



Designation: E1054 – 21^{ε1}

Standard Practices for Evaluation of Inactivators of Antimicrobial Agents¹

This standard is issued under the fixed designation E1054; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

^{ε1} NOTE—Editorial changes were made throughout in May 2021.

1. Scope

1.1 These test procedures are used to determine the effectiveness of methodologies procedures and materials intended for inactivating (neutralizing, quenching) the microbicidal properties of antimicrobial agents; to ensure that no components of the neutralizing procedures and materials, themselves, exert an inhibitory effect on microorganisms targeted for recovery; and to demonstrate that the antimicrobial chemistry tested is microbicidal.

1.2 Knowledge of microbiological and statistical techniques is required for these procedures.

NOTE 1—These methods are not suitable when testing the virucidal activity of microbicides (see Test Method E1482).

1.3 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*²

E645 Practice for Evaluation of Microbicides Used in Cooling Water Systems

¹ These practices are under the jurisdiction of ASTM Committee E35 on Pesticides, Antimicrobials, and Alternative Control Agents and are the direct responsibility of Subcommittee E35.15 on Antimicrobial Agents.

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

E1115 Test Method for Evaluation of Surgical Hand Scrub Formulations

E1482 Practice for Use of Gel Filtration Columns for Cytotoxicity Reduction and Neutralization

E2756 Terminology Relating to Antimicrobial and Antiviral Agents

3. Terminology

3.1 *Definition of Terms:* For definition of terms not listed below, refer to E2756, *Standard Terminology Relating to Antimicrobial and Antiviral Agents*.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *antimicrobial effectiveness evaluation, adj/n*—a determination of microbicidal properties of an antimicrobial agent by methods, such as Practice E645 and Test Method E1115.

3.2.2 *CFU/mL (abbrev.)*—colony-forming units of a microorganism per millilitre of fluid.

3.2.3 *neutralizer effectiveness, adj/n*—ability of a neutralization procedure to inactivate or quench the microbicidal properties of an antimicrobial agent.

3.2.4 *neutralizer toxicity, adj/n*—any inhibitory effects a neutralization procedure may have on the survival of a microbial population.

3.2.5 *test material control, adj/n*—an evaluation of the activity of a test material in reducing a known population of microorganisms.

3.2.6 *test organism viability, adj/n*—the population of a challenge microorganism used in a neutralization assay.

3.2.7 *viability, n*—the ability of a challenge microorganism to form colonies or grow on a nutrient medium.

3.2.7.1 *Discussion*—In the context of these test methods, “viability” is understood to be synonymous with cultivability.

4. Summary of Practices

NOTE 2—The neutralization test procedure selected must be consistent with the methods of testing used in the antimicrobial effectiveness evaluation.

4.1 *Neutralization Assay with Recovery on Semi-solid Medium*—Neutralization assay for antimicrobial effectiveness tests that recover and quantify microbial populations on

semi-solid (agar) media. This method is appropriate for antimicrobial agents that are chemically inactivated or diluted to sub-inhibitory levels and performed entirely *in vitro* or including an *in vivo* component, such as to verify neutralization of an antimicrobial formulation sampled from the skin of a human volunteer.

4.2 Neutralization Assay with Recovery in Liquid Medium—Neutralization assay for antimicrobial effectiveness tests that recover surviving microbial populations in liquid media for a growth/no growth determination. This method is appropriate for antimicrobial agents that are chemically inactivated or diluted to sub-inhibitory levels.

4.3 Neutralization Assay with Recovery by Membrane Filtration—Neutralization assay for antimicrobial effectiveness tests that recover and quantify microbial populations by using membrane filtration. This method is appropriate for antimicrobial agents that cannot be chemically inactivated or diluted to sub-inhibitory levels, as well as for those that can be.

5. Significance and Use

5.1 The effectiveness of antimicrobial agents incorporated into disinfectants, sanitizers, and antiseptics is measured by their ability to kill microorganisms within a specified contact time. Hence, accurate determination of antimicrobial effectiveness requires complete and immediate inactivation (neutralization) of the antimicrobial agent. Inefficient or incomplete neutralization will permit killing or inactivation of microorganisms to continue beyond the experimental exposure time, resulting in an overestimation of antimicrobial activity.

