

RESPIRATOR MAINTENANCE

I. RESPIRATOR MAINTENANCE GENERAL INFORMATION

A. Respirator maintenance is necessary to ensure respirators remain in good working condition and function as designed to provide the expected level of protection against workplace inhalation exposures. Respirator maintenance is part of a comprehensive respirator program and includes the following procedures:

1. Cleaning and sanitizing;
2. Inspecting, repairing, and disposal;
3. Storing.

II. RESPIRATOR MAINTENANCE REQUIREMENTS

A. Respirators must be maintained per manufacturer's instructions to retain NIOSH certification.

1. According to paragraph 1507.a of reference 1, "*Activities shall only use respirators that are currently approved by NIOSH¹ or NIOSH and Mine Safety and Health Administration (MSHA).*" Per reference 2, approved respirators are certified by NIOSH under *42 CFR 84, Respiratory Protective Devices* (reference 3) and **maintained in full compliance with the NIOSH certification.**
2. Paragraph 1510 of reference 1 requires that respirators must be restored to their original condition and configuration (as packaged and sold by the manufacturer) for the NIOSH approval to remain valid.
3. This paragraph further requires the respiratory protection program manager (RPPM) to keep a copy of all respirator user manuals and maintain, clean, disinfect, repair, inspect, and store respirators per manufacturers' instructions in order to maintain their NIOSH certification.

III. RESPIRATOR CLEANING AND SANITIZING

A. Only personnel who have received training through the RPPM are allowed to clean, inspect, and maintain respirators per reference 1 (paragraph 1510).

B. The Occupational Safety and Health Administration (OSHA) in reference 4 uses the term respirator disinfecting, whereas ANSI in reference 2 uses the term sanitizing respirators after cleaning. Basically, disinfecting completely destroys all organisms, whereas sanitizing destroys 99.999%. Hospital applications are concerned with disinfection, while public health is concerned with sanitizing. Although reference 4 refers to sanitation as disinfection, respirator sanitation is the correct terminology.

C. OSHA (reference 4) requires cleaning and sanitizing respirators regularly using the following schedules:

¹ NIOSH is the acronym for *National Institute for Occupational Safety and Health*.

1. Respirators issued for the exclusive use of one worker will be cleaned and disinfected [sanitized] as often as necessary to be maintained in a sanitary condition.
2. Respirators used by more than one worker will be thoroughly cleaned and disinfected [sanitized] before use by another worker.
3. Respirators for emergency use will be cleaned and disinfected [sanitized] after each use.
4. Respirators used in fit testing and training will be cleaned and disinfected [sanitized] after each use.
 - a. Paragraph I.1. of CPL 2-0.120 (reference 5) states that the use of individually-wrapped cleaning towelettes may be used between employees being fit tested, however these respirators shall be thoroughly cleaned at the end of each day.
 - b. However, most of the respirator community, including the ANSI Z88.10 Respirator Fit Testing Subcommittee, does not consider using towelettes a proper respirator cleaning method and does not recommended their use. Therefore, have plenty of respirators during fit test sessions so that they do not have to be cleaned in-between fit tests. Clean and sanitize them later per manufacturer's instructions.

D. Respirator cleaning and sanitizing methods. Respirators should be first washed in a detergent solution as a separate operation and then sanitized by immersion in a sanitizing solution. Note that some commercial respirator cleaners both clean and sanitize respirators in one step. Provided below are examples of respirator cleaning and sanitizing procedures. These procedures, including the maximum cleaning and rinsing temperature may differ from respirator manufacturer's instructions and the OSHA methods listed in Appendix B-2 of reference 4. OSHA's Appendix B-2 is mandatory and states that manufacturer's instructions may be followed if they are equivalent (i.e., if they meet OSHA's objective of successfully cleaning and "disinfecting" respirators without damage to them and if they do not harm the respirator users). Although the methods listed below will properly clean and sanitize respirators, the respirator manufacturer's instructions take precedence.

1. Manual cleaning and sanitizing.
 - a. Remove canisters, filters, valves, straps, and speaking diaphragm from the facepiece.
 - b. Wash facepiece and accessories in warm soapy water. Gently scrub with a soft brush. Cleaning solution temperatures should not exceed 110° F (43° C).
 - c. Rinse parts thoroughly in clean water no hotter than 110° F (43° C) to remove all traces of detergent.
 - i. This is very important to prevent dermatitis.

