by the Colorado Department of Agriculture for consideration of registration of a device, I am providing this summary of our risk assessment that focused on exposures to ozone in indoor settings associated with the use of the EOI Sanitizing Spray Bottle (SB 100-Industrial). The full report, entitled "Risk *Assessment of Exposures to Ozone Resulting From Consumer and Professional Use of the EOI Activated Oxygen Sanitizing Spray Bottle*", is attached.

The typical anticipated concentration of ozone in aqueous solution as dispensed by the EOI Sanitizing Spray Bottle (SB-Industrial) is on the order of 0.5 to 1 ppm. Design targets for the device would theoretically allow for dispensing of large diameter aerosols containing a maximum of approximately 1 to 2 ppm ozone in aqueous solution. In order to be conservative, this maximum use concentration range was the focus of our risk assessment for professional and consumer uses of the device. With respect to professional use (e.g., by hotel housekeeping staff), the risk assessment focused on inhalation and dermal exposures to ozone during use of the EOI Sanitizing Spray Bottle (SB-Industrial). The risk assessment for consumer uses focused on inhalation and dermal exposure to ozone during and following use of the EOI Sanitizing Spray Bottle (SB-Industrial) in residential settings, plus oral ingestion exposures from use of the EOI Sanitizing Spray Bottle (SB-Industrial) as a food treatment spray and for treatment of food-contact surfaces (indirect dietary exposures). The indirect dietary exposure pathway has been added to the risk assessment to be comprehensive. Even though the direct treatment of meat, poultry, fruits, and vegetables with ozone and ozonated water is approved by the USFDA, treatment of food contact surfaces is a future use of the EOI Sanitizing Spray Bottle (SB-Industrial) that is not being pursued by EOI at this time. Addition of this use to the risk assessment provides a complete view of exposures associated with future uses of the device.

The USEPA's Multi-Chamber Concentration and Exposure Model (MCCEM), which is a validated indoor air quality model, was used along with conservative assumptions for room volumes and air exchange rates to estimate the time-concentration profile of ozone in indoor air in a residential setting. The average indoor air level of ozone from use of the EOI Sanitizing Spray Bottle (SB-Industrial) ranged from 0.00123 to 0.00567 ppm, depending on the room of use for the device. These levels are only 1.5 to 7 percent of the National Ambient Air Quality Standards (NAAQS) of 0.08 ppm. The airborne concentrations of ozone are similarly low for professional uses of the EOI Sanitizing Spray Bottle (SB-Industrial), ranging from 3.4 to 21 percent of the OSHA PEL. Indoor ozone levels are predicted to dissipate rapidly following use.

Dermal exposures during use of the EOI Sanitizing Spray Bottle (SB-Industrial) are generally lower than those anticipated for inhalation exposures. Because of the general reactivity and non-specificity of ozone, a large portion of the dermal dose would be anticipated to react with proteins and lipids in the skin, resulting in no substantial effects. Ozone ingested from treated food, from food that contacts treated surfaces, and from object-to-mouth exposures would react harmlessly with food in the GI tract. Alkaline conditions in the small intestine would be anticipated to destroy any residual ozone. Based on available toxicological data and the limited exposures associated with inhalation, ingestion, and dermal contact with ozone resulting from use of the EOI Sanitizing Spray Bottle (SB-Industrial), all resulting exposures are anticipated to be without significant human health effects.

Please feel free to contact me if you any questions or comments.

Sincerely,

Gary Whitmyre, M.A., D.A.B.T.
Senior Director of Exposure and Risk Assessment

Cc: Alan C. Katz (toXcel)
Nicole F. Perkinson (toXcel)
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STUDY TITLE:

Risk Assessment of Exposures to Ozone
Resulting from Consumer and Professional Use of the
EOI Activated Oxygen Sanitizing Spray Bottle

AUTHOR:
Gary K. Whitmyre, M.A., D.A.B.T.

REPORT COMPLETED ON:
August 29, 2012

SPONSOR:
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EXECUTIVE SUMMARY

Background. Electrolytic Ozone Inc. (EOI) has developed an ozone generation cell integrated within a battery-powered spray bottle for sanitizing surfaces in commercial, institutional, and residential settings. The integrated cell uses proprietary technology to generate ozone *in situ* within the ozone treatment cell. The device is designed to reduce microbial contaminants on surfaces without the need to rinse. Design targets would allow for dispensing of large diameter aerosols containing up to a maximum of approximately 1.0 to 2.0 ppm ozone. EOI requested that ***toXcel*, LLC** determine whether end-use professional and consumer exposures to ozone through use of the EOI Activated Oxygen Sanitizing Spray Bottle present any significant human health risks. Professional users (e.g., hotel housekeeping staff) could be exposed via inhalation exposure to ozone and dermal contact with ozonated water during cleaning with the product. Consumers may be exposed to residual ozone in residential settings through volatilization from the treated surface(s) resulting in inhalation exposure for the consumer, through dermal contact with ozonated water, through ingestion of ozone applied to food directly as a rinse and transferred from treated food contact surfaces (e.g., kitchen counters) to food, and through object-to-mouth exposures from pacifiers and toys sanitized using the EOI spray bottle. Route-specific exposures were compared to available toxicological and regulatory benchmarks.

Physical-Chemical and Fate Properties of Ozone. Ozone is a reactive gas and a strong oxidizing agent under ambient conditions. There are two categories of reactions for ozone with chemicals in water or on treated surfaces: (1) indirect reactions in which the decay of ozone leads to formation of secondary free radicals such as hydroxyl radicals; and (2) direct reactions in which ozone reacts with double-bond carbons or electron-supplying moieties such as hydroxyl or amine groups. In the case of indirect reactions, free radicals convert organic chemicals to other short-lived free radical intermediates. These intermediates eventually react with another free radical, resulting in termination of the chain reaction. In contrast with indirect reactions, which are rapid, direct reactions can take place on a somewhat longer timescale.

Background on Toxicology of Ozone. The effects of short-term and long-term inhalation exposures to ozone are well established based on studies in human volunteers and in laboratory animals. Short-term inhalation exposures to airborne ozone at a few tenths of 1 ppm can cause reversible symptoms, including irritation of the mucous membranes, dryness of the throat and coughing. Human subjects engaged in exercise activities and exposed briefly to levels of 0.12 to 0.4 ppm ozone experience reversible decrements in lung function, as measured by how much air they can exhale in a fixed time period. Chronic exposure of laboratory animals to ozone at concentrations slightly greater than 1 ppm for 6 hours per day for 1 year developed symptoms similar to bronchitis. In studies in mice and rats, administration of ozone by inhalation at 0.5 or 1 ppm produced inflammation and thickening of cells in the lungs of treated animals, but not at 0.12 ppm. ACGIH has set recommended standards for ozone in the workplace at 0.05 to 0.2 ppm, depending on the level of physical activity (and associated breathing rate) and daily duration of inhalation exposure. This range encompasses the National Ambient Air Quality Standard (NAAQS) of 0.08 ppm for 8 hours and 0.12 ppm for 1 hour.

Consumer Exposure Assessment. The consumer exposure assessment was based on a range of use rates for the EOI Activated Oxygen Sanitizing Spray Bottle of 70 to 90 ml of ozonated water per use for a residential bathroom and 140 ml for a residential kitchen. To be conservative it was assumed that 80 percent of the ozone on a treated surface would volatilize into the air. The remaining 20 percent of the starting amount of ozone was assumed to be consumed in reactions with other chemicals in the water or on the treated surface. Using standard assumptions for room volumes and air exchange rates, average airborne levels of ozone were estimated to range from 0.00123 to 0.00567 ppm, depending on the room of product use, for target ozone levels in water of 1 to 2 ppm. The exposure profile for most individuals using the EOI Activated Oxygen Spray Bottle would be a series of intermittent acute exposures declining over time, rather than a continuous exposure level, such as occurs with exposures to ambient air pollutants. Inhalation exposures are anticipated to make up 16 percent of the total exposure. Dermal exposures to ozone through skin contact during spraying and wiping of surfaces, and through handling food items rinsed with ozonated water, are estimated to be about 1 percent of the total exposure for the consumer. Oral exposures from direct treatment of fruits, vegetables, meat and poultry, and from transfer to food from treated contact surfaces (e.g., cutting boards), make up the bulk of all exposures – a combined 83 percent of total exposure for the adult consumer. Ingestion of ozone in food is generally-recognized-as-safe, or GRAS (USDA, 2002).