5.2 The neutralization methods commonly used in antimicrobial effectiveness evaluations are chemical inactivation, dilution, and filtration. All critical parameters of an antimicrobial effectiveness evaluation—for example, media, equipment, microorganism(s), and temperature of solutions—must be duplicated in the performance of selected neutralization procedure.

5.3 The neutralization evaluation must include at least three replications (five replications in Section 9) so that a statistical analysis of the microbial recovery data can be performed. The number of replicates used in the evaluation depends on the statistical significance required for the expected results, the variability encountered in the data, and the relative effectiveness of the neutralization procedure.

5.4 A limitation of these evaluation procedures is that they use microorganisms that have not been exposed to an antimicrobial agent. Under experimental conditions, cells exposed to neutralization procedures are likely to be damaged to different degrees by the antimicrobial agent. Sublethal injury may be a factor in recovery, and the effect of the neutralization procedure on recovery of injured organisms should be examined. This method is not intended to assess recovery of injured organisms.

NOTE 3—Ideally, all microorganisms used in the antimicrobial effectiveness evaluation should be tested in the neutralization assay. However, representative organisms may be selected for testing, as judged appropriate by the investigator. The investigator is cautioned that failure to identify neutralizer efficacy and toxicity for all microorganisms could result in biased microbial reductions in an antimicrobial effectiveness evaluation. Also, for a study testing multiple antimicrobial formulations, and in which

samples will contain multiple species of microorganisms (for example, skin flora) that are exposed to the formulations, a single procedure and/or combination of agents suitable for neutralizing the antimicrobial activities of the multiple formulations must be used for testing.

6. Apparatus

6.1 Standard bacteriological devices and equipment should be used for performance of the neutralization assay.

6.2 Colony Counter—Any of several types may be used; for example, Quebec colony counters and similar devices, or automated, computerized plater/counter systems.

6.3 Incubator—Any incubator capable of maintaining a temperature appropriate for growth of the test microorganism(s) may be used.

6.4 Sterilizer—Any steam sterilizer capable of producing the conditions of sterilization.

6.5 Timer (stopwatch)—One that displays hours, minutes, and seconds.

6.6 Vortex Mixer or equivalent.

6.7 Membrane Filter Units—Any sterilizable unit that permits filtration of microorganisms for enumeration. The membrane filter unit must be chemically compatible with the antimicrobial agent and appropriate to efficient recovery of the test microorganisms.

7. Reagents and Materials

7.1 Phosphate Buffered Saline Dilution Water—PBS (see Practice E645).

7.1.1 Phosphate Buffer Solution, Stock—Dissolve 34 g of potassium dihydrogen phosphate (KH_2PO_4) in 500 mL of water. Adjust pH to 7.2 ± 0.2 with 0.1 N NaOH or 0.1 N HCl and bring to 1000 mL with deionized water.

7.1.2 Phosphate Buffer Saline Dilution Water—Add 1.25 mL of stock phosphate buffer solution and 8.75 g of NaCl to a volumetric flask, fill with deionized water to the 1000 mL mark, and mix. Final pH should be adjusted to 7.2 ± 0.2 , if necessary. Sterilize by filtration or autoclave.

7.2 Because the types of materials and reagents required for various antimicrobial effectiveness evaluations are so diverse, it is impractical to list them in this method. The specific materials and reagents to be used in the antimicrobial effectiveness evaluation, however, must be used in the neutralization assay to confirm that the antimicrobial agent is being neutralized in a particular evaluation.

7.3 Table 1 provides a list of materials employed by researchers to inactivate the microbicidal properties of various antimicrobial agents. This list is provided as a guide for selecting neutralizers and is not exhaustive. A neutralization assay must be performed to determine a selected neutralizer's effectiveness.