- ii. Thorough rinsing also removes traces of soap or cleaning solution, along with organic/inorganic material that can remove active ingredients, such as free available chlorine, in sanitizing solutions.
 - d. When the respirator cleaner does not contain a sanitizing agent, immerse respirator and components in a sanitizing solution for two minutes. When using a commercially available cleaner, follow the manufacturer's instructions.
 - e. Air dry in a clean place or wipe dry with a lintless cloth.
 - f. Reassemble respirator.
2. Machine cleaning. Machines may be used to expedite cleaning, sanitizing, rinsing, and drying large numbers of respirators.
- a. Ultrasonic cleaners, clothes-washing machines, dishwashers, and clothes dryers have been specially adapted and successfully used for cleaning and drying respirators.
 - b. Extreme care must be taken to ensure against excessive tumbling and agitation, or exposure to temperatures above those recommended by the manufacturer, as these conditions are likely to result in damage to the respirators.
3. Sanitizing procedures include:
- a. Bleach Solution. Per Appendix B of reference 4, immerse respirators for two minutes in hypochlorite solution (50 ppm of chlorine) made by adding approximately one milliliter of laundry bleach to one liter of water at 43 deg. C (110 deg. F). Rinse thoroughly in clean water no hotter than 110° F (43° C) to remove all traces of "disinfectant" and dry. However, 1 ml laundry bleach per liter of water only makes a 36 ppm solution.
 - i. OSHA adopted their respirator chlorine sanitizing method from the *ANSI Z88.2-1969 Respirator Standard*, which had its basis in the *1962 FDA Food Service Sanitation Manual*. The chlorine sanitation method was also included in the 1980 and 1992 versions of *ANSI Z88.2* (See Appendix A of this document for a complete discussion on the history of chlorine respirator sanitizing).
 - ii. Appendix B of this document includes a practical method for preparing the bleach sanitizing solution used for immersing respirators for two minutes after respirators have been properly cleaned and rinsed. The bleach sanitizing solution is made by mixing either 2 ml 5.25 % bleach per liter of tap water or 2 teaspoons 5.25 % bleach per gallon of tap water, which makes a 72 ppm free available chlorine solution.
 - b. Quaternary Ammonium Solution. Per reference 2, immerse the cleaned respirator body for two minutes in a quaternary ammonium

solution (200 ppm of quaternary ammonium compounds in water with less than 500 ppm total hardness). Depending on water hardness, different concentrations of quaternary ammonium salts are required to achieve sanitizing strength (Please see this website for explanation and calculation of [water hardness](#)). Rinse thoroughly in clean water no hotter than 110° F (43° C) to remove all traces of disinfectant and dry.

c. Iodine Solution. Per Appendix B of reference 4, immerse cleaned respirators for two minutes in an aqueous solution of iodine (50 ppm iodine) made by adding approximately 0.8 milliliters of tincture of iodine (6-8 grams ammonium and/or potassium iodide/100 cc of 45% alcohol) to one liter of water at 43 deg. C (110 deg. F). Rinse thoroughly in clean water no hotter than 110° F (43° C) to remove all traces of disinfectant and dry.

i. Measuring 0.8 ml of tincture of iodine is not a practical method in the field. Measuring 0.8 ml of any liquid requires more precise volumetric measurements than are likely possible for those who are cleaning and sanitizing respirators.

ii. Appendix C of this document includes a practical method for preparing the iodine sanitizing solution used for immersing respirators for two minutes after respirators have been properly cleaned and rinsed. In this method, immerse the respirator for two minutes in a ~ 50 ppm iodine solution made by mixing one tablespoon or 15 ml of 1.75 % aqueous iodine solution in 1.5 gallons of tap water.

Note: Bleach, quaternary ammonium, and iodine solutions can age rubber and rust metal parts. Thoroughly rinse the respirator after cleaning and disinfection to prevent dermatitis and to minimize damage to the respirator.

d. When using a commercially prepared sanitation solution, follow the manufacturer's directions.

