

A Critique of NCCLS Guideline C3-A3 Preparation and Testing of Reagent Water in the Clinical Laboratory

Edition 3

Senior Editor
Erich L. Gibbs, Ph.D.^a
02/02/02

Foreword

As a guideline to creating and maintaining laboratory water purification systems, the C3-A3 Guideline provides some useful insight; however, many sections are vague, internally inconsistent, and misleading. The four grades of laboratory reagent water specified by the Guideline are of little practical value, because the Guideline does not state unequivocally where in a purification system measurements are to be made. Moreover, the specifications depend primarily on the measurement of resistivity, *determined only once a day*. And the same resistivity limits apply to systems that utilize cold-technologies (e.g., ion exchange, carbon sorption, ultra filtration, etc.) in their final stage and those that use distillation, which makes no sense. Thus, Type I water is specified as having a 10 M Ω -cm limit for resistivity (referenced to 25° C), regardless of how the water is purified. If the final stage in a purification system utilizes distillation, a resistivity of 10 M Ω -cm following this final stage would be strong evidence of excellent performance. However, in the case of cold-technology systems, a resistivity of 10 M Ω -cm following the final stage of purification could suggest a rapidly failing, or poorly designed, system.

Besides resistivity, the only other measured limits for Type I water are a viable plate count, VPC, of ≤ 10 CFU/L, performed once a week, and a maximum *soluble* silicate level of 0.05 ppm, performed at the discretion of the laboratory. The VPC and silicate limits are of little practical value and appear to be arbitrary:

^a Dr. Gibbs contributed to the NCCLS C3-A3 and is President of High-Q, Inc., which manufactures laboratory water purification equipment. Comments and questions should be addressed as follows:
Dr. Gibbs – editorial@high-q.com NCCLS – www.nccls.org

1. VPCs require days, perhaps weeks, to complete; therefore, if water samples are obtained only weekly, it could be weeks before it is determined that water used for testing did not meet the Type I specification. This fact is recognized by the Guideline, but no solution is offered.
2. VPCs are likely to underestimate the number of viable bacteria in purified water samples by 100- to 1000-fold.^b
3. VPCs bear little or no relationship to the levels of microbial byproducts in purified water, especially in view of the fact that the Guideline suggests using a 0.22 micron filter at the output of water purification systems.
4. Evidence that low levels of silicate cause non-specific interferences in bioscientific applications is lacking, despite NCCLS claims (unsupported) that silicates (soluble) or colloidal silica (insoluble) can affect enzyme, trace metal, and electrolyte determinations. Furthermore, NCCLS recommends a molybdate method for determining silica and this method is not sensitive to insoluble silica.

If clinical laboratories rely on the C3-A3 Guideline, it seems very likely that laboratory tests will be performed with water that does not meet the limits specified by the Guideline, because the Guideline permits such long intervals between measurements. In fact, considering the many instances of vague, confusing, and contradictory language, the Guideline may do more to weaken laboratory quality control than to improve it.

^b *McAlister MB, Kulakov LA, Larkin MJ, Ogden KL. Microbials - Analysis of bacterial contamination in different sections of a high-purity water system. Ultrapure Water 2001; 18(1):18-26.*

Critique

Important: The published text of D1193 is shown in black. Comments and corrections are contained within square brackets, [], and shown in blue.

[C3-A3 is protected by a 1997 NCCLS copyright, so it would be inappropriate for anyone to reconstruct a copy of the original document from this critique or to reference this critique for any purpose that would be served by direct reference to the original document without NCCLS permission.]

[The fact that sections of C3-A3 have been skipped is not intended to give the impression that they do not require revision and upgrading.]

Beginning of C3-A3 . . .

**Preparation and Testing of Reagent Water
in the Clinical Laboratory; Approved Guideline - Third Edition
Volume 17 Number 18 / October 1997**

[It is not clear whether as a *guideline* (Defined as a standard or principle by which to make a judgement or determine a policy or course of action.) C3-A3 is, or can include, a specification that becomes part of any regulations.]

Foreword

This guideline describes water of three specific levels of quality (Types I, II, and III) [The table of limits in Section 6 includes processes parameters that are not controlled and the required frequency of measurement for the four product parameters is so low that water produced according to C3-A3 is likely to be variable and unknown, not specific.] and the methods for producing [Section 4 is too vague and general to be of practical value.] and testing such water. The classifications and specifications are designed to enable laboratory scientists and supporting industries to specify the quality of water to be used in such procedures as, for example, reagent preparation, reconstitution of lyophilized materials, and sample dilution.

The committee believes that the criteria and measurements specified for monitoring water quality are the minimum necessary. The parameters are as follows:

- Resistivity [Measured perhaps once a day for Type I water with no recommendation for measurement frequency for Types II and III (See Section 6.)]
- Microbial content [Measured at least weekly (See Section 9). This is a notoriously inaccurate and difficult measurement that may require a week to incubate properly.]
- pH [pH is not required to be monitored for Type I or Type II waters – see Table 2 and measurement is essentially optional for Type III water (see Appendix B).]
- Silicate content [Only soluble silicates are measured and they are measured at the user's discretion (See Appendix B).]
- Particulate matter [Particulates are not required to be *monitored*; instead NCCLS requires the use of a 0.22 µm filter as a final step of purification.]
- Organic content. [Organics are not required to be *monitored*; instead NCCLS requires the use of granulated activated carbon (GAC), reverse osmosis (RO), or distillation to control organics – see below.]

...

Measurements of resistivity are practical and readily available, and they provide significant information about the water sampled. As the sensitivity of laboratory analytical processes increases and sample size decreases, microbial content of the reagent water becomes increasingly important. [The use of sampled and sample size with very different meanings is confusing. In any case, the second sentence is not necessarily accurate. Furthermore, TOC and endotoxin concentrations are likely to be much more important, because free-floating microorganisms represent a relatively small percentage of the organic contaminants in most water systems.] Microorganisms can inactivate reagents, contribute to total organic contamination, or alter optical properties of the test solutions. [By the time microorganisms are contributing significantly to the optical properties of solutions and inactivating reagents, their concentrations are likely to be exceptionally high by pure water standards.]

The monitoring of other parameters – namely pH, silicate content, particulate matter, and organic content – depends on many variables. Each laboratory should assess the need for, and frequency of, monitoring any of these on a routine basis. If the source water and the purification system produce water [How does the source water produce water?] that is typically negative for some contaminant, the frequency of testing for that contaminant can be decreased. However, it is necessary to ensure occasionally that the end product is free from all significant contaminants. [This statement provides the user with no practical guidance. What is meant by *occasionally*? Does NCCLS want laboratories occasionally to measure for every possible type of contamination that is measurable?]

This guideline recommends that the laboratory examine the acceptability of the type of reagent water to be used and record the rationale for this decision. A laboratory should

also check to see if there are requirements applicable to its specific uses. [It is not clear what this sentence means.]