8. Neutralization Assay with Recovery on Semi-solid Medium (Fig. 1)

8.1 At least three replicates of each test condition are required for these procedures. The number of additional replicates necessary to the evaluation is dictated by the

TABLE 1 Processes Applied for Neutralization of Certain Antimicrobial Agent^A

| Antimicrobial Agent | Neutralizers/Inactivators |
|--|--|
| Alcohols Isopropanol, Phenoxyethanol | Polysorbate 80, dilution to sub-inhibitory levels |
| Aldehydes 2-Bromo-2-nitropropane-1, 3-diol (Bronopol) | Serum, cysteine, thiosulfate, thioglycolate, metabisulfite |
| Formaldehyde | Sodium sulfite, ammonia, histamine |
| Glutaraldehyde | Dilution to sub-inhibitory levels, sodium bisulfite, sodium sulfite, glycine, cystine, cysteine |
| N-(3-Chloroallyl)hexaminium Chloride (Dowicide Q) | Dilution to sub-inhibitory levels |
| Dimethylol-5, 5-dimethylhydantoin (Glydant) | Dilution to sub-inhibitory levels |
| Biguanides and Bis-biquanides Chlorhexidine | Lecithin/polysorbate 80, sodium oleate |
| Polyhexamethylene biguanide HCL (Cosmocil CQ) | Polysorbate 80/lecithin |
| Phenolics Phenylphenol, Chloroxylenol, Cresols, Chlorocresols, Phenol | Nonionic surfactants, polysorbate 80, and/or dilution to sub-inhibitory levels |
| Bis-Phenols Triclosan | >10 % polysorbate 80/lecithin, and dilution to sub-inhibitory levels |
| Hexachlorophene | >10 % polysorbate 80/lecithin, and dilution to sub-inhibitory levels |
| Quaternary Ammonium Compounds Cetrimide, Benzalkonium and Benzethonium Chloride | Lecithin/polysorbate, suramin sodium, organic material, 0.5 % polysorbate 80, cyclodextrins |
| Mercurials and Silver | Sulphydryl compounds, thioglycolic acid, thiosulfate, bisulfite, ammonium sulfite |
| Organic Acids Benzoic, Propionic, Sorbic | Nonionic surfactants, dilution to sub-inhibitory levels, pH 7 or above |
| Halogens Hypochlorite | Thiosulfate and/or dilution to sub-inhibitory levels |
| Iodine | Thiosulfate, polysorbate 80, skim milk |
| Bromine | Thiosulfate and/or dilution to sub-inhibitory levels |
| EDTA | Mg ⁺² or Ca ⁺² ions |
| Imidazolidinyl urea | Dilution to sub-inhibitory levels |
| Methyl-, and dimethylchloroisothiazolinone (Kathon) | Amines, sulfites, mercaptans, sodium bisulfite, heparin |
| Parabens Methyl-, ethyl-, propyl-, butyl-parahydroxybenzoate | Lecithin, filtration, dilution to sub-inhibitory levels, polysorbate surfactants, 1 % polysorbate 80 or 20 |
| Hydrogen Peroxide | Catalase |
| Peroxyacetic Acid | Thiosulfate |

^A Sutton, S. V. W., "Neutralizer Evaluations as Control Experiments for Antimicrobial Effectiveness Tests," Ch. 3 in *Handbook of Disinfectants and Antiseptics*, Marcel-Dekker, NY, 1996, p. 300.

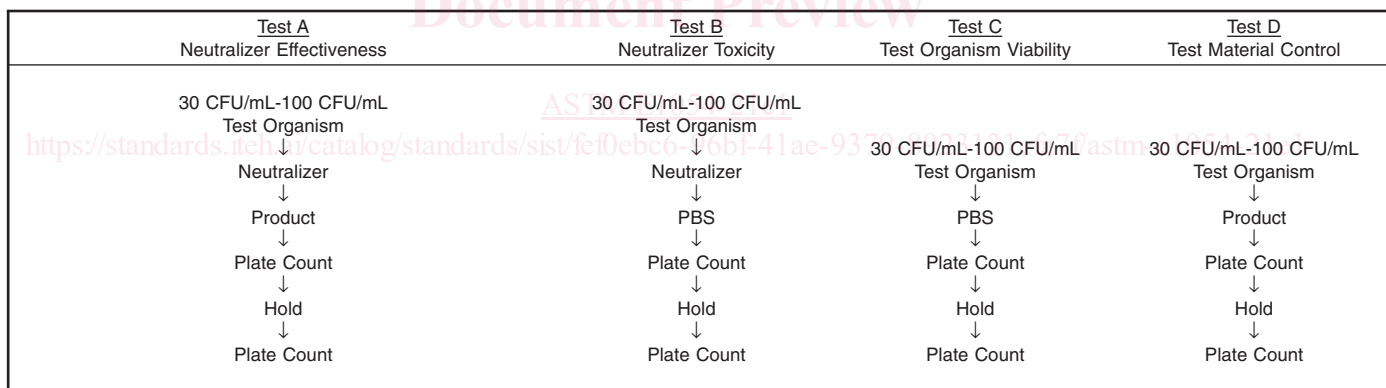


FIG. 1 Testing Schema for Neutralization Assay with Recovery on Semi-solid Medium

statistical significance required for the expected results, the variability encountered in the data, and the relative effectiveness of the neutralization procedure.