Worker Exposure Assessment. The worker exposure assessment was based on a hypothetical exposure scenario of hotel housekeeping staff cleaning bathrooms in 16 hotel suites per day. As with the consumer exposure assessment, it was assumed that 80 percent of the ozone on a treated surface would volatilize into the air. Using assumptions for hotel bathroom volumes, room air exchange rate, and human inhalation rates during light activity, daily inhalation exposures to ozone were estimated. Inhalation exposures to ozone for professional users are predicted to make up the bulk of professional use exposures (91 to 97 percent of the total exposure). Dermal exposures to ozone for workers from skin contact during spraying and wiping of surfaces are estimated to be only about 3 to 9 percent of the total exposure.

Risk Characterization. Available toxicological and regulatory benchmarks for ozone were not exceeded during or following use of the EOI Activated Oxygen Sanitizing Spray Bottle. The time-weighted average (TWA) airborne levels of ozone resulting from consumer use of the EOI spray bottle in residences are predicted to be only 1.5 percent to 7 percent of the NAAQS of 0.08 ppm. The anticipated TWA airborne levels of ozone associated with professional use of the EOI spray bottle by housekeeping staff are only 3.4 to 21 percent of the OSHA PEL of 0.1 ppm. The available benchmarks were not exceeded for either use scenario, even if it was assumed that 100 percent of the ozone becomes airborne. Dermal exposures during spraying and wiping of hard surfaces are lower than exposures via the inhalation route. Because of the general reactivity and non-specificity of ozone, a large portion of the dermal dose would be anticipated to react with proteins and lipids in the skin, resulting in minimal effects or no effects. Ozone ingested from treated food, from food that contacts treated surfaces, and from object-to-mouth exposures would theoretically react non-specifically with tissues and food in the GI tract. There is no available evidence that exposure of the GI tract to low levels of ozone would result in any irritation of tissues. Alkaline conditions in the small intestine would be anticipated to destroy any residual ozone. Based on available toxicological data and the limited exposures associated with inhalation, ingestion, and dermal contact with ozone resulting from use of the EOI spray bottle, the resulting exposures are anticipated to be without significant human health effects.

Risk Assessment of Exposures to Ozone Resulting From Consumer and Professional Use of the EOI Activated Oxygen Sanitizing Spray Bottle

I. INTRODUCTION

The structure of ozone (O_3) involves 3 oxygen atoms. Ozone is a naturally-occurring substance in the Earth's crust and atmosphere, and is generated by natural processes (e.g., lightning discharges). Ozone is effective for sanitizing, deodorizing, and bleaching, and has been used for purification of drinking water for over 100 years. Ozone is effective against bacteria and viruses, and is used in some municipal drinking water treatment facilities. Electrolytic Ozone Inc. (EOI) has developed an ozone cell integrated into a battery-powered spray bottle for sanitizing hard surfaces in residential, commercial, and institutional settings. The EOI ozone generation cell uses proprietary technology, involving a specially-designed electrolytic device to generate ozone *in situ* in water within a spray bottle. The patented process that is involved is known as the Active Diamond Electrolytic Process Technology (ADEPT). The purpose of the EOI Activated Oxygen Sanitizing Spray Bottle is to reduce microbial contaminants on surfaces by treating them with ozonated water. The use sites could include residential, commercial, and institutional settings. The amount of ozone generated by the EOI ozone cell varies depending on a number of factors, including the quality of the starting water, temperature, mineral content, level of contamination, and the applied electrical voltage and current. The recommended hardness of the water is $\leq$ 250 ppm $CaCO_3$, and the recommended temperature range of the water for use is 40 °F (4 °C) to 86 °F (30 °C). Design levels would allow for attaining ozone levels of 1 to 2 ppm as dispensed from the spray bottle for application to surfaces. The actual concentration of ozone present in the dispensed ozonated water from the EOI unit also depends on pH, turbidity, organic matter, and metals such as iron and manganese (USEPA 2011a). The water reservoir holds 350 ml. The device is charged through a built-in AC adaptor. Typically, a single charge would be sufficient to power dispensing of about 6 refills of the water reservoir. The SB-100 industrial version and the residential use version of the EOI Activated Oxygen Sanitizing Spray Bottle are each intended for sanitizing non-porous hard surfaces, including tables, counters, other kitchen surfaces, bathroom surfaces, doors, drink dispensers, and other human contact areas. The ozonated water produced by the EOI spray bottle unit is a strong oxidant that can achieve a better than 99.9 percent pathogen kill rate. The ozonated water dispensed by the EOI spray bottle can kill common pathogens, including *E. coli*, Salmonella species, and MRSA without the use of harmful chemicals. Importantly, because of the non-specific mode of action of ozonated water as an oxidizer, pathogenic organisms are not able to develop resistance to treatment with ozonated water dispensed from the EOI spray bottle.

EOI requested that ***toXcel,* LLC** determine whether consumer (non-professional) and worker (professional) exposures to ozone from use of the EOI Activated Oxygen Sanitizing Spray Bottle present any significant human health risks. What follows is an overview of the physical, chemical, and fate properties of ozone (Section II); information on the available toxicological data and regulatory benchmarks for ozone (Section III); methods, assumptions, and results for modeling human exposures to ozone through the use of the EOI spray bottle for consumers (Section IV) and workers (Section V); discussion (Section VI); conclusion (Section VII), and a complete section of reference citations (Section VIII).

II. PROPERTIES OF OZONE

A. Physical-Chemical Properties of Ozone

Ozone (O_3) is a gas under ambient conditions. The gaseous form is colorless to blue with a very pungent odor. Ozone has a relative vapor density of 2.144 at 0 °C (air = 1). It has a boiling point of -169 °F and a freezing point of -315 °F (BOC 1997). It has limited solubility in water, measured at 10 mg/liter, or 10 ppm, at 0 °C. Ozone can be flammable, but only at very high levels attained only under industrial settings. Ozone dissolved in water up to its limit of solubility is not flammable or hazardous.

B. Environmental Fate Summary

Ozone (O_3) is a powerful oxidizing agent. It is unstable in air, decaying to ordinary oxygen (O_2) with a half-life of about 30 minutes under ambient conditions. Ozone reacts with nitric oxide (NO) in the atmosphere to form nitrogen dioxide (NO_2) and oxygen. Ozone is formed naturally in the stratosphere; this layer is protective, filtering some of the harmful ultraviolet (UV) light. In the lower portions of the atmosphere, ozone is formed by the reaction of hydrocarbons and nitrogen oxides (NO_x), as catalyzed by sunlight.

The overall reactions of ozone with dissolved or suspended matter in water are 2-fold, involving both direct and indirect reactions. The indirect reaction pathway involves free radical species, which are molecules that have an unpaired electron. The first step in the indirect pathway involves decay of ozone resulting in formation of secondary radicals, such as hydroxyl radicals, the most common degradation product. The hydroxyl radical regains its missing electron from an organic molecule, converting it into a radical. This chain continues until the secondary radical reacts with another radical, resulting in a complete pairing of electrons and termination of the chain reaction. As a result, this pathway is complex and is influenced by a number of factors (Gottschalk, *et al.*, 2010). The overall stoichiometry of this reaction is that 3 ozone molecules produce 2 hydroxyl radicals and 4 oxygen molecules (Gottschalk, *et al.*, 2010). Due to reactivity, hydroxyl radicals have a very short half-life, less than 10 milliseconds (0.010 second) at an initial concentration of 10^{-4} moles/liter (Gottschalk, *et al.*, 2010). Bicarbonate, carbonate, and phosphate anions, which are commonly found in the environment, and tertiary butyl alcohols are efficient scavengers for hydroxyl radicals and, thus, can terminate the chain reaction. By comparison, the direct oxidation of organic chemicals by ozone is associated with somewhat slower rate constants. Ozone reacts fastest with organic molecules that contain unsaturated double-bonded carbon atoms, or with chemicals that contain electron-supplying moieties such as hydroxyl or amine groups. When ozone is subjected to alkaline conditions, it is destroyed more quickly because more hydroxyl radicals are present to react with ozone under high pH conditions (Gottschalk, 2010; USEPA 2011a). At pH values less than 7, the decomposition of ozone is slowed. The half-life of ozone at near-neutral pH in drinking water is typically less than 30 minutes (USEPA 2011a).