Key Words

Laboratory water, microbial contamination, reagent water, resistivity, special-purpose water, specifications, testing, water contamination, water purity, water-soluble silicates. [Water-soluble silicates are emphasized by including them in the list of key words, despite the fact that most references to silicates in the Guideline do not mention solubility and this Guideline provides no evidence for its claims that silica, soluble or insoluble, is a potential contaminant worthy of special note.]

1 Introduction

This guideline describes water of three specific levels of quality (Types I, II, and III) [The table of limits in Section 6 includes processes parameters that are not controlled and the required frequency of measurement for the four product parameters is so low that water produced according to C3-A3 is likely to be variable and unknown – this sentence may be technically correct, but it gives the false impression that the three Types of water are rigorously controlled when they are not.] and the methods for producing [Section 4, Preparation, is too vague and general to be of practical value – see comments under the Section.] and testing such water in the clinical laboratory (e.g., chemistry, hematology, and microbiology). The classifications and specifications [What is the meaning of “classifications” in this context – perhaps the wording should be changed to, “The classifications and their specifications . . .] are designed [Intended?] to enable laboratory scientists and supporting industries to specify the quality of water to be used in such procedures, e.g., reagent preparation, reconstitution of lyophilized materials, and sample dilution. [The specifications do not appear to be adequate for these purposes, so the statement is misleading – especially when the word, “designed” is used.]

No one specific method is recommended for producing purified water. A single method or combination of methods may be used satisfactorily, provided that the end product [Product water?] meets the required specifications stated in this guideline. [The product water specifications are too vague to control the process(es) or the purity of the product.] Understand that any changes [Would usage that results in wear and tear be considered a change?] to a previously qualified water-purification process or source water require a revalidation [The contaminant profile of source water is not constant, so source water will be changing all the time! The Guideline does not define “revalidation”?] of the reagent water system.

2 Scope

This document addresses requirements for water purified for laboratory use as described below (see Table 1 on page 4), irrespective of the site of water production. [Table 1, *Water Purification Process Comparison*, does not address or describe any requirements for water purification. Perhaps NCCLS meant to refer to Table 2, *Reagent Water Specifications*, on page 8. The meaning of this sentence is not clear, especially the phrase, “irrespective of the site of water production.”] Three grades of water are specified, and special reagent water is also addressed (see Table 2 on page 8): [Special Reagent Water is not addressed in Table 2. It is addressed in Sections 7.3 and 9.6.]

- Clinical laboratory reagent water, Type I
- Clinical laboratory reagent water, Type II
- Clinical laboratory reagent water, Type III
- Special reagent water.

Water that conforms to specifications published by the American Chemical Society (ACS)^a, the American Society for Testing and Materials (ASTM)^b, the College of American Pathologists (CAP)^c [CAP does not publish specifications for water.], and the United States Pharmacopeia (USP)^d may or may not be equivalent to the reagent water [Which reagent water – more than one is described.] described in this document. [What is the point of this sentence – any water may, or may not, be equivalent.] USP specifications apply to a variety of in vitro and in vivo uses. [This sentence seems irrelevant in this context and does not appear to be accurate.] Classification is based on the ability of the purified water to pass a series of designated tests rather than on its ability to meet definitive concentrations of contaminants. [The meaning of this sentence is very unclear – how is passing a series of designated tests different from meeting definitive concentrations of contaminants?]

^a American Chemical Society. Reagent Chemicals, Eighth Ed., American Chemical Society Specifications (April 1993), pp. 69, 70, and 777-778. American Chemical Society, 1155 Sixteenth Street, N.W., Washington, DC 20036.

^b ASTM. Standard Specification for Reagent Water. ASTM document D 1193-91 (1991). ASTM, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania, 19428-2959.

^c College of American Pathologists Commission on Laboratory Inspection and Accreditation. Reagent Water Specifications (1985). College of American Pathologists, 325 Waukegan Road, Northfield, Illinois 60093-2750.

^d USP 23, Official Monographs: Water, pp. 1635-1637; High Purity Water, pp. 1782; Water for Pharmaceutical Purposes, pp. 1984; Reagents, Indicators, and Solutions, pp.1987. United States Pharmacopeia, 12601 Twinbrook Parkway, Rockville, Maryland 20852.

3 Definitions

...

Activated carbon, n - Porous carbon material used for adsorption [Adsorption/absorption – sorption. Carbon sorption, involves both adsorption and absorbtion.] of organic contaminants and chlorine. [Chlorine reacts *chemically* with carbon. This is a poor definition.]

Adsorption, n - [Adsorption/absorption – Sorption.] Process [A process?] in which molecules, atoms, and ions [This is a peculiar list that is both incomplete and tangled.] become attached to the surfaces of solids and liquids. Activated carbon will remove some organic compounds by adsorption. [Note that GAC is described as removing *some* organic compounds. This is important, because C3-A3 is extremely inconsistent on this point (see Tables 1 & 2 and sections 6.1.6 and A.4)] Note: Contrast with absorb.

Carbon adsorption, n - A process during [By?] which the surface of carbon takes on, or [Omit, “takes on, or.”] adsorbs in an extremely thin layer, molecules of gases, of dissolved substances, or of liquids with which it is in contact. [This sentence is poorly constructed.]

...

Conductivity // electrolytic conductivity // specific conductance [Electrolytic is not the appropriate word – electrical would be better.], n - Electrolytic conductivity is a quantitative measure of the ability of a solution to carry an electric current. It is the electrical conductance of an aqueous solution measured between opposite parallel [Parallel is redundant.] faces of a 1-cm cube at a specified temperature. The unit of conductance is the siemens (S), formerly the mho (reciprocal ohm). For these specifications, electrolytic conductivity should be reported at [referenced to] 25° C in microsiemens per centimeter ($\mu\text{S}/\text{cm}$). The reciprocal of electrolytic conductivity is resistivity. To illustrate, a solution with an electrolytic conductivity of 0.1 $\mu\text{S}/\text{cm}$ will have a resistivity of 10 M Ω -cm. See Resistivity. [This definition is not well written.]

...

Deionization, n - A purification process that uses synthetic [Not necessarily.] resins to accomplish a selective [Selective?] exchange. The removal of ions from a solution by ion exchange. [This is a very poor definition.]

Dissolved ionized gases, n - Charged molecules that possess perfect molecular mobility [HCO_3^- does not have perfect mobility – what does?], the ability to expand indefinitely, and are dispersed [Dispersed? The definition is about *dissolved* gases.] in water. [This is a confusing and inaccurate definition.]

Dissolved ionized solids, n - The mass of charged constituents in a filtered water sample. For operational purposes, the filter pore is usually 0.45 μm . [This is a confusing and inaccurate definition.]