IV. REPAIR, INSPECTION, AND DISPOSAL.

Respirators must be maintained according to manufacturer's instructions to retain NIOSH certification. This includes following manufacturer's respirator user instructions for repairing and inspecting respirators to restore them to their original NIOSH approved condition and configuration. Respirators not passing manufacturer's user instruction inspection criteria must not be worn and must be repaired, replaced, or disposed. Per paragraph (h)(4) of reference 4, respirator repairs and adjustments must only be made by appropriately trained personnel using only respirator manufacturer's NIOSH-approved parts designed for the specific respirator assemblage. Reference 4 further states that reducing and admission valves, regulators, and alarms must be adjusted or repaired only by the manufacturer or by technicians trained by the manufacturer. After parts replacement or repairs, respirators must be inspected. Although the methods listed below

will ensure proper respirator inspection, the respirator manufacturer's instructions take precedence.

A. Disposable air-purifying respirators.

1. Check for holes in the filter.
2. Check for damage to sorbent, such as loose charcoal granules for disposable respirators equipped with sorbent material.
3. Check straps for elasticity and deterioration.
4. Check metal nose clip, found on some filtering facepiece respirators, for rust or deterioration.
5. If present, check integrity of sealing surfaces on disposable respirators approved by NIOSH with pliable foam or elastic sealing surfaces.

B. Reusable air-purifying respirators.

1. Check elastomeric facepieces for dirt, pliability of rubber, deterioration, cracks, tears, or holes.
2. Check straps for breaks, tears, loss of elasticity, broken attachment snaps, and proper tightness.
3. Check exhalation and inhalation valves for holes, warpage, cracks, and dirt. Some warped inhalation valves have undulating edges causing them to not lay flat on the valve housing, which results in leakage into the respirator.
4. Check filters, cartridges, and canisters for dents, corrosion and expiration dates. Cartridges and canisters are to be changed according to the cartridge change schedule or immediately if any odors, eye irritation (in the case of full-face masks) or respiratory irritation are detected or increased breathing resistance is first noticed.

C. Supplied-air respirators.

1. Check appropriate items listed under air-purifying respirators.
2. Check hood, helmet, blouse, or suit for cracks, tears, torn seams, and abrasions; check integrity of headgear suspension.
3. Check face shields for cracks, breaks, abrasions, or distortions that would interfere with vision.
4. Check the condition and integrity of abrasive blasting respirator protective screen.
5. Check air supply system for air quality, breaks, or kinks in supply hoses and detachable coupling attachments, tightness of connectors, and manufacturer's recommendations concerning the proper setting of regulators and valves.
 - a. Ensure the supplied-air respirator coupling is incompatible with other non-breathing air couplings used at the activity.

- b. Ensure hoses are approved for use with the respirator assembly.
 - i. Only the breathing air supply hose specified on the NIOSH approval label from the original manufacturer of the supplied-air respirator is allowed for use.
 - ii. No hose substitutions are allowed!
 - iii. Check that hose lengths and pressure settings are as specified in the NIOSH approval label.
- 6. When an air compressor is used to provide breathable air, check air-purifying elements, carbon monoxide and/or high temperature alarm. Check the location of the compressor air inlet to ensure it is in a fresh outdoor atmosphere, such as above roof level, away from ventilation and vehicular exhausts.
- D. Self-contained breathing apparatus.
 - 1. Check the facepiece and hoses for integrity as described above for atmosphere-supplying respirators. Also, check the integrity of the regulator, harness assembly, and all straps and buckles. Check the air cylinder integrity and air pressure. Ensure the regulator and warning devices (end-of-service alarm) function properly.
 - 2. Ensure that cylinders have current hydrostatic test approval stamps/stickers. Typically, the SCBA maintenance including management of DOT hydrostatic test dates and other related cylinder maintenance programs are controlled by the issuing fire department qualified technicians. The National Fire Protection Association (NFPA) codes such as NFPA 1404 (reference 6) and NFPA 1500 (reference 7) require regular maintenance checks of the hydrostatic test dates. As shown in Table 1, the required test frequency varies based on the cylinder composition.

Table 1 Hydrostatic Test Frequency for SCBA Cylinders	
Cylinder Construction	Hydrostatic Test Frequency
Steel	5 years
Aluminum	5 years
Composite	3 years

- a. Steel and aluminum SCBA cylinders (not including hoop-wrapped) have indefinite service life as long as they pass inspection and hydrostatic testing.
 - b. The service life of metal-lined, fiber-reinforced-composite SCBA cylinders is limited to 15 years because the fiber filaments, which provide much of the cylinder strength, are susceptible to brittle fracture

and stress rupture. Brittle fracture and stress rupture may occur without any visual indication of damage and cannot be detected by current non-destructive tests. In time, these fiber filament properties produce a general reduction in a cylinder's strength, which can lead to cylinder rupture during service.