III. BACKGROUND ON TOXICOLOGY OF OZONE

A. Summary of Available Toxicology Data on Ozone

(1) *Effects of inhalation exposure to ozone*. The adverse effects of ozone on the respiratory tract are well established, and a National Ambient Air Quality Standard (NAAQS) exists for ozone. Ozone reacts with the lining of the lung, and can cause peroxidation of polyunsaturated fatty acids in the cells lining the lungs (NTP 1994). Removal of ozone by the lungs has been observed to have 91 percent efficiency, suggesting that nearly all of the inspired ozone is adsorbed by, or reacts with, cells and fluids lining the airway passages (NTP 1994). The effects of ozone in the respiratory tract of humans depends on a number of factors, including the concentration of ozone in the inspired air, the duration of exposure, and the level of activity of subjects. The latter affects the inhalation rate of individuals and, thus, the total volume of air and the dose of ozone inhaled during the exposure period. Researchers have used a number of markers to compare ozone dose and effect in animals and human, such as bronchiolar lavage (BAL) fluid markers (Hatch, *et al.*, 1988). Elevated levels of BAL protein were associated with exposure of 10 human subjects to 0.4 ppm ozone for 2 hours, during which the subjects had intermittent periods of heavy exercise. Exercise increases the effective dose to the deep lung. Damage to the terminal bronchioles is reversible following inhalation of single doses of ozone (Costa 2001). Exercising humans exposed to 0.12 to 0.4 ppm ozone experience reversible concentration-related decrements in forced expiratory volumes (FEV_1), which is a measure of lung function (Costa 2001). Airborne ozone concentrations exceeding a few tenths of a ppm[1] can cause occasional discomfort in exposed individuals in the form of headache, coughing, dryness of throat, and irritation of mucous membranes following exposures of short duration. Studies in welders indicate that 0.2 ppm is a No-Observed-Adverse-Effect-level (NOAEL) for pulmonary congestion when exposures are limited in duration (ACGIH, 2001). Chronic exposures of laboratory animals to ozone at concentrations slightly greater than 1 ppm for 6 hours per day for 1 year are known to cause bronchitis-like symptoms (BOC 1997). The odor threshold for ozone is about 0.02 ppm, which is an order of magnitude below short-term inhalation effect levels (Gottschalk, *et al.*, 2010). The symptoms from chronic exposure to ozone are similar to those from acute exposures, with impacts on the respiratory tract dependent on concentration, activity level, and duration of exposure. Some of the respiratory effects of ozone may be due to an inflammatory response (Costa 2001). Repeated dose studies in which rats were exposed to 0.12 to 0.25 ppm ozone for 12 hours per day showed hyperplasia of cells in the distal part of the lung. The National Toxicology Program (NTP) conducted subchronic and chronic studies of inhalation exposures to ozone. Mice (strain $B6C3F_1$) and rats (strain F344/N) were exposed to levels of 0, 0.5, or 1.0 ppm ozone in the subchronic 4-week studies and to 0, 0.12, 0.5, or 1.0 ppm zone in the chronic 2-year studies (NTP 1994). The exposure regimen was for 6 hours per day, 5 days per week for the duration of each study. Inflammation and metaplasia (thickening of cell layers) occurred in the lung of treated animals at doses of 0.5 and 1.0 ppm in the chronic and subchronic studies (NTP 1994). Adverse effects were not observed in rats and mice treated at a level of 0.12 ppm ozone in the NTP study (1994). Ozone has been listed as A4: Not classifiable as a human carcinogen (NLM 2011). In many studies to date, the severity of injury to the respiratory systems may depend on both the concentration of ozone and the duration

[1] For ozone, 1 ppm = 2 mg/m^3 @ 20 °C.

of exposure, although higher exposure levels may have more than proportional effects on the lung compared to low exposure levels. Long-term chronic exposures to a given level of ozone are typically more severe in frequency and intensity than short-term exposures to the same level. Although there are some epidemiological data, the presence of other ambient air pollutants in the studies limits the conclusions that can be drawn for ozone specifically. The most robust dose-response data on adult humans comes from chamber studies, in which human volunteers were exposed to ozone in controlled environments at known levels and for known durations of exposure. Most of these studies were conducted at exposure times of between 2 and roughly 6.6 hours, at concentrations ranging from 0.08 ppm to 1.5 ppm, and at various levels of physical activity. For 2 hour exposures, decrements in pulmonary function in human volunteers occurred above 0.2 ppm ozone. At very heavy exercise loads, exposures at or above 0.12 ppm resulted in statistically-significant decrements in lung function (ACGIH 2001). Human volunteers showed a transient 7.0 to 8.4 percent decrement in mean pulmonary function immediately following 6.6 hour exposures to 0.08 ppm ozone. These levels were not sufficient to cause overt symptoms in the volunteer human subjects.

(2) *Effects of orally ingested ozone*. Adequate toxicological data are not available for ozone for non-inhalation routes. Ozone is Generally-Recognized-As-Safe (GRAS) by the oral ingestion route. The Food and Drug Administration (FDA), per 21 CFR Section 173.368 *Ozone*, permits the use of ozone in the treatment, storage and processing of foods. Ozone is defined as an antimicrobial agent by FDA per 21 CFR Section 170.3(o)(2). 21 CFR Section 184.1563 permits a maximum level of 0.4 ppm (mg/liter) ozone in bottled water. Ozone is approved for use in the processing of meat and poultry as a secondary direct food additive and processing aid "in accordance with current industry standards of good manufacturing practice," per 21 CFR 173.368. Secondary direct food additives provide a "momentary technical effect" and any residuals that may carry over to the final product are not anticipated to have any effect. Ozone is permitted for use as part of the USDA's National Organic Program (NOP). Due to its high reactivity and high redox potential, ozone can directly oxidize organic compounds in water, as well as produce highly-reactive short-lived free radicals that can attack organic materials. Ozone rapidly degrades in water, leaving behind oxygen and minor amounts of oxidized by-products (Gottschalk, *et al.*, 2010).

(3) *Effects of dermal exposure to ozone*. Contact of high levels of gaseous ozone with skin may result in irritation of the skin (Gottschalk, *et al.*, 2010). Ozone exposure to the skin of laboratory animals at 8 ppm triggered oxidative stress responses (Valacchi *et al.* 2002). However, brief skin exposures to lower levels of ozone can assist in wound healing, for both acute wounds and for chronic wounds from infection (Valacchi *et al.* 2005; Kim *et al.* 2009). Material Safety Data Sheets (MSDSs) indicate low potential for skin irritation from short-term exposures to ozone or ozonated water (BOC 1997, DEL Ozone 2012). Dosimetry data for dermal effects on skin from ozonated water are limited. However, it is unlikely that ozone dissolved in water at the target levels of 1 to 2 ppm would be sufficiently concentrated to result in any symptoms from the brief dermal contact times resulting from use of ozonated water. Ozone present in ozonated water will partially "strip" out of the water to air, which will reduce the concentration of ozone available to contact the skin. This reduction in the dissolved amount, the low concentrations in water, and the running off and removal of ozonated water from the skin will reduce the amount of ozone that may penetrate skin.

(4) *Ocular exposure to ozone*. Individuals exposed to ozone may experience eye irritation at or above airborne levels of 0.1 ppm ozone (Gottschalk, *et al.*, 2010). NSF Standard 50 requires that the finished water(s) in pools, spas, and recreational waters contain no more than 0.1 ppm ozone. This standard may relate to the issue of eye irritation for those in contact with the finished water for a defined period of time. Because of the limited potential for exposure of the eyes to ozonated water dispensed from the EOI spray bottle, and the brief time frame for exposure, there is no indication that ozonated water dispensed in this manner would pose a significant hazard.

B. Regulatory Benchmarks for Ozone

The U.S. Environmental Protection Agency has promulgated the NAAQS for ozone. This standard for human exposure to ambient air includes a 1-hour benchmark of 0.235 mg/m^3 (equivalent to 0.12 ppm) and an 8-hour limit of 0.157 mg/m^3 or 0.08 ppm. The U.S. Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) have promulgated allowable exposure limits for ozone in the workplace of 0.1 ppm. In the case of OSHA, 0.1 ppm is the 8-hour limit. In the case of NIOSH 0.1 ppm is a short-term exposure limit, or STEL (ACGIH, 2010). The OSHA Permissible Exposure Limit (PEL) has been set at 0.1 ppm. This is the same as the threshold for respiratory effects observed in monkeys in repeat dose studies (ACGIH, 2001).