8.2 All tests must be performed in a timely manner so that significant proliferation of the test organism does not occur.

8.3 *Test A—Neutralization Effectiveness:*

8.3.1 Inoculate the neutralizer with a volume of the challenge microbial suspension to result in a suspension that contains 30 CFU/mL to 100 CFU/mL of the microorganism.

NOTE 4—The challenge inoculum should be prepared in the same manner to be used in the antimicrobial effectiveness evaluation. The

volume of the challenge inoculum should be kept to a minimum so that it does not cause significant dilution.

8.3.2 Add a volume of product, or solution containing product, to the neutralizer/microbial suspension that will result in the same dilution ratio used in the antimicrobial effectiveness evaluation. If the antimicrobial effectiveness evaluation will employ the use of carriers, use instead a carrier bearing an amount of product used in the effectiveness evaluation.

NOTE 5—The dilution ratio of product to neutralizer can be manipulated to determine the dilution at which adequate neutralization of the product will occur, particularly when testing products not readily neutralized by chemical means.

8.3.3 Within 1 min of execution of 8.3.2, transfer aliquots of the product/neutralizer/microbial suspension to pour or spread plates, in duplicate, using an appropriate semi-solid medium. If neutralizers are incorporated in the plating medium for the antimicrobial effectiveness evaluation, use this same medium for plating the suspension.

8.3.4 Allow the product/neutralizer/microbial suspension to stand for the longest exposure period representative of that used in the antimicrobial effectiveness evaluation. For example, if the product/neutralizer/microorganism from the antimicrobial effectiveness evaluation will be plated within 30 min, then the longest exposure period for the neutralization assay is 30 min.

8.3.5 After the hold-time, transfer aliquots of the product/neutralizer/microbial suspension to pour or spread plates, in duplicate, using an appropriate semi-solid medium. If neutralizers are incorporated in the plating medium for the antimicrobial effectiveness evaluation, use this same medium for plating the suspension.

NOTE 6—The duration of the hold time must not be such that proliferation of the test organism introduces a variable.

8.3.6 Repeat this procedure (8.3.1 – 8.3.5) an additional two or more times, for a total of at least three replicates.

8.3.7 Incubate the plates under the same conditions as those used in the antimicrobial effectiveness evaluation, and following incubation, enumerate colony-forming units.

8.4 Test B—Neutralizer Toxicity:

8.4.1 Inoculate the neutralizer with a volume of the challenge microbial suspension such that the resulting suspension contains 30 CFU/mL to 100 CFU/mL of the microorganism (see Note 4).

8.4.2 Add a volume of sterile PBS or other appropriate buffering agent to the neutralizer/microbial suspension that will result in the same dilution ratio as that used in Test A (see 8.3.2).

8.4.3 Within 1 min of execution of 8.4.2, transfer aliquots of the PBS/neutralizer/microbial suspension to pour or spread plates, in duplicate, using an appropriate semi-solid medium. If neutralizers are incorporated in the plating medium for the antimicrobial effectiveness evaluation, use this same medium for plating the suspension.

8.4.4 Allow the PBS/neutralizer/microbial suspension to stand for the same period used in Test A (see 8.3.4).

8.4.5 After the hold-time, transfer aliquots of the PBS/neutralizer/microbial suspension to pour or spread plates, in duplicate, using an appropriate semi-solid medium. If neutralizers are incorporated in the plating medium for the antimicrobial effectiveness evaluation, use this same medium for plating the suspension.

8.4.6 Repeat this procedure (8.4.1 – 8.4.5) an additional two or more times, for a total of at least three replicates.

8.4.7 Incubate the plates under the same conditions as those used in the antimicrobial effectiveness evaluation, and following incubation, enumerate the colony-forming units.