3. NFPA 1852 (reference 8) sets forth generic SCBA maintenance testing requirements. The [PosiChek³](#), made by Biosystems and the newer version, the new [Posi3 USB](#) are computerized test benches designed to evaluate performance of completely assembled SCBA via a computer-controlled bellows that simulates inhalation and exhalation of a person wearing the SCBA. These are the only SCBA test equipment that performs all of the maintenance testing required by NFPA 1852. In addition to SCBA testing by the PosiChek³ or the Posi3 USB, software from each SCBA manufacturer must be used with these test benches for the specific SCBA being tested. Plus, the operator must be trained and certified by the SCBA manufacturer.

a. Originally, in the mid-1980s there were only a few testing apparatus that could perform the NFPA 1981 SCBA flow rate testing. This original equipment was expensive and cumbersome and no fire department was capable of performing the SCBA manufacturer's required maintenance in-house.

b. Today, SCBAs can still be sent back to their manufacturers or sent to manufacturers' authorized repair centers. However, if a fire department has 15 - 20 SCBAs to maintain it may be more cost effective to purchase the PosiChek³ or the Posi3 USB, purchase the SCBA manufacturer's software, and have their repair technicians trained and certified by the SCBA manufacturer.

E. Emergency use respirators.

1. Inspect emergency use respirators monthly in addition to before and after each use. Ensure inspection records are maintained. The preamble to the OSHA Respirator Standard (reference 4) states that examining emergency respirator performance before each use is not intended to be as extensive and thorough a process as the monthly inspection, but includes a basic examination conducted prior to each use to assure the wearer that the respirator which they are about to don in an emergency situation will work properly (e.g., that the cylinders on the SCBA are charged, that air is available and flowing). Ensure air cylinders are fully charged (i.e., regulator gauge must read between 90% to 100% of the rated cylinder pressure).

a. Since the pressure of air cylinders drops during storage in cold environments, do not add air to a cylinder with a decrease in pressure due to storage in lower temperatures.

b. It may be hard to distinguish between low pressure caused by a leaking cylinder and a cylinder stored in low temperature. Therefore, air

cylinders should be pressurized and stored in warm atmospheres prior to use.

2. CBRN Respirator Inspection. According to paragraph 2606.c.(3) of reference 1, since CBRN respirators are worn for emergency use, they must be inspected monthly according to manufacturer's instructions and a written inspection record will be maintained for the life of the respirator.

- a. Employees must inspect their CBRN approved respirators for serviceability prior to donning them.
- b. OSHA monthly emergency respirator inspection is not applicable to CBRN escape respirators because inspection will destroy the protective storage package, which is vacuumed sealed.

F. Respirator disposal.

1. According to reference 2, *"If applicable, respirator components shall be disposed of in accordance with appropriate federal, state and local regulations."*

2. Per reference 1, dispose of CBRN respirators that have been contaminated with liquid chemical warfare agents after the respirators have been decontaminated.

- a. Decontamination requirements are specified in the *Navy Shore Installation Emergency Management Program*, reference 9.
- b. Guidelines for decontaminating emergency response personnel and their equipment after exposure to hazardous materials, and for planning for decontamination before an incident occurs are in reference 10.
- c. Reference 11 provides additional guidelines for decontaminating chemical protective clothing and equipment.

V. **STORAGE.**

A. Respirators must be stored in a convenient, clean, and sanitary location.

1. Ensure that respirators are stored in such a manner as to protect against dust, harmful chemicals, sunlight, excessive heat or cold, excessive moisture, and even insects. Storage measures include plastic bags capable of being sealed and plastic containers with tight-fitting lids, such as freezer containers.

- a. Aboard some ships, clear plastic bags are prohibited because they cannot be seen in the bilge water and can potentially clog the bilge pumps.
- b. However, tinted bags, which can be seen, may be allowed. Check with the ship's foreign material exclusion policy for bilge protection.

2. Pack or store the respirator so that the facepiece and exhalation valves will rest in a normal position. Do not hang the respirator by its straps. These precautions will help avoid distorting respirator components and stretching the straps.

B. Emergency use respirators. Respirators placed at stations and work areas for emergency use should be accessible at all times. They should be stored in clearly marked compartments dedicated to emergency equipment storage.