Endotoxin/pyrogen [Endotoxins and pyrogens are not equivalent.], n - A thermostable component of viable or nonviable gramnegative microorganisms that can cause a fever when injected or infused. [Into . . . certain types of animals? A better definition for endotoxin might be: A thermostable, lipopolysaccharide component from the cell wall of viable or nonviable gram-negative microorganisms.]

Filtration, n - A purification process in which the passage of liquid through a porous substance [Would sand be considered a porous substance?] results in the removal of impurities based on the interaction ["Interaction" – poor choice of word.] of the impurities with that porous substance. Note: This interaction is usually physical in nature and is often based on particle size. [This is a confusing and inaccurate definition.]

High performance liquid chromatography (HPLC), n - An analytical technique for performing chromatographic separations of organic compounds in which the mobile phase, eluent, or carrier, is a liquid under pressure. [What is the difference between the mobile phase, eluent, and carrier? If the mobile phase is to be mobile, there must be a pressure difference. This is an incomplete and confusing definition.]

Microbial content, n - In reagent water testing, the quantity of viable organisms, as determined by total colony count after incubation at $36 \pm 1^\circ \text{C}$ for 24 hours, followed by 24 hours at ambient temperature ($23 \pm 3^\circ \text{C}$) and reported as colony-forming units per milliliter (CFU/mL). [This is an incomplete definition of CFU; media plays a very important role in the results. Also, viable plate counts are likely to underestimate the total numbers of viable organisms in the sample by 100- to 1000-fold. (McAlister MB, Kulakov LA, Larkin MJ, Ogden KL. *Microbials - Analysis of bacterial contamination in different sections of a high-purity water system*. *Ultrapure Water* 2001; 18(1):18-26.)]

...

Particulate matter, n - Discrete quantities of solid matter dispersed in water. [Why dispersed in water – this is an inaccurate definition.]

pH, n - [The symbol for the power of hydrogen defined as] [sic] the negative decadic logarithm of the [relative molal] [sic] hydrogen ion activity. [This is a confusing definition – the square brackets suggest that someone was making corrections that were never completed.]

"Polish", n - A term that describes the post-treatment processing of source water to remove all or some of the remaining contaminants, depending on the intended use. [Actually a colloquialism for which there does not appear to be a consistent definition. This term should not be used in C3-A3.]

Pyrogen, n - See Endotoxin. [Pyrogen and endotoxin are not equivalent.]

Reagent water, n - Water purified and classified [“Classified” – why classified?] for specific analytical uses. [This definition applies better to *reagent-grade water* than to *reagent water*, which might be water which is part of a reaction.]

Resistivity // specific resistance, n - The electrical resistance in ohms measured between opposite parallel [*Parallel is redundant.*] faces of a 1-cm cube of an aqueous solution at a specified temperature. For these specifications, the resistivity is corrected to 25° C and reported as megohm-cm (MΩ-cm). The reciprocal of resistivity is electrolytic [*Electrolytic is not the appropriate word – electrical would be better.*] conductivity (formerly referred to as specific conductance). See Conductivity.

Reverse osmosis, n - A process in which water is forced under pressure through a semipermeable membrane leaving behind a percentage of dissolved organic, dissolved ionic, and suspended impurities. [This is a weak definition – how is RO distinguished from ultrafiltration. Listing organic and dissolved ionic impurities leaves out inorganic impurities and organic and inorganic impurities can be ionic or non-ionic.]

...

Total organic carbon (TOC), n - Carbon in the form of organic compounds. [This is a definition for organic carbon, not TOC.]

Ultrafiltration, n - A process during [By?] which water is forced under pressure through a semipermeable membrane leaving behind a percentage of dissolved organic [*Leave out organic or add inorganic.*] and suspended impurities. The dissolved organic and suspended impurities [*The dissolved impurities . . . – leave out organic and suspended.*] are filtered [*Should the word “filtered” be in italics, because the process is more complex than what occurs in simple depth filters.*] based on molecular weight and size.

...

Ultraviolet sterilization, n - A process by which an ultraviolet light source (254 nm) is used to destroy microorganisms. [*UV is not an effective way to sterilize water, though it can kill a high percentage of microorganisms – either the term is an oxymoron or the definition is inaccurate (See footnote for Table 1).*]

...

4 Preparation

An acceptable method for water purification produces water that meets the specifications stated in Section 6. [*Except that the specifications provided in Section 6 are inadequate and should not be acceptable.*] Each preparation process has its own

source water [Would it not be better to refer to input water, since source water is usually considered to be the tap water.] requirements and can also have residual contaminants that should be considered. [What exactly does this sentence mean – there is no way to determine what NCCLS had in mind.] It is important to recognize that systems that are improperly chosen, designed, or maintained can actually add contaminants to the water. [This sentence makes an profound, which deserves considerable expansion. The fact that the Guideline does not go further is a serious shortcoming.]

Because there are many options in water purification technology, the working group cannot recommend a particular purification process to produce a particular grade of water. The decision as to which system or systems to install depends on past experience, and on present and future needs. [These two sentences are too vague to serve any practical purpose. Instead the reader should be referred to Appendix A, which attempts to discuss the major purification technologies in some detail.] A major consideration is the quality of the source water. [Does NCCLS mean tap water in this case – see preceding paragraph?] If there is a high concentration of total dissolved solids, it is likely that the water will have to be pretreated before further purification. [How does NCCLS distinguish between pretreatment and other stages of a water purification system, which must be sequential – all put the final stage would be a pretreatment stage.] Therefore, [Why therefore?] a combination of the commonly available processes for water purification, summarized in Table 1 on the next page, can be necessary to produce water of the desired quality, particularly Type I and special reagent water. [There are processes that are not included in Table 1, which could be useful.]

Table 1 is intended only as a guide to the strengths of discrete commercial [“Commercial” – this word is unnecessary.] technologies that are commonly employed in various combinations to reduce the concentrations of impurities in reagent water. The user is urged to consult with suppliers and colleagues, especially those with experience with the same or similar source water and applications. The user should bear in mind that each discrete technology has weaknesses. The only generalization that can be made with some degree of certainty is that some means for monitoring the performance of a water purification system should be selected to reasonably ensure that the failure of any stage of the system will be detected. [This last sentence contains excellent advice; however, the Guideline does not appear to follow it.]