8.5 Test C—Test Organism Viability:

8.5.1 Inoculate a volume of sterile PBS or other appropriate buffering agent with a volume of the challenge microbial

suspension such that the resulting suspension contains 30 CFU/mL to 100 CFU/mL of the microorganism (see Note 4).

8.5.2 Within 1 min of execution of 8.5.1, transfer aliquots of the PBS/microbial suspension to pour or spread plates, in duplicate, using an appropriate semi-solid medium that does not contain neutralizers and is not a selective or differential medium.

8.5.3 Allow the PBS/microbial suspension to stand for the same exposure period used in Test A (see 8.3.4).

8.5.4 After the hold-time, transfer aliquots of the PBS/microbial suspension to pour or spread plates, in duplicate, using an appropriate semi-solid medium that does not contain neutralizers and is not a selective or differential medium.

8.5.5 Repeat this procedure (8.5.1 – 8.5.4) an additional two or more times, for a total of at least three replicates.

8.5.6 Incubate the plates under the same conditions as those used in the antimicrobial effectiveness evaluation, and following incubation, enumerate the colony-forming units.

8.6 Test D—Test Material Control:

NOTE 7—A test of a product's antimicrobial effectiveness is necessary to demonstrate that the neutralizer actually does neutralize the activity of an antimicrobial agent. However, performance of the Test Material Control phase is situational and may not be necessary for specific formulations with which the researcher has prior experience.

8.6.1 Inoculate the product with a volume of the challenge microbial suspension such that the resulting suspension contains 30 CFU/mL to 100 CFU/mL of the microorganism (see Note 4).

8.6.2 Hold the product/microbial suspension for an exposure period necessary to allow detection of an antimicrobial effect. The hold time must not be longer in duration than the hold time in Test A (see 8.3.4).

8.6.3 After the hold time, transfer aliquots of the product/microbial suspension to pour or spread plates, in duplicate, using an appropriate semi-solid medium that does not contain neutralizers and is not a selective or differential medium.

8.6.4 Repeat this procedure (8.6.1 and 8.6.2) an additional two or more times, for a total of at least three replicates.

8.6.5 Incubate the plates under the same conditions as those used in the antimicrobial effectiveness evaluation, and following incubation, enumerate the colony-forming units.

9. Neutralization Assay with Recovery in Liquid Medium (Fig. 2)

9.1 At least five replicates are required for these procedures. The number of replicates used in the evaluation depends on the statistical significance required for the expected results, the variability encountered in the data, and the relative effectiveness of the neutralization procedure. The same nutrient medium should be used in all phases of the assay.

9.2 All tests must be performed in a timely manner so that significant proliferation of the test organism does not occur.

9.3 Test A—Neutralization Effectiveness:

9.3.1 Inoculate the neutralizer-nutrient medium with a volume of the challenge microbial suspension such that the resulting suspension contains 30 CFU/mL to 100 CFU/mL of the microorganism (see Note 4).

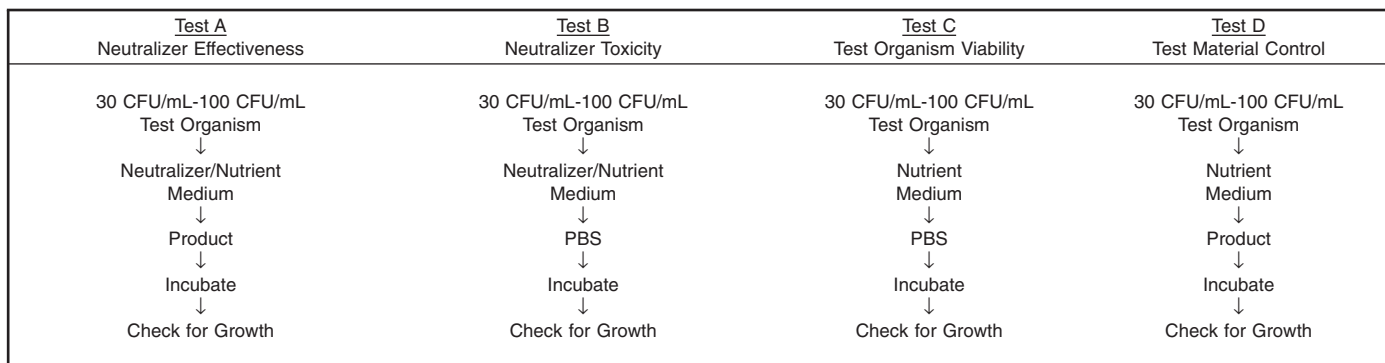


FIG. 2 Testing Schema for Neutralization Assay with Recovery in Liquid Medium

9.3.2 Add a volume of product, or solution containing product, to neutralizer-nutrient medium/microbial suspension that will result in the same dilution ratio used in the antimicrobial effectiveness evaluation. If the antimicrobial effectiveness evaluation will employ the use of carriers, use instead a carrier bearing an amount of product representative of that used in the test.