The American Conference of Governmental Industrial Hygienists (ACGIH) has recommended activity level-specific occupational limits for ozone (ACGIH, 2010). The ACGIH standards, which are specific to different levels of physical activity, are for an 8-hour exposure as follows: 0.05 ppm for heavy work, 0.08 ppm for moderate work, and 0.1 ppm for light work. For short (2-hour) durations of exposure or less, a TLV of 0.2 ppm is recommended by ACGIH, based on 2-hour ozone chamber studies of human volunteers (ACGIH, 2001). For exposures to ozone between 2 hours and 8 hours, the TLV is interpolated linearly between the 0.2 ppm for a 2-hour exposure, and the lower allowable concentration of ozone for the 8-hour period and matching workload.

For light work, the USEPA recommends an 8-hour exposure limit of 0.08 to 0.1 ppm, which would provide some margin of safety for the general population (ACGIH, 2001). ACGIH felt that the upper range value would be satisfactory for an adult working population, because active workers are less likely to include individuals with risk factors that would make them particularly sensitive to ozone. For moderate work, the reduction in FEV_1 values by 8 percent after 8 hours of exposure to ozone at 0.08 ppm is anticipated to be without symptoms. Therefore, ACGIH established the 0.08 ppm level as the TLV for moderate work (ACGIH, 2001). The ACGIH worst-case TLV is 0.05 ppm, as an 8-hour time-average level of ozone in air for long-term respiratory effects from repeated exposures during heavy work. This compares to the USEPA's NAAQS of 0.08 ppm as an outdoor average.

IV. CONSUMER USE EXPOSURE ASSESSMENT

A. Background on Consumer Use

Consumers using the EOI spray bottle in their residence to sanitize hard surfaces could potentially be exposed by the inhalation, dermal, and oral ingestion routes of exposure. It was assumed that 80 percent of ozone in the applied ozonated water volatilizes during application and wiping from the treated surface. It was also assumed that ozone in aerosols remaining in air "strip out" at an 80 percent removal rate. This combined amount of ozone is then available for inhalation exposure in the room of product use. Skin contact with ozonated water during application and wiping could result in limited dermal exposure to ozone during each use. Incidental post-application ingestion exposure could occur from contact of food with treated food contact surfaces, and from use of the ozonated water produced by the EOI Activated Oxygen Sanitizing Spray Bottle as a rinse for direct application to fruits, vegetables, meat and poultry. Methods for assessing incidental ingestion exposure are available in the updated residential exposure assessment SOPs (USEPA 2012). Object-to-mouth post-application ingestion exposures may occur per anticipated mouthing behavior in young children, for example, when ozonated water produced by the EOI spray bottle is used to sanitize pacifiers and toys.

B. Assumptions for Consumer Exposure Assessment

(1) *Product use profile*. The amount of ozonated water dispensed from the EOI spray bottle would vary depending on the type of surface treated. The kitchen and bathroom would be the most likely rooms of use of the product. Typical use in the bathroom entails dispensing 70 to 90 ml of ozonated water per bathroom in about 30 seconds of spraying. Maximum residential use in the bathroom would entail at most one reservoir per day, with the reservoir volume being 350 ml. This higher residential use rate could be represented by cleaning of all bathroom surfaces, including a shower or bathtub. The typical anticipated use for surface cleaning in the kitchen would involve 10 seconds of application of 30 ml of ozonated water on a kitchen counter and 3.3 seconds of application of 10 ml onto a cutting board surface. For direct application as a food rinse, it was assumed that 100 ml was used on fruit, vegetables, meat, and/or produce. Use on surfaces in the kitchen and as a food item rinse on raw agricultural commodities (RACs) would bring the total use in the kitchen to 140 ml per use. For nonfood uses, the directions are to apply until the surface is wet, then allow the spray to remain on the surface from 30 seconds up to 3 minutes, and wipe dry or air dry. The typical use frequency is anticipated to be 3 times per week for sanitizing surfaces. For food contact uses, there is no indication that rinsing of the treated food or food contact surface is necessary. The typical anticipated use frequency is twice a day for rinsing food prior to cooking and/or consumption.

(2) *Human time-activity data*. Human time-activity data (USEPA 1991a) indicate that on average people spend 96 minutes per day in their kitchen based on national data (58 minutes for men; 135 minutes for women). The average value of 96 minutes per day was taken as the duration of exposure to ozone in the kitchen during and following use of the product. Time-activity data also indicate that on average people spend about 36 minutes per day in the bathroom (USEPA 1991a); however, it is unclear how much of this time is spent cleaning. It was assumed that individuals spent an average time for cleaning of 15 minutes in the bathroom.

(3) *Surface area of object mouthed*. One of the factors used in object-to-mouth post-application exposure assessment for toddlers is the surface area of the object that is mouthed by the child. Based on observation of children, the average area determined to be mouthed is approximately 10 cm^2 (USEPA 2012). This value was used in the assessment.

(4) *Fraction of chemical extracted by saliva*. Another factor used in object-to-mouth post-application exposure assessments for children is the fraction of a chemical extracted from a surface by saliva. The USEPA's Residential SOPs indicate a 50^{th} percentile extraction efficiency of 0.5, or 50 percent (USEPA 2012). This value was used rather than a higher percentile, in part, because it is anticipated that some loss of ozone due to volatilization from and reaction with the object's surface will occur.

(5) *Skin surface area contacted*. The skin area contacted by the consumer during dispensing of ozonated water from the EOI spray bottle and wiping of surfaces, assuming exposure of ½ of one hand, is 210 cm^2 (USEPA 2011b). The skin surface area involved in use the EOI Activated Oxygen Spray Bottle for rinsing vegetable, fruits, meat and poultry is ½ of both hands (420 cm^2).

(6) *Room volume and air exchange*. A conservative room volume of 20 m^3 was assumed for a small kitchen, corresponding with a floor space of 9.4 ft x 9.4 ft, with a ceiling height of 8 ft. For the bathroom, a small room volume of 10 m^3 was assumed, equivalent to a floor space of 6 ft x 7.4 ft, with a ceiling height of 8 ft. For both rooms, an air exchange rate of 0.5 air changes per hour (ACH) equivalent to the median residential air exchange rate nationally was assumed (Pandian, *et al.*, 1998).

C. Assessment of Consumer Inhalation Exposures

Screening level inhalation exposures to ozone were assessed for a typical consumer population. Inhalation exposures depend on the inhalation rate associated with the level of activity in the room of product use. Higher inhalation rates are associated with higher levels of activities, with aerobic exercise being associated with the highest inhalation rate. The assigned room volume and room air exchange rate depend on the room of product use. The off-gassing of ozone from the applied spray into the air of the room, assuming that it occurs rapidly, was calculated using the following equation:

$$MR\ (\mu g/event) = f_v \times C_{Ozone}\ (\mu g/ml) \times V_{event}\ (ml/event),\ \text{where}$$

MR	=	Mass released to air due to stripping of ozone (µg/event)
f_v	=	Fraction of ozone released from applied spray (0.8)
C_{ozone}	=	Concentration of ozone in applied spray (ppm, or µg ozone per ml water)
V_{event}	=	Volume ozonated water applied per event (ml)

As an example, based on a maximum target concentration of 2 ppm for sanitizing surfaces, the per-event mass of ozone released into the kitchen during use on surfaces and for rinsing of fruits, vegetables, meat, and poultry is:

MR = (0.8) x (2 μg/ml water) x (140 ml water/event) = 224 μg/event

Whereas, use for cleaning in a residential bathroom would release:

MR = (0.8) x (2 μg/ml water) x (90 ml water/event) = 144 μg/event

Indoor air modeling was performed using Multi-Chamber Concentration and Exposure Model, or MCCEM (USEPA 1991b) to integrate exposures across the day during and immediately following dispensing of ozonated water for sanitizing in the kitchen and bathroom. MCCEM is a user-friendly indoor air model developed by the USEPA for assessing inhalation exposures. The conservative assumption was made that once ozonated water is applied in a given room, 80 percent is evolved into the air within 1 minute. This assumes that 20 percent of the ozone in the ozonated water is consumed in reactions with materials or contaminants on the surface. This assumption of rapid release, especially if the treated surface is air-dried, may bias the maximum airborne concentrations high.