Table 1. Water Purification Process Comparison (see Appendix A)

Purification Process						
	Dissolved Ionized Solids	Dissolved Ionized Gases	Dissolved Organics	Particulate Matter	Micro-organisms	Pyrogens/Endotoxins [not equivalent]
Distillation	E	G/P [E ¹]	G [E/G ²]	E	E	E
Deionization	E	E	P	P	P	P
Reverse osmosis	G	P	G	E	E	E
Carbon ³ adsorption/absorption	P	P	E/G [G/P ⁴]	P	P	P
Filtration (0.22 µm)	P	P	P	E [G ⁵]	E [G ⁵]	P
Ultrafiltration	P	P	P	E	E	E
Nanofiltration	G/P	P	G	E	E	E
Chemical oxidation [Ozone] ⁶	P	P	P	P	E/G [P] ⁷	E/G [E/G or P] ⁸
Ultraviolet oxidation* [*– Incorrect footnote]	P	P	G [P] ⁹	P	G/P [P] ⁷	P
Ultraviolet sterilization*	P	P	P	P	G [P] ¹⁰	P

* = Ultraviolet light kills microorganisms but does not remove them. Another process is required to remove them.
E = Excellent (capable of complete or near total removal).
G = Good (capable of removing large percentages). I
P = Poor (little or no removal).

[This table gives the erroneous impression that someone could string together technologies that are rated “E” for each of the listed classes of impurities and produce very pure water – water purification is not that simple. Also, the table seriously exaggerate the potential of many of the technologies.

It is not clear what meaning NCCLS attaches to the columns for Microorganisms and Pyrogens/Endotoxins. Some technologies will actually remove all of these contaminants, whereas others will only kill or inactivate cells.

Note 1: Distilled water with a specific resistance of $>10 \times 10^6$ ohms-cm contains very little dissolved ionized gas. Poorly designed stills will not remove gases effectively, but this is no excuse for downgrading the process of distillation, because poorly designed and maintained deionizers will fail to remove gases effectively and their resins can literally “slime” though their

screens. Furthermore, ionized gases are just as likely to dissolve into both types of water during use.

- Note 2: If reverse osmosis is ranked as “G”; then, distillation must be ranked at “E/G”, because distillation is the most effective single process for removing organics, even though it has limitations (See Appendix A).
- Note 3: The convention is to refer to the combination of adsorption and absorption and as “sorption”
- Note 4: It is true that carbon can sorb some organics with excellent efficiency; however, its effectiveness across the broad spectrum of organics typically found in water is poor compared with reverse osmosis and distillation. Carbon should not be used with the expectation that it will remove most organics (meaning organics in general). When carbon is used in a high-purity application, there must be means for determining its effectiveness on a continuous basis, because the sorption of organics by carbon is so complex as to be quite unpredictable. The extensive use and acceptance of carbon in the absence of such monitoring is not proof of carbon’s effectiveness; it is proof that market forces can often be stronger than scientific reason.
- Note 5: It is inconsistent to go above “G” for 0.22 micron filtration, especially since the NCCLS definition of microorganisms includes viruses. Certainly a 0.22 micron filter is not on a par with distillation or reverse osmosis.
- Note 6: Ozone is a practical means of performing chemical oxidation on a laboratory scale. Peroxides and chlorine will pose significant dosing and neutralization problems for most laboratories. Also, ozone is far more effective at killing bacteria and breaking down endotoxins.
- Note 7: Ozone and UV will not remove the microorganisms they kill. Strictly speaking, oxidizing UV (185 nm) is not particularly effective at killing microorganisms; however, since UV sources that produce 185 nm UV also produce 254 nm UV, which damages the nuclear material of microorganisms, one would expect the oxidizing UV source to kill microorganisms. Ozone kills microorganisms far more effectively than 254 nm UV.
- Note 8: Ozone will oxidize endotoxins to the point where they lose their endotoxin activity; however, it does not fully oxidize all of the organic carbon associated with endotoxins.
- Note 9: Ozone and UV oxidation are effective at reducing trace organics, provided the oxidation is combined with recirculation through a stage of

deionization. As stand-alone technologies they are poor at removing organic contamination.

Note 10: UV sterilization is an oxymoron, because a 254 nm UV is not likely to *sterilize* the water flowing over it in a typical application. UV is not as effective for killing microorganisms as ozone and UV does not remove those microorganisms that it does kill.]

NCCLS is aware, or should be, that Table 1 has been widely reproduced without context and is used to support the sale of water purification systems. Therefore, NCCLS should make every attempt to see that the table does not misrepresent the relative effectiveness of the discrete technologies. And NCCLS should discourage the reproduction of the table out of context by placing such a warning within the table itself.]

5 Design Considerations

[This section says virtually nothing about the design of water purification systems, but devotes 2 ½ pages to an inadequate discussion of storage and distribution.]

5.1 Initial Considerations

If a laboratory needs to install either a new water-purification system or modify an existing one, there are several issues to consider. [Several issues? – only source water testing is discussed?] Initially, an analysis of the source water by the manufacturer should be requested. This analysis should include a minimal list of contaminants (e.g., silica, organics, magnesium, calcium, microorganisms, and total and free chlorine), as well as pH and resistivity. (Both chlorine and pH should be measured on site. [If it is important to measure pH on site, it is important to measure resistivity on site.]) The larger and more complex the system using tap water, or the more diverse the intended application(s), the more testing is required. [What does this sentence mean – clinical laboratories are expected to use water in a great diversity of applications. What does the scale of a system have to do with the need to understand the nature of the contaminants in the tap water?] Also, multiple periodic testing can be important because of seasonal variations in contaminant concentrations. In some instances, it can be helpful to consult local water-testing authorities for advice on the impurity content of the local source water. [These are good thoughts, but NCCLS does not explain why all of this testing is important.]

5.2 General Considerations

The overall design should be such that there are no deadlegs in the system. [Accidental hard return.]

Deadlegs provide areas for stagnation and the potential for microbial growth. The working group [Why is working group inserted here – is this not an NCCLS document?]

strongly recommends a system that recirculates [Back through the entire purification system?] with a minimal velocity of 5 feet per second. [What evidence does the working group have that this minimum velocity is so important – the rate of recirculation required will depend on the minimum level of purity required in a system, the size of a distribution system, and the rate at which the distribution system contributes contaminants to the circulating water (see Section 5.3)] Recirculation also helps minimize microbial growth. [Because most microorganisms in a water purification system are attached to surfaces, recirculation in the absence of some factor lethal to microorganisms will have no significant effect on their numbers. This paragraph is too vague to be useful in a practical sense.]

Because there are several [“Several” – there are a great many combinations and permutations of components that can be used in any given system.] approaches to water purification, it is necessary to review the capital outlay and operating costs of various systems. [How about performance?] It is recommended that the cost analysis include expenditures for maintenance of the system. [Knowing what sorts of maintenance might be required, would be useful. Most laboratory systems are not adequately maintained, because those in charge of them do not understand the technologies. However, it is not clear why NCCLS is diverging into a halfhearted discussion of cost benefit analysis.]