C. Special Considerations for Storing CBRN Respirators. CBRN gasmask and tight-fitting PAPRs must be stored per the *Minimum Packaging Requirements* (MPC) established by NIOSH and the respirator manufacturer. MPC is the protective packaging in which the end user must store or maintain the CBRN respirator and its components after the CBRN respirator has been issued for use. Failure to store CBRN respirators in the respirator manufacturer's recommended MPC may allow damage to occur that could affect the respirator's or its components' ability to provide the expected level of protection.

1. Examples of common minimum packaging configurations include hard plastic carriers, clamshell containers, canvas carry bags, drawstring plastic bags, and sealed canister bags.
2. Each respirator manufacturer is likely to have unique MPC requirements. The manufacturer's user instructions and the NIOSH full approval label will identify the MPC.

VI. POINT OF CONTACT

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APPENDIX A
ORIGIN OF OSHA TWO MINUTE, 50 PPM CHLORINE SOLUTION
RESPIRATOR IMMERSION SANITIZATION PROCEDURE

I. INTRODUCTION

A. The following discussion is on the origin of the Occupational Safety and Health Administration (OSHA) 50 ppm chlorine, two minute immersion respirator sanitizing method in *Appendix B2* of the *OSHA Respirator Standard*, 29 *CFR 1910.134* (reference 1). Per reference 2, OSHA adopted their chlorine sanitizing method from the *ANSI Z88.2-1969 Respirator Standard* (reference 3). This sanitation method was also included in the 1980 and 1992 versions of *ANSI Z88.2*. According to ANSI Z88.2 subcommittee members (references 4 and 5), the *ANSI Z88.2-1969 Respirator Standard* adopted this method from the 1962 Food and Drug Administration (FDA) standard for restaurants and food preparation equipment (reference 6).

1. Per reference 4, their internet search of FDA standards resulted in finding the following almost identical sanitizing procedure in the current version of [21 CFR 129.80 \(d\)\(3\)](#) (reference 7):

“Chemical sanitizers shall be equivalent in bactericidal action to a 2-minute exposure of 50 parts per million of available chlorine at 57 deg. F when used as an immersion or circulating solution. ...”

2. However, 21 CFR 129.80 is the *FDA Standard for Processing and Bottling of Bottled Drinking Water* - not the FDA standard for restaurants and food preparation equipment.

B. To reiterate, *ANSI Z88.2-1969 Respirator Standard* adopted its chlorine-based sanitizing method from the 1962 FDA standard for restaurants and food preparation equipment (reference 6).

II. 1962 FDA FOOD SERVICE SANITATION MANUAL

A. As result of conversations with the FDA (reference 8), concerning historical data confirming that a 2 minute immersion in 50 ppm available chlorine is an effective sanitation method, the FDA sent pertinent excerpts from the 1962 FDA Food Service Sanitation Manual (reference 6), which was the food code in force at the time *ANSI Z88.2-1969 Respirator Standard* was written. This 1962 FDA chlorine sanitizing method is reproduced below:

1. *All eating and drinking utensils and, where required, the food-contact surfaces of all other equipment and utensils shall be sanitized by one of the following methods:*
2. *Immersion for a period of at least 1 minute in a sanitizing solution containing at least 50 ppm of available chlorine at a temperature not less than 75° F...*

B. The 1962 *FDA Food Service Sanitation Manual* used the 50 ppm available chlorine solution as the “Gold Standard” by which all other chemical-sanitizing agents were required to be equivalent in effectiveness.

1. The 1962 *FDA Food Service Sanitation Manual* stated that other chemical-sanitizing agents must provide the equivalent bactericidal effect of a solution containing at least 50 ppm of available chlorine at a temperature not less than 75° F.

2. The footnote to this text indicated that the 50 ppm chlorine solution produces a 99.999 percent kill of 75 - 125 million *E. coli*¹ ATCC² 11229 and 75 - 125 million *M. pyogenes* var. *aureus* FDA 209³ per ml within 60 seconds at 70° - 75° F.

- a. Not surprisingly, the FDA could not find the test data from 1962.

- b. However, the above FDA efficacy requirement lead this author to conclude that the FDA must have tested the efficacy of the 50 ppm available chlorine sanitation method to determine that this sanitizing solution kills 99.999 percent of test bacteria and to establish this sanitation method as the “Gold Standard” to which other sanitizing methods must be equivalent.