9.3.3 Repeat this procedure (9.3.1 and 9.3.2) an additional four or more times, for a total of at least five replicates.

9.3.4 Incubate the product/neutralizer-nutrient medium/microbial suspension under the same conditions as those used in the antimicrobial effectiveness evaluation.

9.3.5 Following incubation, check for growth. If growth is present, record as a “1,” and if no growth is present, as a zero. Confirm growth of the challenge microorganism by plating the suspension.

9.4 Test B—Neutralizer Toxicity:

9.4.1 Inoculate the neutralizer-nutrient medium with a volume of the challenge microbial suspension such that the resulting suspension contains 30 CFU/mL to 100 CFU/mL of the microorganism (see Note 4).

9.4.2 Add a volume of PBS to the neutralizer-nutrient medium/microbial suspension in the same dilution ratio as that used for product in Test A (see 9.3.2).

9.4.3 Repeat this procedure (9.4.1 and 9.4.2) an additional four or more times, for a total of at least five replicates.

9.4.4 Incubate the PBS/neutralizer-nutrient medium/microbial suspension under the same conditions as those used in the antimicrobial effectiveness evaluation.

9.4.5 Following incubation, check for growth. If growth is present, record as a “1,” and if no growth is present, as a zero. Confirm growth of the challenge microorganism by plating the suspension.

9.5 Test C—Test Organism Viability:

9.5.1 Inoculate the nutrient medium with a volume of challenge microbial suspension such that the resulting suspension contains 30 CFU/mL to 100 CFU/mL of the microorganism (see Note 4).

9.5.2 Add a volume of PBS or other appropriate buffering agent to the nutrient medium/microbial suspension in the same volume as that used for product in Test A (see 9.3.2).

9.5.3 Repeat this procedure (9.5.1 and 9.5.2) an additional four or more times, for a total of at least five replicates.

9.5.4 Incubate the PBS/nutrient medium/microbial suspension under the same conditions as those used in the antimicrobial effectiveness evaluation.

9.5.5 Following incubation, check for growth. If growth is present, record as a “1,” and if no growth is present, as a zero. Confirm growth of the challenge microorganism by plating the suspension.

9.6 Test D—Test Material Control (see Note 7):

9.6.1 Inoculate the nutrient medium with a volume of challenge microbial suspension such that the resulting suspension contains 30 CFU/mL to 100 CFU/mL of the microorganism (see Note 4).

9.6.2 Add a volume of product to the nutrient medium/microbial suspension in the same volume as that used for product in Test A (see 9.3.2).

9.6.3 Repeat this procedure (9.6.1 and 9.6.2) an additional four or more times, for a total of at least five replicates.

9.6.4 Incubate the product/nutrient medium/microbial suspension under the same conditions as those used in the antimicrobial effectiveness evaluation.

9.6.5 Following incubation, check for growth. If growth is present, record as a “1,” and if no growth is present, as a zero. Confirm growth of the challenge microorganism by plating the suspension.

10. Neutralization Assay with Recovery by Membrane Filtration (Fig. 3)

10.1 At least three replicates of each test condition are required for these procedures. The number of additional replicates necessary to the evaluation is dictated by the statistical significance required for the expected results, the variability encountered in the data, and the relative effectiveness of the neutralization procedure.

10.2 All tests must be performed in a timely manner so that significant proliferation of the test organism does not occur.

10.3 Test A—Neutralization Effectiveness:

10.3.1 Filter through the membrane a volume of product, or solution containing product, that is the same as that used in the antimicrobial effectiveness evaluation.

NOTE 8—This can be achieved by adding 1 mL of a microbial suspension containing 30 CFU/mL to 100 CFU/mL to the PBS.

NOTE 9—The membrane filter type and apparatus must be the same as