Once the selection and installation [A system cannot be installed until it has been selected!] of a system is complete, it is necessary to sanitize the system before use and then at least semiannually, or more often as recommended by the manufacturers, or as determined by quality control criteria. [It is inconsistent to recommend semiannual sanitization when a system can become contaminated to a steady-state level within weeks – Section 5.3, suggests that sanitization may have to be performed weekly. Would it not be better to advise the user how to monitor for biofilm and how to remove it.] Procedures for sanitization can be performed by the manufacturer of the system or according to a procedure provided by the manufacturer. [Of course – this sentence is unnecessary.] With extended lack of use, there is a danger of stagnation. [With any lack of use a system will become stagnant.] If the system is shut down for more than 72 hours, sanitization is recommended. [Does NCCLS have any evidence that this is necessary in order to meet the specifications in Table 2 – unlikely.] [New paragraph?] Reverse osmosis systems can require the use of a disinfectant to sanitize the membrane. Consult the manufacturer for recommendations for appropriate disinfectants. To ensure complete removal of the disinfectant after the sanitization process, the reagent water must be tested before use. In some instances, commercial test kits are available. [In some instances?] Otherwise, consult the manufacturer of the reverse osmosis system for guidance in evaluating reagent water for traces of residual disinfectant. [Is NCCLS saying that reagent water that meets the Table 2 specifications might contain contaminants that could affect applications adversely?] Appropriate safety and disposal precautions should be used when handling the water [What water – is the water in the system so dangerous that it requires special handling?] after maintenance of the membrane. [This paragraph is vague and confusing.]

In general, the system [What system?] will operate optimally when used daily. [Does this sentence mean that sanitization is not necessary, if the system is used daily?]

5.3 Materials for Distribution and Storage

Much of the data relating to the suitability of materials for the distribution and storage of reagent water are proprietary. Therefore, little objective data relating to the suitability of these materials is available. As a general rule, the selection of materials for the distribution and storage of reagent water depends on the desired water quality and cost. A material is acceptable for a given application as long as it functions well from a mechanical standpoint and can be treated adequately to prevent the growth of microorganisms, which aid in establishing biofilms. [“Aid” – microorganisms are usually an important part of a biofilm. Biofilm is essentially inevitable, regardless of the materials used, unless a system is sanitized very frequently and aggressively.] Additionally, the material should not leach significant concentrations of contaminants (a function of surface area, flow volume, and flow rate) that are not effectively removed during downstream stages of purification. If a system is sanitized on a periodic basis, the periods might have to be as frequent as weekly, depending on local conditions. [This sentence seems disconnected and stands in sharp contrast to the recommendations for sanitization in Section 5.1.] Uncontrolled, biofilm production produces more total organic carbon (TOC) than TOC-leaching piping materials. [There may be other sources of TOC, besides biofilm – GAC and ion exchange beds for instance.]

The control and elimination of microorganisms from water-purification systems is important. [If one eliminates microorganisms, they have certainly been controlled. However, it is impossible to eliminate microorganisms from most laboratory water purification systems. Perhaps the word, “elimination” should be removed.] Microorganisms [Microorganisms actually produce biofilm.] and chemical analytes [“Chemical analytes” – what does this mean?] contribute to biofilm formation, which can occur in or on distribution systems, surfaces, sides of storage tanks, housing materials, as well as membranes and ionic beds. [Ionic beds – “beds of ion exchange resin and GAC” would be a better choice of words. Biofilm can occur anywhere in a water purification system, there is no point in listing just a few of the possible surfaces] Periodic sanitization is a necessary step in the control of microorganisms that make up these biofilms (see Section 5.2). Once a biofilm has been established, removal is difficult. [Other paragraphs have suggested that biofilm development is inevitable in the absence of continuous harsh biocides.] Some agents that have been shown to have a limited effect on biofilm build-up include ozone, sodium hydroxide, and sodium hypochlorite. [What does this sentence mean – that there is no way to control biofilm?]

Increasingly, plastics tend to be the materials of choice, although stainless steel remains in wide use. [This sentence seems to be mixing two thoughts. Is NCCLS recommending stainless steel and plastics?] Glass, aluminum, tin, tin-lined, and titanium piping possess various combinations of reactivity, mechanical shortcomings,

and cost. The requirements for production facilities are likely to be different from those of clinical and research laboratories. In general, it is preferable not to distribute high-purity water but, rather, complete purification to desired levels at the point of use. [Very good thought, but there is no follow up.]

5.3.1 Piping

[The 1 ½ page overview of piping materials is interesting and reasonably informative, but entirely inconsistent with the lack of any information about purification technologies in the body of the Guideline.]

...

5.3.2 Storage

...

5.3.3 Spigots

...

6 Specifications

[The four grades of laboratory reagent water specified by the Guideline are of little practical value, because the Guideline does not state unequivocally where in a purification system measurements are to be made.

The specification for Type I water appears to be:

1. A once daily measurement of resistivity, somewhere in the purification system, with a limit of ≥ 10 M Ω -cm (referenced to 25° C), except for some confusion introduced by section 6.1.6.

The same resistivity limits apply to systems that utilize cold-technologies (e.g., ion exchange, carbon sorption, ultra filtration, etc.) in their final stage and those that use distillation, which makes no sense. Thus, Type I water is specified as having a 10 M Ω -cm limit for resistivity (referenced to 25° C). If the final stage in a purification system utilizes distillation, a resistivity of 10 M Ω -cm following this final stage would be strong evidence of excellent performance. However, in the case of cold-technology systems, a resistivity of 10 M Ω -cm following the final stage of purification could suggest a rapidly failing, or poorly designed, system.

2. Collecting a sample of water once a week (see Section 9) in order to obtain a plate count of viable organisms that can take a week or more to grow out, with the understanding that even if the CFU is greater than the specified limit of 10/ml no

action is necessary regarding those tests that were done during the period when the water did not meet the specification (potentially 2-3 weeks, or longer).

CFU is not a reliable means of determining the number of viable microorganisms in purified water, typically underestimating total numbers in the sample by 100- to 1000-fold and the 10 CFU/L NCCLS limit appears to be quite arbitrary. (McAlister MB, Kulakov LA, Larkin MJ, Ogden KL. *Microbials - Analysis of bacterial contamination in different sections of a high-purity water system*. *Ultrapure Water* 2001; 18(1):18-26.) Furthermore, NCCLS specifies the use of a 0.22 micron final filter to block the passage of the bulk of viable microorganisms (see Section 6.1.5). Whether or not a 0.22 micron filter will block all viable microorganisms may be debatable; however, it is clear that a 0.22 micron filter will not block soluble products of microorganism growth or the fragments from microorganisms that die on its surface of the filter or elsewhere in the system. Endotoxin testing could provide a much more meaningful and rapid means of determining the degree to which microorganisms may be proliferating within a water purification system.

3. Occasionally, determining that soluble SiO₂ levels are no higher than 0.05 mg/L, perhaps by sending a water sample to a reference laboratory.