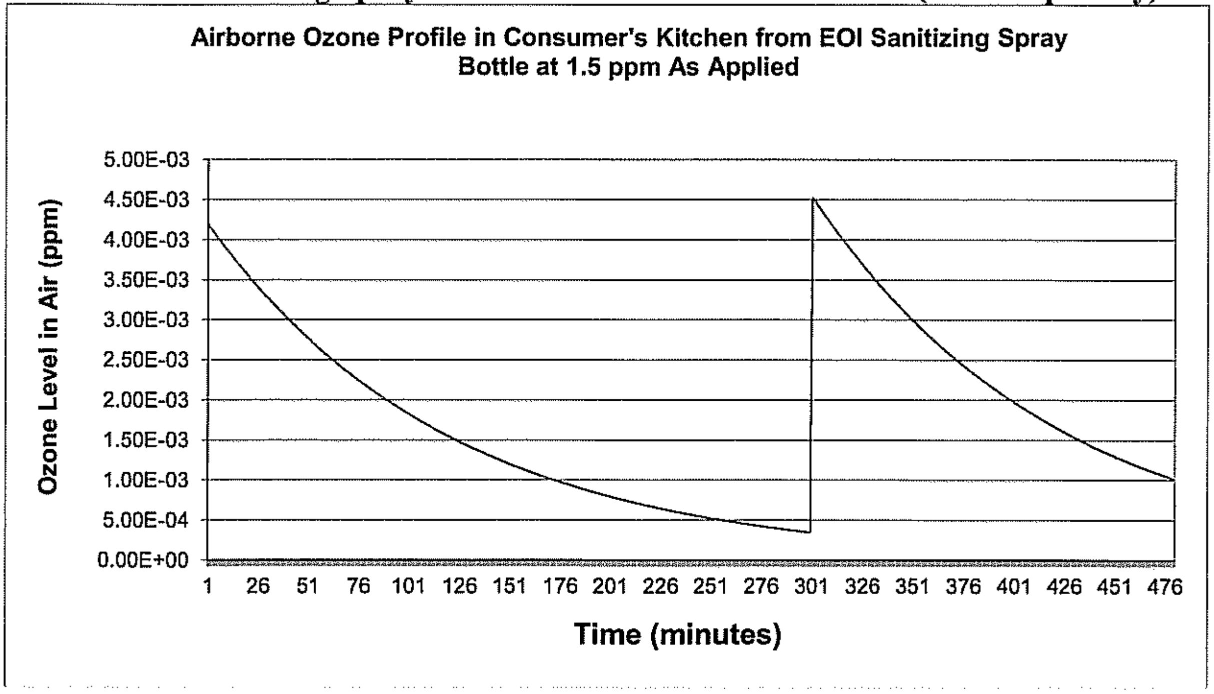
MCCEM was run in the conservative single-chamber mode, using room volumes of either 20 m^3 (kitchen) or 10 m^3 (bathroom) and an air exchange rate of 0.5 room volumes per hour (Pandian, *et al.*, 1998). To maximize airborne concentrations of ozone, the model was run to represent the release of ozone in one minute at the beginning of the exposure period. The results of the modeling exercise are shown in Table 1. An example time-concentration profile is shown in Figure 1 for the use of the EOI Activated Oxygen Sanitizing Spray Bottle for 2 use events in the kitchen separated by 6 hours. After each use event involving dispensing of ozonated water, the airborne concentration rises quickly, but then falls due to air exchange, as shown in Figure 1. For target concentrations of 1 to 2 ppm ozone in water, the average airborne concentrations in a small kitchen range from 0.00123 to 0.00246 ppm. The maximum airborne levels attained in the kitchen for the 1 to 2 ppm target ozone range are 0.00302 to 0.00603 ppm. These maximum levels would be attained only briefly after spraying ozonated water on a surface. Similarly, the maximum levels in the bathroom ranged from 0.00359 to 0.00717 ppm.

Table 1. Summary Statistics for Airborne Levels of Ozone Associated With Spraying Ozonated Water on a Surface in a Small Residential Kitchen (20 m^3, ACH = 0.5)

Ozonated Water Sprayed (ml/day)	*Target Ozone Concentration*	*Amount Released*[a] *(μg)*	*Period Modeled (hr)*	*Airborne Concentration of Ozone (mg/m^3)*		*Airborne Concentration of Ozone (ppm)*[b]	
				TWA	*Maximum*	*TWA*	*Maximum*
Kitchen[c] (140 ml)	1 ppm	112	8	0.00246	0.00603	0.00123	0.003015
	2 ppm	168		0.00492	0.0121	0.00246	0.00603
Bathroom[d] (90 ml)	1 ppm	72	1	0.00567	0.00717	0.002835	0.003585
	2 ppm	108		0.0113	0.0143	0.00567	0.00717

[a] Source active once an hour for 1 minute; 80% of applied ozone in water assumed to flash into room air.
[b] For ozone, 1 ppm = 2 mg/m^3.
[c] For the kitchen, a conservative room volume of 20 m^3 and an air exchange rate of 0.5 ACH were assumed.
[d] For the bathroom, a conservative room volume of 10 m^3 and an air exchange rate of 0.5 ACH were assumed.

Figure 1. Time-Concentration Profile: Release of Ozone from Use of EOI Sanitizing Spray Bottle in Small Residential Kitchen (2 events per day).



Assuming an average adult inhalation rate of 0.64 m^3/hr (USEPA 2012), and a 100 percent absorption in the lung, the average exposures by inhalation in the kitchen would be:

$E_{inh\text{-}kitchen}$ (μg/day) = (0.00246 to 0.00492 mg/m^3) x (0.64 m^3/hr) x (1.6 hr/day) x (1000 μg/mg)

= 2.5 to 5.0 μg/day

and the maximum inhalation exposures in the bathroom would be:

$E_{inh\text{-}bathroom}$ (μg/day) = (0.00717 to 0.0143 mg/m^3) x (0.64 m^3/hr) x (0.6 hr/day) x (1000 μg/mg)

= 2.8 to 5.5 μg/day

Thus, the total exposure due to the inhalation route is:

(2.5 to 5.0 μg/day) + (2.8 to 5.5 μg/day) = 5.3 to 10.5 μg/day

D. Assessment of Consumer Ingestion Exposures

It was assumed that 100 ml of ozonated water are applied to fruits, vegetables, meat, and poultry when the ozonated water produced by the EOI Activated Oxygen Sanitizing Spray Bottle is used to rinse these food items. Assuming that half of the applied ozonated water runs off of the food items, the amount of ozone ingested per day for this source is calculated as follows, assuming that 80 percent of the ozone in the portion of the applied ozonated water not running off the food is available for ingestion with the food items, that no cooking losses occur (which is a conservative assumption), and that the food is prepared for a family of 4. The per-person ingestion exposure will be ¼ the total available ozone on the food:

$$E_{food\ ingestion} = 0.8 \times C_{ozone}\,(mg/l) \times Volume\,(ml) \times (1\text{-}f_{runoff}) \times (liter/1000\ ml) \times (N) \times (1/4)$$

$$= 0.8 \times (1\ to\ 2\ mg/liter) \times (100\ ml) \times (1\text{-}0.5) \times (liter/1000\ ml) \times (2/day) \times (1/4)$$

$$= 0.020\ to\ 0.040\ mg/day = 20\ to\ 40\ \mu g/day$$

Ozonated water from the EOI Activated Oxygen Sanitizing Spray Bottle may leave some short-lived amount of ozone on the surface after wiping or air drying. Ozone is also approved under 21 CFR Section 173.368 for treatment, storage, and processing of foods. Ozone is permitted to be in contact with food, including meat and poultry, in the gaseous or liquid phase, in accordance with current industry standards of good manufacturing practice. Because ozone would be extremely reactive with proteins (Mudd, *et al.*, 1969) and unsaturated lipids (Gottschalk, *et al.*, 2010) in food, no significant amounts of ozone are anticipated to remain in food. Therefore, oral exposures to ozone through the indirect ingestion route are anticipated to be minimal.