III. DISCUSSION AND CONCLUSIONS

A. Written data, documentation, and procedures from the 1960s are hard to find. Research determined that the OSHA chlorine respirator sanitizing method was adopted from the *ANSI Z88.2-1969 Respirator Standard*, which had its basis in the 1962 *FDA Food Service Sanitation Manual*. Today, the FDA uses a hypochlorite sanitation method that is almost identical to OSHA respirator chlorine sanitizing method in 21 CFR 129.80, *FDA Standard for Processing and Bottling of Bottled Drinking Water*.

B. The immersion time for the 1962 *FDA Food Service Sanitation Manual* 50 ppm chlorine sanitizing method for food-contact surfaces and eating/drinking utensils was **one minute**. However, when the ANSI Z88.2-1969 Subcommittee adopted this method for sanitizing respirators they probably doubled the immersion time to two minutes to be more conservative. Since respirators are worn on the face any microorganisms inside the facepiece would be a source of biological inhalation exposure. The subparagraphs below expound upon the probable subcommittee logic for increasing the immersion time from one to two minutes:

1. For food service sanitation, the route of concern for microorganism entry into the body is ingestion. Microorganisms that are ingested may be destroyed by the digestive system. In contrast however, when wearing a

¹ *Erichia coli* ATCC. 11229

² ATCC is the abbreviation for *American Type Culture Collection*

³ *Micrococcus pyogene* var. *aureus*, strain FDA 209

respirator, the route of microorganism entry is of course inhalation. Of all the routes of entry into the body, inhalation is the quickest and most significant route of exposure for microorganisms and other toxic substances.

2. To expound upon this discussion, in contrast to ingestion, microorganisms have a greater opportunity to infect the body directly when inhaled into the respiratory tract, which is not an effective barrier in preventing absorption of toxic materials or excluding microorganisms. This is particularly important with microorganisms that cause high infectivity, such as those resulting in a pandemic because in only a small number they can impart a high risk of infection when inhaled.

IV. REFERENCES

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APPENDIX B

PREPARING BLEACH SANITIZER SOLUTION

I. INTRODUCTION

A. The actual method of preparing bleach solution for sanitizing respirators has been a mysterious enigma within the respirator community. This appendix discusses preparation of bleach respirator sanitizing solution and by necessity will discuss “*Free Available Chlorine*.”

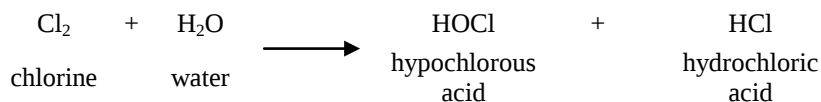
B. Respirator literature usually states that a 50 ppm chlorine solution should be prepared using 5.25% bleach (NaOCl) to sanitize respirators. Some of the literature recommends using a 50 ppm “*available chlorine*” sanitizing solution but does not explain how to prepare it. Other well-known respirator literature recommends sanitizing respirators with 5.25% bleach (NaOCl) solution; however, the dosage of bleach specified to prepare it ranges from mixing 1 ml, 2 ml, 1 teaspoon, 2 teaspoons, up to 2 tablespoons of bleach into the same amount of water to prepare the same concentration!

1. For example, Appendix B of reference 1 states that 1 ml laundry bleach/liter of water makes a solution of 50 ppm chlorine. However, this actually results in a solution with 36 ppm active ingredient.
2. The literature also assumed that the active ingredient of bleach solution is free chlorine (Cl₂). This appendix explains why Cl₂ could not be the active ingredient and provides a practical procedure for preparing respirator sanitizing solution from 5.25% bleach (NaOCl) by adding either 2 ml of 5.25% bleach (NaOCl) per liter of water or by adding 2 teaspoons of 5.25% bleach (NaOCl) per gallon of water. This makes a little stronger solution with 72 ppm active ingredient instead of 50 ppm.

II. DISCUSSION AND RECOMMENDATION

A. There are no free chlorine (Cl₂) or chloride ions (Cl⁻) in 5.25% bleach (NaOCl) or bleach sanitizing solutions. Therefore, all the recommendations for a 50 ppm chlorine sanitizing solution made from bleach are incorrect. Per the Chlorine Institute, NaOCl solutions have a pH of 12.5 or higher which adds alkalinity to the water. NaOCl and water yield sodium ions (Na⁺) and hypochlorite ions (OCl⁻).