NCCLS claims that soluble and insoluble silica *can interfere with certain assays*; however, it does not require the measurement of insoluble silica and it lacks evidence that traces of soluble silica interfere with the overwhelming majority of measurements (not specific for silica) performed in clinical laboratories.

4. Installing a 0.22 micron, or finer, filter to block particulates, including microorganisms, larger than 0.2 microns.

The intention of the filter is to block the passage of particulates and microorganisms that would be trapped by such a filter; however, filter will not block soluble products of microorganism growth or the fragments from microorganisms that die on its surface or elsewhere in the system. And microorganisms can grow through such filters.

5. Controlling organic contamination to unspecified levels with some combination of GAC, RO, or distillation – except that according to NCCLS, the use of RO or distillation (what about GAC) may prevent a system from achieving the 10 MΩ-cm (referenced to 25° C) resistivity limit for Type I water (see Section 6.1.6).

The use of GAC is very likely to increase organic contamination and is virtually certain to increase the number of microorganisms. The use of properly engineered RO or distillation will not prevent Type I water from meeting the 10 MΩ-cm at 25° C resistivity limit.

This specification will not provide meaningful controls for laboratory reagent water.]

All specifications are stated for water as measured at the time of production. [It is not clear what this sentence, which is stressed for importance, actually means. What water? Measured where? The failure to state that the specifications apply to water at the point where it exits a purification system for storage or use – or in the case of recirculating systems after the last spigot – means that the specifications are essentially useless.] The resistivity of Type I water should be measured inline [Where in the system?] daily [Daily! – an ion exchange bed can fail in a matter of a few minutes, so resistivity should be measured continuously. How often should the resistivity of Type II and Type III water be measured?]; all other specifications relate to the samples measured offline. [Relate to the samples measured offline? – does NCCLS mean, all other measurements are made offline?]

Additional purification can be required for selected clinical laboratory procedures [The list of tests that require additional purification is likely to be very long.], such as:

- Preparation of water with no endotoxin/ pyrogen levels for cell culture
- Preparation of microorganism-free water for direct fluorescent detection of microorganisms, such as Legionella (sp.), for direct fluorescent antibody testing, or for direct fluorescent stains of mycobacteria
- Preparation of water with minimal organic content for HPLC.

Special requirements should be discussed with the manufacturer of the water-purification [sic] system when the system is purchased or modified.

6.1 Requirements for Reagent Water

The specifications for reagent water Types I, II, and III are summarized in Table 2 on the next page.

6.1.1 Microbial Content

Ideally, Type I water should be free of microorganisms. [Is this a statement of hope or fact? Based on the vague recommendations regarding means of purification and the thin product specifications, there is no reason to believe that Type I water would be free of microorganisms.] (For a discussion of the effects of microbial contamination, see Section 9.1.2.) It is recognized, however, that water manufactured by a continuous process might not be sterile at all times. [If the process has been described in this Guideline, it would be the exception if the water was ever sterile.] The working group suggests that the microbial content specification for Type I water be ≤ 10 CFU/mL at the time of production. [This suggested level is not the same as “free” (see the first sentence in this paragraph. This sentence seems to be contradicting other sections of

the specifications by indicating that the CFU limit is only *suggested*, not *required*. Furthermore, the sentence reinforces the point that measurements, or samples, need only be acquired “at the time of production”, not at some specific point in the system.] Similarly, the working group suggests that 1,000 CFU/mL should be considered the upper limit for microbial content in Type II water. [The plate counting methods described in Sections 9.1.5 and 9.1.6 is likely to understate the actual count by 100-1000 times. (McAlister MB, Kulakov LA, Larkin MJ, Ogden KL. *Microbials - Analysis of bacterial contamination in different sections of a high-purity water system*. Ultrapure Water 2001; 18(1):18-26.)] When microorganisms are present in water, the microbial content of the water changes over time. [Is this sentence really necessary?]

6.1.2 pH

The pH requirements for reagent water Types I and II are not specified. The other specifications for Types I and II water are so rigorous as to render a pH specification, a less sensitive measure of purity, less than useful. [This sentence is inaccurate and does not make sense.] However, the pH specification of 5.0 to 8.0 for Type III water does provide a measure of, and limit to, the impurity for this grade. [pH can be adjusted and gives very little indication of purity.]

6.1.3 Minimum Resistivity

The resistivity limits for the three grades of reagent water define the allowable ionic content of the respective water (see Section 9.4).

The 10 megohm - cm at 25° C [Surely, NCCLS means, *reference to 25° C*.] resistivity cutoff for Type I water defines an ionic concentration of less than 10^{-6} gram equivalent weight [This statement is not accurate; resistivity is a function of mobility and equivalent weight will depend on the molecular weight, both of which vary with the species of ion.], which is close to the concentration of the hydrogen and hydroxyl ions contributed by the water itself. Should this stringent requirement [This is certainly not a stringent requirement for a cold-technology system that uses ion exchange. In fact, any mixed-bed ion exchange system that cannot produce water with a resistivity of 17 megohms-cm has been poorly prepared or installed, or may be exhausting. In either case the bed is likely to be contributing large amounts on organic material to the water stream.] be necessary for an application, then Type I water must be used immediately after production in order to avoid the rapid decrease in resistivity due to carbon dioxide absorption from the air or solubilization of ions from the container. [The resistivity of 10 megohm-cm water is likely to drop below 1 megohm-cm in less time than any technician could possibly use the water, unless he is handing the water in a special atmosphere. The object of achieving a high resistivity during purification is not because applications require high resistivity. It is because achieving a high resistivity will ensure that the purification process effectively removed ionic contaminants. Very few applications are negatively affected by traces of CO₂.]

Table 2. Reagent Water Specifications

	Type I	Type II	Type III
Maximum microbial content, colony forming units per ml (CFU/ml)	10	1000	NS
pH	NS	NS	5.0 - 8.0
Minimum resistivity , megohm-centimeter (megohm-cm 25° C)	10 (Inline)	1.0	0.1
Maximum silicate mg/L SiO ₂	0.05	0.1	1.0
Particulate matter*	0.22 µm filter	NS	NS
Organic contaminants*	Activated carbon or distillation or reverse osmosis	NS	NS
*: This a purification process requirement and is not measured by the end user. NS: Not Specified.			

6.1.4 Maximum Silicate

Soluble or colloidal silica can be present in the source water and it might not be adequately removed in the purification process. Silicates or colloidal silica can interfere with certain assays. [\[NCCLS does not have any evidence to support this statement?\]](#) Levels of 0.05 mg/L or below, measured as SiO₂, do not appear to cause interferences. The higher level of silica as specified for Type II water, may or may not cause interferences; however, satisfactory use should be documented.