Although probably minor compared to direct ingestion of ozone from treatment of fruit, vegetables, meat and poultry with ozonated water from the EOI Activated Oxygen Sanitizing Spray Bottle as a food rinse, transfer of ozone from a treated cutting board or counter top to food (indirect dietary exposure) was also addressed. For use of ozonated water on food items, it was assumed that the initial film thickness of ozonated water on the food items is 2×10^{-3} cm, analogous to the film thickness of water on skin (Versar 1987). It was assumed that 80 percent of the applied ozone in the water remains on the cutting board, and that 100 percent of the residues transfer to food placed on the cutting board. Assuming 2,000 cm^2 of food per person is placed on the cutting board, and that the cutting board is sprayed at the time of food preparation twice a day, the daily oral exposure per person for transferred ozone (as ozonated water, based on target ozone concentrations in the water of 1 to 2 ppm) is:

$$E_{oral\text{-}transfer} = (2\ events/day) \times (2000\ cm^2/event) \times (0.002\ cm) \times 0.8 \times (1\ to\ 2\ \mu g/g) \times (1\ g/cm^3)$$

$$= 6.4\ to\ 12.8\ \mu g/day$$

The total oral exposure is the sum of the oral exposure from use of ozonated water at target ozone levels of 1 to 2 ppm as a food rinse, and indirect dietary exposure from transfer of ozone from treated surfaces to food, or:

$$E_{oral\text{-}total} = (20\ to\ 40\ \mu g/day) + (6.4\ to\ 12.8\ \mu g/day) = 26.4\ to\ 52.8\ \mu g/day$$

E. Assessment of Bystander Object-to-Mouth Ingestion Exposures

The standard method for assessing object-to-mouth exposures in a residential post-application setting is described in the USEPA's SOPs for residential exposure assessment (USEPA 2012). The object-to-mouth exposure pathway is relevant for toddlers exhibiting mouthing behavior, primarily in the 1 to 2 year old age group. In the case of the EOI spray bottle, post-application object-to-mouth exposures to ozone may result from application of ozonated water to pacifiers and toys. The mass of ozone that would be ingested by a toddler per day from ozone on treated pacifiers and toys is a function of chemical loading, the surface area mouthed, the fraction of chemical extracted by saliva, and the frequency of mouthing of objects by toddlers. Assuming no replenishment (i.e., no retreatment of pacifiers and toys), the object-to-mouth exposure is described by the following equation:

$E_{OTM} = SA \times T \times (C_{ozone}) \times SE \times F \times ED$, where:

E_{OTM}	= Object-to-mouth exposure (µg/day)
SA	= Surface area of object mouthed (cm^2)
T	= Film thickness of ozonated water on surface (cm), per Versar (1987)
C_{ozone}	= Concentration of ozone in ozonated water as dispensed (µg/cm^3)
SE	= Saliva extraction efficiency (0.5)
F	= Number of object-to-mouth contacts per hour (hr^{-1})
ED	= Exposure duration (hr/day)

Using assumptions from the USEPA's SOPs for residential exposure assessment (USEPA 2012):

$$E_{OTM} = (10\ cm^2) \times (0.002\ cm) \times (1 \text{ to } 2\ \mu g/cm^3) \times 0.5 \times (14/hr) \times (2\ hr/day)$$

$$= 0.28 \text{ to } 0.56\ \mu g/day$$

F. Assessment of Consumer Dermal Exposures

The only available standard relevant to dermal exposure to ozonated water (although it also involves inhalation exposure) is the NSF 50 standard in terms of allowable ozone levels in swimming pools, spas, and hot tubs. For this setting, the level of ozone in the finished water may not exceed 0.1 ppm. This may be more associated with eye irritation and respiratory irritation than with dermal contact. The use of the EOI Activated Oxygen Sanitizing Spray Bottle is not anticipated to result in contact of more than a portion of the hands, which may occur when dispensing ozonated water from the EOI spray bottle and when wiping a treated surface. For an adult, the skin surface area of both hands is approximately 840 cm^2 (USEPA 2011b). It is anticipated that dermal exposure for the EOI spray bottle would be limited to ½ of one hand, or 210 cm^2 of skin area, during dispensing and wiping of surfaces. Because most dermal exposures to ozonated water will be brief, the dermal permeability approach (USEPA 1992) was used to quantify dermal exposure. If the exposure period is shorter than the lag time for a chemical to cross the skin, the equation for per-event absorbed dose is:

$$E_{derm} = N \times 2\ K_p\ C_w\ SA\ [(6\ \tau\ t_{event})/\pi]^{0.5} \times 1000$$, where

E_{derm}	=	daily per-event exposure (μg/day)
N	=	number of exposure events per day (day^{-1})
K_p	=	permeability coefficient of chemical (cm/hr)
C_w	=	concentration of chemical in water (mg/cm^3)
SA	=	surface area of exposed skin (cm^2)
τ	=	lag time for movement of chemical through skin (hr)
t_{event}	=	duration of exposure (hr)

Substituting values for this case, in which the target ozone range for sanitizing surfaces is 1 to 2 ppm, or 0.001 to 0.002 mg/cm^3, a frequency of 2-minute hand contact twice per day during hard surface sanitation, and a default dermal permeability coefficient of 0.0015 cm/hr, equivalent to that of water:

$$E_{derm}\ (\mu g/day) = (2/day) \times 2 \times (0.0015\ cm/hr) \times (0.001\ to\ 0.002\ mg/cm^3) \times (210\ cm^2)$$

$$\times\ [6 \times (0.11\ hr) \times (0.0333\ hr)/\pi]^{0.5} \times (1000\ \mu g/mg) = 0.11\ to\ 0.21\ \mu g/day$$

Assuming 5 minutes of dermal contact with ozonated water in the kitchen involving ½ the surface area of both hands (420 cm^2), the dermal exposure to ozone from rinsing food twice a day with ozonated water is, by the same calculation method, 0.33 to 0.66 μg/day. Thus, the total dermal exposure for the consumer for sanitizing surfaces and rinsing of food with ozonated water from the EOI Activated Oxygen Sanitizing Spray Bottle is 0.44 to 0.87 μg/day.

G. Total Exposure for Consumer Use

The contributions of different exposure routes to total exposure to ozone through the use of the EOI Activated Oxygen Sanitizing Spray Bottle on surfaces and food items are compared in Table 2. The total exposures range from 32 to 64 μg/day.

Table 2. Relative Contribution of Exposure Pathways to Total Exposure to Ozone for Adult Consumer Use of EOI Activated Oxygen Sanitizing Spray Bottle

Scenario	*Exposure Route*	*Basis for Modeling*	*Reference*	*Exposure Range (μg/day)*	*% of Total Exposure*
General use	Inhalation	MCCEM	USEPA (1991b)	5.3 to 10.5	16 %
Food rinse	Oral ingestion	-----	----	20 to 40	63 %
Indirect dietary	Oral ingestion	Transfer factor	----	6.4 to 12.8	20 %
Surface/Food Rinse	Dermal	Permeability	USEPA (1992)	0.44 to 0.87	1 %
			TOTAL	**32 to 64**	**100**

For the adult consumer use scenario, the direct oral ingestion of ozone from use of ozonated water from the EOI spray bottle as a food rinse is the major route of exposure, accounting for 63 percent of the total exposure. This is followed by inhalation and indirect dietary exposure, which together account for the bulk of the remaining exposure budget. Dermal exposure represents a minor exposure route. Because (1) dermal exposure is low compared to inhalation exposure, and (2) the effects of ozone on the lungs are anticipated to be greater than effects on the skin, the impact of dermal exposure from dermal contact with ozonated water from the EOI spray bottle unit is anticipated to be minimal.

V. PROFESSIONAL USE EXPOSURE ASSESSMENT

A. Background on Professional Use

A professional user, such as housekeeping staff at a hotel using the EOI spray bottle during their work day to sanitize hard surfaces in bathrooms in hotel suites, could potentially be exposed by the inhalation and dermal routes of exposure. It was assumed that 80 percent of ozone in the applied ozonated water volatilizes from the treated surface during application and wiping. It was also assumed that any ozone in aerosols remaining in air strip out at an 80 percent removal rate. The combined amount of ozone is then available for inhalation exposure in the room of product use and in an adjacent room. Contact of ozonated water with ½ of both hands during application and wiping could result in dermal exposure to ozonated water during each use. Unlike for the consumer exposure scenario, no incidental ingestion exposure is anticipated to occur. The exposures for these pathways have been estimated below.