1. Depending on the pH of the water being treated, either hypochlorous acid (HOCl) or the hypochlorite ion (OCl⁻) is the active sanitizing species.
2. In contrast, molecular chlorine (Cl₂) creates an acidic solution when added to water and decreases alkalinity.
 - a. Chlorine (Cl₂) and water yield both hydrochloric acid (HCl) and hypochlorous acid (HOCl) as shown below (Note that this reaction does not result in any free Cl₂ in the final solution).



b. The respirator community has been under the impression that bleach either reacts in water like Cl_2 or that the resulting solution contains free Cl_2 but it doesn't.

B. To reiterate, the respirator literature inappropriately describes sanitizing solutions made from laundry bleach as “50 ppm chlorine.” Again, the real active ingredients in diluted bleach are hypochlorous acid (HOCl) and the hypochlorite ion (OCl^-), depending on the pH.

1. Reference 2 describes sanitizing water for drinking purposes with NaOCl and defines “Free Available Chlorine” as the chlorine available (after the chlorine demand has been satisfied) in the forms of hypochlorous acid and hypochlorite ions. In other words free available chlorine is the available hypochlorous acid and hypochlorite ions after the “chlorine demand” has been satisfied.

a. The “chlorine demand” refers to the portion of hypochlorite and hypochlorous acid that reacted with organic and inorganic contaminants in the water.

b. Since we are using tap water for the sanitizing solution, the “chlorine demand” should not be significant.

2. A critical step in the cleaning process is to thoroughly rinse respirators after cleaning to remove residual detergent before immersing respirators in the bleach sanitizing solution. Any residual detergent will react with active ingredient (hypochlorite ion or hypochlorous acid) to increase the chlorine demand. In other words any residual detergent left on the respirator dilutes the bleach sanitizing solution by reducing the free available chlorine.

C. Sodium is an inactive ingredient in bleach. Therefore, bleach’s active ingredient (hypochlorite ion or hypochlorous acid) would not be available on a one to one ratio with the amount of 5.25% bleach added to the sanitizing solution. The percentage of hypochlorite ion must be taken into account in the dilution calculation. Therefore, as shown in the calculation below, 1.38 ml of 5.25% bleach is required to mix with one liter of tap water to make a 50 ppm OCl^- solution:

[Bleach]	Volume of Solution	50 ppm	Ratio Taking into Consideration [Sodium, an inactive ingredient]	ml of 5.25% Bleach Needed
↓	↓	↓	↓	↓
		50g NaOCl	100g Chlorox	
$\text{ml 5.25\% bleach} = 1000 \text{ ml solution} \times \frac{50 \text{g NaOCl}}{10^6 \text{g solution}} \times \frac{100 \text{g Chlorox}}{5.25 \text{g NaOCl} \times (51.5 \text{g OCl}^- / 74.5 \text{g NaOCl})} = 1.38 \text{ ml}$				

III. PREPARATION OF RESPIRATOR BLEACH SANITIZING SOLUTION

A. It would not be practical to measure 1.38 ml of bleach, so we could mix either 1.5 or 2 ml of 5.25% bleach to a liter of water. Addition of 1.5 ml bleach would make a 54 ppm solution and adding 2 ml bleach would make a 72 ppm

solution. However, in actual practice, accurately measuring 1.5 ml is probably almost as impractical as measuring 1.38 ml, so for convenience add 2 ml to a liter of water, which makes a sanitizing solution of 72 ppm free available chlorine solution as shown below:

$$\text{For 1.5 ml 5.25\% bleach} \quad \text{ppm} = (1.5\text{ml})(50\text{ppm})/1.38 \text{ ml bleach} \quad = \quad 54 \text{ ppm}$$

$$\text{For 2 ml 5.25\% bleach} \quad \text{ppm} = (2\text{ml})(50\text{ppm})/1.38 \text{ ml bleach} \quad = \quad 72 \text{ ppm}$$

B. For a larger volume of sanitizing solution, add 2 teaspoons of 5.25% bleach per gallon of tap water. Mixing 2 ml of 5.25% bleach per liter equates to 2 teaspoons per gallon of water since 1 teaspoon equals 4.928922 ml and one gallon equals 3785.412 ml. The following ratios show that two teaspoons per gallon is sufficiently close enough to 2 ml per liter:

$$2 \text{ ml}/1000\text{ml} = 0.002$$

and

$$2 (4.928922 \text{ ml})/3785.412 \text{ ml} = 0.0026$$

IV. CONCLUSION

A. Respirators may be washed in a detergent solution, thoroughly rinsed, and then sanitized by two minute immersion in a bleach sanitizing solution consisting of a diluted 5.25% bleach solution (**72 ppm free available chlorine solution made from mixing either 2 ml per liter of tap water or 2 teaspoons per gallon of tap water**). The slightly higher concentration (72 ppm rather than 50 ppm) will help compensate for any chlorine demand from residual detergent left over from the cleaning step.