[\[There appears to be no evidence to support the statement, "Silicates \[soluble\] or colloidal silica \[insoluble\] can interfere with certain assays." Moreover, C3-A3 does not discuss the fact that ion exchange will not remove silica if the resistivity of the water is less than 18 MΩ-cm \(referenced to 25° C\) and that ion exchange resins may polymerize soluble silica to form insoluble silica.](#)

a) The issue of silica was raised at the June 13, 1999 ASTM D19.02 Meeting, Louisville, KY and members were asked to spread the word that references were needed to support the contention that silica caused general interferences in laboratory experiments/tests. The challenge was repeated at the January 17, 2000 ASTM Meeting in Cocoa Beach, FL. To this date, no references have been proffered by anyone.

b) At the June 13, 1999 ASTM D19.02 Meeting, Louisville, KY, Erich L. Gibbs, Ph.D. reported that he had performed the most extensive Dialog search he could arrange (over 20,000 journals from

1989>1999) to search for any articles dealing with silica contamination as a source of interference in laboratory tests/experiments. None were found.

c) At the May June, 1999 ASTM D19.02 Meeting, Louisville, KY, Erich L. Gibbs, Ph.D. announced that his company had conducted an e-mail survey of over 23,000 bioscientists around the world in search of any evidence that silica contamination was a source of interference in laboratory. The few reports of interferences all involved experiments where silica could be expected to impact the results (i.e., the growth of diatoms etc.)

d) Dr. David Jeffers, Chairholder of the National Committee for Laboratory Standards reported to the Working Group on Reagent Water, March 7, 1996, that an NCCLS survey of the literature was unable to find any references to support the statement, "Silica adversely affects most enzyme determinations, and trace metal and electrolyte analyses" (Section 9.5 C3-A2 Preparation and Testing of Reagent Water in the Clinical Laboratory: Approved Guideline – Second Edition, 1991) In the absence of data supporting silica interferences in clinical testing, the wording was changed to, "Silicates or colloidal silica can interfere with certain assays [which are unspecified]." (Section 6.1.4 of C3-A3 Preparation and Testing of Reagent Water in the Clinical Laboratory: Approved Guideline – Third Edition, 1997)

e) Dr. Wes Byrne offered the following comments in support of sections of a new ASTM standard (06/19/00): "My experience is that most of the boron and colloidal silica would shed prior to reaching 17 megohm-cm. These materials are so poorly ionized that they shed even before a bed reaches 18 megohm-cm (assuming its effluent resistivity was greater than this prior to approaching exhaustion). I recognize that it may not be practical to have a specification for laboratory water of 18.1 megohm-cm. The bottom line is resistivity cannot be used to determine when to take a mixed-bed ion exchange unit off line if the intent is to prevent dumping of boron and colloidal silica."

6.1.5 Particulate Matter

Type I water should be free of particulate matter, including microorganisms, larger than 0.2 μm . [Is this a statement of hope or fact? Based on the vague recommendations regarding means of purification and the thin product specifications, there is no reason to believe that Type I water would be free of particulate matter. Furthermore, if Type I water were free of particulate material, it could not contain any microorganisms.] This can be achieved by passing the water through a post-membrane (vinyl) filter [What is a "post-membrane (vinyl) filter"?] with a mean pore size no larger than 0.22 μm . However, note that many users elect to add a postmembrane filter [What is a "postmembrane filter"?] with a pore size of 0.1 μm . [Water that is produced by an effective still will not contain significant particulates; however, it appears that NCCLS requires the use of a 0.22 μm ., or finer, filter in all cases – this does not make sense.] Purification process requirements for particulate matter are not specified for Types II and III reagent water. [Does this mean that these types of water can be loaded with particulates?]

6.1.6 Organic Contaminants

Organic contaminants should be kept to a minimum [What minimum?] in Type I water. The content of organic material is reduced when water is distilled, subjected to reverse osmosis, or passed through activated carbon. [GAC can increase organic contamination and will certainly increase the number of microorganisms (See Appendix

A.4).] A combination of these processes can be more effective in removing organic material. If activated granular carbon is used, periodic replacement of the activated carbon is necessary. [What period – carbon can be very unpredictable. How would one determine when it should be replaced?] If distillation or reverse osmosis is used, resistivity measurements might not meet the requirements for Type I water. [What about carbon, which will bleed ions? There is no reason that the use of RO or distillation would prevent a purification system from achieving resistivities substantially higher than 10 MΩ-cm @ 25° C. However, is NCCLS waiving its 10 MΩ-cm @ 25° C limit for Type I water with this statement, or is it saying that distillation and RO may not be acceptable means for producing Type I water?]

6.1.7 Degradation of Water Quality

Because certain characteristics, such as resistivity and microbial content, change quickly once the water is produced, their influence on usability [“Influence on usability” – this phrase is not clear.] must be evaluated (see Section 7).

7 Storage and Handling

The working group recommends that the laboratory examine the acceptability of the type of reagent water to be used and record the rationale for this decision (see Section 8.3.3). [What does this have to do with storage and handling?]

7.1 Type I Water

When Type I water is stored, its resistivity will decrease, metals and/or organic contaminants will be leached from the storage container, and microbial contamination can occur. [If the container is properly designed, these effects will be minimal.] However, these changes may not have an impact on the quality of certain testing applications. [NCCLS appears to be saying that Type I water cannot be stored without verifying that storage will not adversely affect the use of the water. Is the reader to conclude that Type I water cannot also be used, because usage will, of necessity involve some degree of storage?]

Type I water can be thought of as the "ideal" general purpose water that can be produced with currently available water treatment/purification technology and used at the time of production. [This statement is incorrect, incredibly confusing, and outrageously unscientific. However, if one reads between the lines, part of the sentence seems to be saying that Type I water cannot be stored.] Type I water should be used in test methods that require minimal interference or when lack of interference from water of lesser purity cannot be documented or inferred. [The sentence is confusing.]

...

7.2 Type II and Type III Water

...

[This section is a brief statement that struggles to find reasons for having specified such poorly defined type of water as Type II and Type III water in the first place. Type III water is recommended for washing glassware. *However, a paragraph that describes the storage of Type II and Type III water cautions laboratories to avoid contamination by microorganisms and substances that are not specified for these two types of water, and goes on to say that all Type II and Type III water, including solutions made with these waters, must be replaced daily.*]

7.3 Special Reagent Water

Special reagent water can be necessary for highly sensitive analytical techniques, such as HPLC and chromosomal analyses. Water of this specified purity might be beyond that attainable by the laboratory's existing purification system. [If storage of Type I water is not recommended (see Section 7.1), how would a laboratory obtain Special Reagent Water if the laboratory cannot produce it on site?] Such water is discussed in Section 9.6 of this document. [This paragraph says essentially nothing about special reagent water and Section 9.6 makes a number of incorrect statements about endotoxins.]

...

8 Commercially Available Reagent Water

...