B. Assumptions for Professional Use Exposure Assessment

(1) *Inhalation rates*. The inhalation rates are available in the Exposure Factors Handbook (USEPA 2011b), as cited in the current USEPA SOPs for residential exposure assessment (USEPA 2012). The inhalation rates originally provided in the Exposure Factors Handbook (USEPA 2011b) averaged 1.1 m^3/day for light activity, which is representative for the inhalation rate of workers during cleaning of bathrooms.

(2) *Product use profile*. The amount of ozonated water dispensed varies depending on the type of surface that is treated. The possible range of use volumes entails dispensing as much as 1 to 3 reservoirs, or 350 to 1,050 ml of ozonated water in the course of cleaning each bathroom in 16 hotel rooms. The minimum amount used professionally to clean and sanitize a hotel bathroom is about twice that used by a consumer during sanitizing their bathroom on average. Professional use of the EOI spray bottle could utilize as much as 16 to 48 reservoirs per day by a given individual, with the reservoir volume being 350 ml. The typical use frequency is anticipated to be 5 days per week for sanitizing surfaces by housekeeping staff.

(3) *Human time-activity data*. Available estimates for hotel housekeeping staff indicate that one staff member is in a given hotel room cleaning for 20 minutes for a continuing guest and 35 minutes following checkout. We assume for our analysis that on average hotel staff spend 30 minutes per hotel room engaged in cleaning activities, ½ of which they spend in the bathroom cleaning. These data are for residential exposures and individuals staying in hotels as guests may have somewhat different time profiles. For the purpose of this assessment, it was assumed that housekeeping staff spend an average time per cleaning event of 15 minutes in each hotel bathroom.

(4) *Skin surface area contacted*. The skin area contacted by the ozonated water during dispensing and wiping of surfaces for housekeeping staff, assuming exposure of ½ of both hands, is 420 cm^2 (USEPA 2011b).

(5) *Room volume and air exchange*. A conservative room volume of 20 m^3 was assumed for a hotel bathroom, corresponding with a floor space of 9.4 ft x 9.4 ft, with a ceiling height of 8 ft. An air exchange rate of 1.5 air changes per hour (ACH) equivalent to the median commercial building air exchange rate was assumed.

C. Assessment of Professional Use Inhalation Exposures

Using assumptions on the range of ozone concentrations in ozonated water from the EOI Activated Oxygen Sanitizing Spray Bottle, screening-level inhalation exposures to ozone were assessed for a typical professional population (housekeeping staff in a professional use scenario). Inhalation exposures depend on the inhalation rate associated with the level of activity in the room. The emission rate of ozone from the applied surface into the air of the hotel bathroom was calculated using the following equation:

$$MR\ (\mu g/release) = f_v \times C_{Ozone}\ (\mu g/ml) \times V_{event}\ (ml/event), \text{ where}$$

MR	=	Mass released to air due to stripping of ozone (µg/event)
f_v	=	Fraction of ozone released from applied spray (0.8)
C_{ozone}	=	Concentration of ozone in applied spray (ppm, or µg ozone per ml water)
V_{event}	=	Volume ozonated water applied per event (ml)

As an example, based on a target effective concentration of 2 ppm for sanitizing water, the per-event mass of ozone released into a hotel bathroom during use on surfaces is:

MR = (0.8) x (2 µg/ml water) x (350 to 1,050 ml water/event) = 560 to 1,680 µg/event

Indoor air modeling was performed using Multi-Chamber Concentration and Exposure Model, or MCCEM (USEPA 1991b) to integrate exposures across the day during and immediately following dispensing of ozonated water for sanitizing in the hotel bathrooms. MCCEM is a user-friendly indoor air model developed by the USEPA for assessing inhalation exposures. The conservative assumption was made that once ozonated water is applied in a given room, 80 percent will transport into the air. This assumes that 20 percent of the ozone in the ozonated water is consumed in reactions with materials or contaminants on the surface.

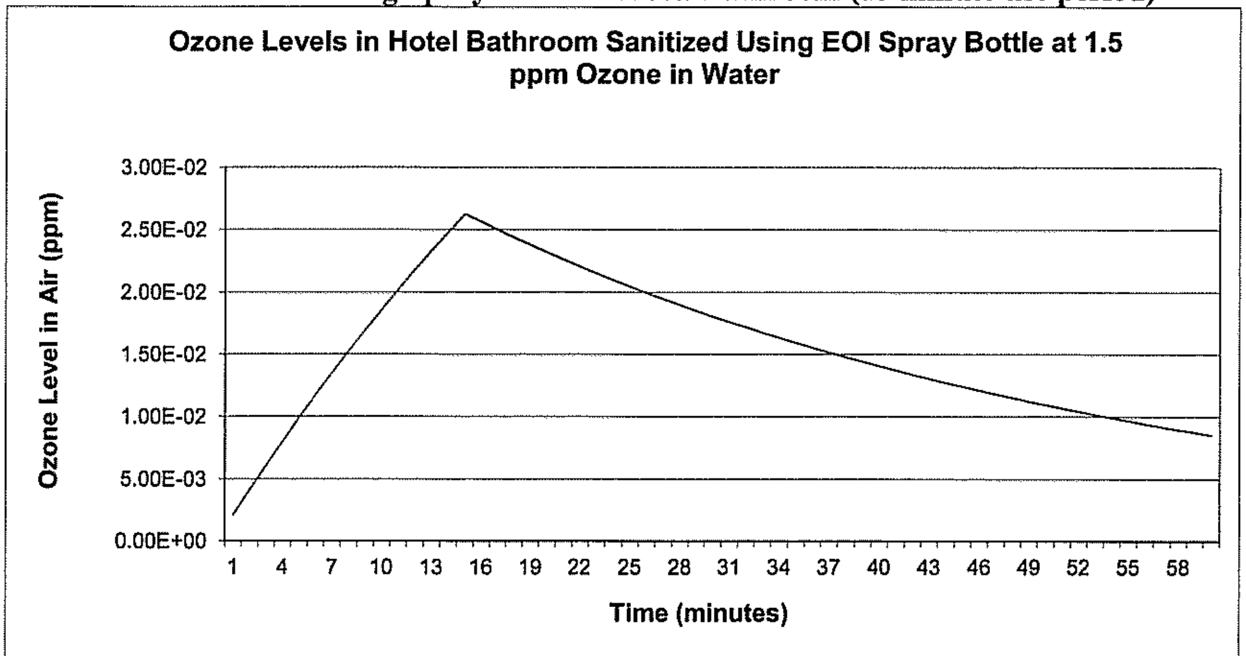
MCCEM was run in the conservative single-chamber mode, using a bathroom volume of 20 m^3 (hotel bathroom) and an air exchange rate of 1.5 room volumes per hour for commercial buildings. The model was run to represent the release of 280 to 1680 µg of ozone in 15 minutes. The results of the modeling are shown in Table 3. An example time-concentration profile is shown in Figure 2 based on a mid-range concentration of ozone in water of 1.5 ppm from the EOI spray bottle when used in a hotel bathroom. After each use event involving dispensing of ozonated water, the airborne concentration rises and equilibrium is reached quickly, but then falls due to air exchange after the use period, as shown in Figure 2. For use concentrations of 1 to 2 ppm ozone, the 1-hr average airborne concentrations in a hotel bathroom are 0.00342 to 0.0206 ppm. The maximum airborne levels in the hotel bathroom experienced by housekeeping staff while cleaning that room range from 0.00585 to 0.0350 ppm. Maximum air levels would be attained only briefly after spraying ozonated water on a surface.

Table 3. Summary Statistics for Airborne Levels of Ozone Associated with Spraying Ozonated Water on Surfaces in a Hotel Bathroom (20 m³, ACH = 1.5)

Ozonated Water Sprayed (ml)	*Target Ozone Concentration*	*Amount Released*[a] *(µg)*	*Period Modeled (hr)*	*Airborne Concentration of Ozone (mg/m³)*		*Airborne Concentration of Ozone (ppm)*[b]	
				TWA	*Maximum*	*TWA*	*Maximum*
350 ml per bathroom[c]	1 ppm	280	1	0.00684	0.0117	0.00342	0.00585
	2 ppm	560		0.0137	0.0234	0.00684	0.0117
1,050 ml per bathroom[d]	1 ppm	840	1	0.0206	0.0350	0.0103	0.0175
	2 ppm	1,680		0.0412	0.0700	0.0206	0.0350

[a] Ozone release over 15 minutes; 80% of applied ozone in water assumed to volatilize into room air.
[b] For ozone, 1 ppm = 2 mg/m³.
[c] Assumes a per-event use of 1 reservoir by housekeeping staff per hotel bathroom.
[d] Assumes the use of 3 reservoirs (350 ml each) by housekeeping staff per hotel bathroom as a worst case.