B. To reiterate, the active disinfecting ingredient of bleach is free available chlorine¹ – Not Cl₂.

C. According to reference 3, ensure that the bleach being used to create the sanitizing solution is actually 5.25% sodium hypochlorite by changing the supply of bleach with a fresh container of bleach every three months. Use the 72 ppm free available chlorine sanitizing solution within 24 hours after preparation. After that length of time it loses its sanitizing properties.

¹ Hypochlorous acid or hypochlorite ions depending on the pH of the sanitation solution.

V. REFERENCES

- 1 Occupational Safety and Health Administration (OSHA): 29 CFR Parts 1910 and 1926 Respiratory Protection: Final Rule. Federal Register 63(5):1278–1279. Washington, D.C.: U.S. Government Printing Office, Office of the Federal Register, January 8, 1998. http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=12716
- 2 NAVMED P-5010-6, Chapter 6, Manual of Naval Preventive Medicine Water Supply Afloat (Rev. 7-2005), S/N 0510-LP-103-9057.
- 3 University of Oklahoma Health Sciences Environmental Health and Safety Office Saf-T-Gram. Letter from the Clorox Company. <http://www.ouhsc.edu/ehso/saf-t-gram/Spring01.pdf>.

APPENDIX C PREPARING IODINE SANITIZER SOLUTION

I. PRACTICAL METHOD FOR PREPARING IODINE SANITIZER SOLUTION

A. Appendix B of reference 1 recommends mixing 0.8 ml of tincture of iodine with 1 liter of water. However, measuring 0.8 ml is not a practical measurement to perform in actual practice. The following explanation shows the calculations for the actual amount of tincture of iodine (Wescodyne) needed to mix with water to prepare a 50 ppm iodine sanitation solution. As will become apparent, a more practical method of iodine sanitizing solution is to mix 1 tablespoon (14.8 ml) of Wescodyne in 1.5 gal H₂O, which makes 51.53 ppm iodine solution.

B. The active disinfecting species in Wescodyne is 1.75% iodine. A solution of 50 ppm would require mixing 2.53 ml of Wescodyne (1.75% iodine) per liter of tap water as shown below:

[Wescodyne Solution]	Grams of Solution	50 ppm	Specific Gravity & % Ratio	ml of Wescodyne Needed
↓	↓	↓	↓	↓
50ppm iodine = 1000 g solution	50g iodine	10 ⁶ g solution	1.13g X (1.75g iodine /100g Wescodyne)	= 2.53 ml Wescodyne

C. A more practical quantity of iodine solution to prepare is 1.5 gallons of sanitizing solution. The addition of 14.36 ml (0.97 tablespoon) of Wescodyne makes a 50 ppm iodine solution in 1.5 gallon H₂O as shown below.

[Wescodyne Solution]	Grams of Solution	50ppm	Specific Gravity & % Ratio	ml of Wescodyne Needed
↓	↓	↓	↓	↓
50ppm iodine = 5678.12 g solution	50g iodine	10 ⁶ g solution	1.13g X (1.75g iodine /100g Wescodyne)	= 14.36 ml Wescodyne

D. However, measuring 14.36 ml Wescodyne (0.97 tablespoon Wescodyne) is impractical. **One tablespoon (1 tablespoon = 14.8 ml) of Wescodyne in 1.5 gal H₂O makes 51.53 ppm iodine solution** as shown below:

$$\frac{14.36 \text{ ml}}{50 \text{ ppm}} = \frac{14.8 \text{ ml}}{X \text{ ppm}}$$

$$X \text{ ppm} = 14.8 \text{ ml}(50 \text{ ppm}) / (14.36 \text{ ml}) = 51.53 \text{ ppm}$$

II. REFERENCE

1 Occupational Safety and Health Administration (OSHA): 29 CFR Parts 1910 and 1926 Respiratory Protection: Final Rule. Federal Register 63(5):1278–1279. Washington, D.C.: U.S. Government Printing Office, Office of the Federal Register, January 8, 1998. http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=12716