[This section is confusing. There is a strong implication that commercially available reagent water will not meet Type I specifications. Yet, laboratories are advised not to purchase commercial water unless it is tested for the parameters of Type I water and for endotoxins. Furthermore, the Section appears to be permitting laboratories to use commercial water for any application, provided each lot of water (clearly marked) is validated for each application in which it is used. There is a contradiction here – if lots of commercially available water, which are likely to be more consistent than Type I water (given the low frequency of monitoring), must be validated for each application, why would this not also be the case for Type I water?]

9 Testing

It is essential to monitor water quality through testing that addresses those contaminants that are found in the source water or the end product. [This statement is certainly correct, but it suggests a completely different approach than the specification of water based on Table 2.] Monitoring is required at regular specified time intervals. [This statement is inconsistent with statements made throughout C3-A3, which suggest

that most limits can be determined on a variable time line.] The time intervals can be seasonally dependent for some contaminants; however, microbial content should be monitored at least weekly. [This is the first indication of how often microbial content should be tested?] Although such testing can be retrospective [Is by its nature retrospective.], it provides the laboratory with useful data and it can be helpful in the detection of trends and impending problems. [This sentence is indicating that laboratory results, reported during a period when the lab water may not have met specs, do not have to be repeated!] Additional testing [More frequent testing or additional types of tests?] is necessary when a component of the water purification system is changed or inline monitoring devices [What devices would these be? Only one type of inline device has been discussed so far, resistivity monitors. This sentence does not make sense.] indicate a decrease in the water purity. Assays to test for water purity described in this guideline use ACS reagent-grade or equivalent chemicals. [Including ACS Reagent Water?] All tests performed, results, actions taken, and repeated test results should be recorded in an appropriate log (see Appendix B, "Quality Assurance Procedures").

...

9.6 Special Water Considerations: Endotoxins and Specifications

Endotoxins are heat-stable metabolic products [Metabolic products? – this does not match the definition provided under Section 3.] formed from the cell walls of viable and nonviable gram-negative bacteria. When injected into humans [Other animals? – actually the test is usually done with rabbits.] in small quantities [Are large quantities less harmful?], pyrogenic effects are observed and death can follow. However, when ingested little affect [Effect?] is seen in humans. [Other animals?]

However [However? – why however?], laboratory procedures can be altered by the presence of endotoxins in reagent-grade water. The limulus amoebocyte lysate test (LAL) is used to measure endotoxin levels in water and other materials. Although there is no LAL standard limit for reagent-grade water [The AH/LabWater-1 and ASTM D1193 standards have limits.], as with pharmaceutical water(s), some laboratories use a cut-off level at 0.25 endotoxin units/mL for reagent-grade and special-purpose water. [And why do some laboratories use this cut-off limit? Such a level will amount to 2500-25,000 gram negative bacteria, or their cell wall equivalent, per ml – that is a great deal of contamination.]

The specifications for special water may vary according to the application for which it is intended. End users are encouraged to refer to published literature references specific for the intended use. [Intended use of what? – this sentence does not make sense.]

...

[Appendix A.4, Carbon Adsorption/Absorption, and Appendix B, Quality Assurance Procedures, have been included in this critique, because they are specifically referenced in sections that have been included in this critique and they raise interesting contradictions.]

...

A.4 Carbon Adsorption/Absorption

[This section is extremely inconsistent with Table 1, Table 2, and comments in Section 6.1.6.]

Carbon adsorption/absorption is virtually always used as a pretreatment step and in combination with other purification processes. [This is not an accurate statement. For example, if chlorine-tolerant CA RO membranes are used, it might be not be desirable to use carbon pretreatment.] There are special grades of activated carbon and other synthetic adsorbents [What are these – if they are so effective why not let the reader know?] that exhibit excellent capabilities for removing organic contaminants. [The preceding and following sentences do not seem compatible.] Their use, however, is targeted toward specific compounds and applications. [What grade of GAC or other synthetic adsorbents should the user consider?] The geometry and quantity of activated carbon used should be sufficient to maximize contact time and, therefore, the adsorption of substances in the water stream. [NCCLS seems to be suggesting an infinitely long column of GAC.] Activated carbon beds are particularly effective in removing chlorine from water. Although carbon beds are viable locations [“Viable locations” – poor choice of words.] for microbial growth, the adsorptive affinity for chlorine [Chlorine reacts chemically with carbon it is not adsorbed.] can greatly increase the growth of these organisms in downstream sections of the purification system. [In can also result in explosive growth of microorganisms in the carbon bed. This is a very poorly worded sentence.] The limitations of carbon use are as follows:

- Carbon is mechanically degraded to produce fines that must be captured downstream
- Leaches ash minerals into the water stream
- Only weakly adsorbs other contaminants as a function of contact time.

In practice, the primary use of carbon is to remove chlorine from water entering ion-exchange resin systems. [Not to remove organics? – yet, NCCLS has been recommending GAC to remove organics throughout C3-A3.] The working group recommends consulting with the manufacturer before using carbon for water purification. [Is this a warning not to use carbon, except under certain conditions?]

...

Appendix B. Quality Assurance Procedures

[This Appendix seems to be saying that laboratories are expected to do what is necessary to ensure that laboratory results are accurate, regardless of any other recommendations and information contained in C3-A3. The appendix does not say clearly whether C3-A3 should be part of a laboratory procedure manual.]

To ensure sample quality throughout sample collection and analysis, a set of operating procedures should be established by each laboratory. A quality assurance program should include both quality control and quality assessment. Guidelines addressed in the 17th edition of Standard Methods for the Examination of Water and Wastewater can serve as the basis for program development. [Does this mean that laboratories should ignore the C3-A3 Guideline?] The subsequent procedure manual should be prepared in accord with NCCLS document GP2-A3, Clinical Laboratory Procedure Manual – Third Edition; Approved Guideline.

When standard operating procedure manuals are compiled, consideration should be given to the following topics:

- A quality assurance plan with approval signatures, organizational charts, and responsibilities.
- Procedures for the preventive maintenance of equipment: Frequency of these procedures should be determined through discussions with manufacturers of the system and based on the performance of the product water. [Performance of the product water – strained, unclear wording.]
- Calibration procedures, corrective actions, internal quality control activities, performance audits, and data assessments.
- Special worksheets designed for reporting the results of daily, weekly, and monthly tests, etc.
- Quality control checklists.

Resistivity checks should be recorded daily. Microbiological testing should be performed weekly. [Not at least weekly, as stated in Section 9.] All other parameters [What parameters – the limits in Table 2 or parameters established by individual laboratories?] should be tested as necessary, depending on geographical and seasonal considerations, or the manufacturer's recommendations. [This sentence is very unclear. If a laboratory is located east of the Mississippi or it is winter is it unnecessary to perform some tests? Manufacturers of what?]

...

End Critique