Figure 2. Time-Concentration Profile: Release of Ozone from Professional Use of EOI Sanitizing Spray Bottle in Hotel Bathroom (15 minute use period)



Using the maximum modeled ozone levels in air in a hotel bathroom to capture worst-case ozone levels during professional use of the EOI spray bottle for sanitizing surfaces, and assuming an average adult inhalation rate for light activity of 1.1 m^3/hr (USEPA 2012), 100 percent absorption in the lung, and that housekeeping staff would spend about ½ of an 8-hour shift cleaning hotel bathrooms and ½ involved in cleaning other parts of a hotel suite or engaged in other activities, the average inhalation exposures for housekeeping staff sanitizing surfaces in a hotel bathroom with the EOI spray bottle would be:

$E_{inh\text{-}bathroom}$ (μg/day) = (0.0117 to 0.0700 mg/m^3) x (1.1 m^3/hr) x (4 hr/day) x (1000 μg/mg)

= 51 to 308 μg/day

D. Assessment of Professional Use Dermal Exposures

The only available standard relevant to dermal exposure to ozonated water (although it also involves inhalation exposure) is the NSF 50 standard in terms of allowable ozone levels in swimming pools, spas, and hot tubs. For this setting, the level of ozone in the finished water may not exceed 0.1 ppm. The use of the EOI Activated Oxygen Sanitizing Spray Bottle is not anticipated to result in contact of more than a portion of the hands, which may occur when dispensing ozonated water from the EOI spray bottle and when wiping a treated surface. For an adult, the skin surface area of both hands is approximately 840 cm^2 (USEPA 2011b). It is anticipated that dermal exposure for the EOI spray bottle during professional use would be limited to ½ of both hands or 420 cm^2 of skin area, during dispensing and wiping. Because most dermal exposures to ozonated water will be brief, the dermal permeability approach (USEPA 1992) was used to quantify dermal exposure. If the exposure period is shorter than the lag time for a chemical to cross the skin, the equation for per-event absorbed dose is:

$E_{derm} = N \times 2\, K_p\, C_w\, SA\, [(6\, \tau\, t_{event})/\pi]^{0.5} \times 1000$, where

E_{derm}	=	daily per-event exposure (mg/day)
N	=	number of exposure events per day (day^{-1})
K_p	=	permeability coefficient of chemical (cm/hr)
C_w	=	concentration of chemical in water (mg/cm^3)
SA	=	surface area of exposed skin (cm^2)
τ	=	lag time for movement of chemical through skin (hr)
t_{event}	=	duration of exposure (hr)

Substituting values for our case, in which the target range for sanitizing water is 1 to 1.5 ppm, or 0.001 to 0.002 mg/cm^3, and a frequency of 15-minute hand contact 16 times per day, assigning a default dermal permeability coefficient of 0.0015 cm/hr, equivalent to that of water:

E_{derm} (mg/day) = (16/day) x 2 x (0.0015 cm/hr) x (0.001 to 0.002 mg/cm^3) x (420 cm^2)

x $[6 \times (0.11\ hr) \times (0.25\ hr)/\pi]^{0.5}$ x (1000 μg/mg) = 4.6 to 9.2 μg/day

E. Total Exposure for Professional Use

The contributions of different exposure routes to total exposure to ozone through professional use of the EOI Activated Oxygen Sanitizing Spray Bottle on surfaces in hotel bathrooms are compared in Table 4. The total exposure ranges from 56 to 317 μg/day.

Table 4. Relative Contribution of Exposure Pathways to Total Exposure to Ozone from Professional Use of the EOI Activated Oxygen Sanitizing Spray Bottle

Scenario	*Exposure Route*	*Basis for Modeling*	*Reference*	*Exposure Range (μg/day)*	*% of Total Exposure*
Housekeeping Staff	Inhalation	MCCEM	USEPA (1991b)	51 to 308	91 - 97 %
	Dermal	Permeability	USEPA (1992)	4.6 to 9.2	3 - 9 %
			TOTAL	**56 to 317**	**100**

For the professional use scenario, inhalation is the most important route of exposure to ozone from use of ozonated water from the EOI spray bottle by professional users, accounting for 91 to 97 percent of the total exposure. In contrast, the dermal exposure pathway accounts for only 3 to 9 percent of the total exposure for professional use. Because (1) dermal exposure is low relative to the inhalation exposure, and (2) the effects of ozone on the lungs are anticipated to be greater than effects on the skin, the impact of dermal exposure from intermittent contact with ozonated water from the EOI spray bottle unit during professional use is anticipated to be minimal.

VI. DISCUSSION

Available toxicological and regulatory benchmarks for ozone were not exceeded during or following to use of the EOI Activated Oxygen Sanitizing Spray Bottle. The time-weighted average (TWA) airborne levels of ozone resulting from consumer use of the EOI spray bottle in residences are predicted to be only 1.5 to 7 percent of the NAAQS of 0.08 ppm. The anticipated TWA airborne levels of ozone associated with professional use of the EOI spray bottle by housekeeping staff are only 3.4 to 21 percent of the OSHA PEL of 0.1 ppm. The available benchmarks were not exceeded for either use scenario, even if it is assumed that 100 percent of the ozone becomes airborne. Ambient air concentrations of ozone indoors due to use of the EOI spray bottle are much less than ambient air concentrations of ozone outdoors from all sources, which usually ranges from 0.2 to 0.5 ppm frequently during summer months (NTP 1994). Inhalation exposures to ozone as a result of volatilization from ozonated water used to sanitize surfaces in the residence and professionally are anticipated to be intermittent and brief, and not similar to a long-term chronic dose that would be obtained from ambient air or other long-term sources.

The maximum levels of ozone in indoor air associated with use of the EOI Activated Oxygen Sanitizing Spray Bottle for sanitation of surfaces in the home also are below effect levels. Average airborne concentrations of ozone modeled in a small residential kitchen or bathroom were well below any of the available allowable exposure limits for ozone in the work environment, which includes the OSHA Permissible Exposure Limit (PEL) of 0.1 ppm and the activity-specific ACGIH standards (0.05 ppm to 0.1 ppm for an 8-hour exposure, and 0.2 ppm for a 2-hour exposure. This conclusion is true regardless of whether it is assumed that 80 percent or 100 percent of the ozone applied to a surface is released into indoor air during use of the EOI spray bottle. The 1-minute maximum predicted concentrations of ozone in a small kitchen or bathroom environment, as modeled, were also below the NIOSH recommended short-term exposure limit (STEL) of 0.1 ppm and the 1-hr NAAQS value of 0.12 ppm for either the 80 or 100 percent release assumption. Another reference point is provided by the airborne levels associated with other indoor devices, such as certain photocopy machines, which can produce peak concentrations in the 0.1 to 0.2 ppm range (Lipsett, *et al.*, 1994). Most measured ozone levels generated by photocopy machines were in the 0.001 to 0.15 ppm range (Hansen and Andersen 1986), although some located in small poorly-ventilated spaces may produce ozone levels up to 0.20 ppm (Allen *et al.* 1978). Air cleaners that intentionally emit ozone into indoor air will typically produce levels less than 0.030 ppm. The predicted airborne concentrations of ozone resulting from the use of the EOI Activated Oxygen Sanitizing Spray Bottle will typically be less than those produced by these other products.

Estimated dermal exposures to ozone from the EOI spray bottle are less than inhalation exposures. Because of the general reactivity and non-specificity of ozone, a large portion of the dermal absorbed dose would likely react with proteins and lipids in the skin, resulting in either no effects or mild irritation that would be rapidly reversible. Ozone ingested in food treated by the EOI Activated Oxygen Sanitizing Spray Bottle could theoretically react non-specifically with tissues and food in the GI tract. There is no available evidence that exposure of the GI tract to 1 to 2 ppm ozone on food would result in any irritation or other adverse effect on tissues. Alkaline conditions in the small intestine would be anticipated to destroy any residual ozone.

VII. CONCLUSION

Based on available toxicological data, the limited exposures associated with the inhalation, ingestion, and dermal exposure routes for the small amounts of ozone resulting from the EOI Activated Oxygen Sanitizing Spray Bottle are anticipated to be without significant human health impact.

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