

<1112> APPLICATION OF WATER ACTIVITY DETERMINATION TO NONSTERILE PHARMACEUTICAL PRODUCTS

The determination of the water activity of nonsterile pharmaceutical dosage forms aids in the decisions relating to the following:

1. optimizing product formulations to improve antimicrobial effectiveness of preservative systems,
2. reducing the degradation of active pharmaceutical ingredients within product formulations susceptible to chemical hydrolysis,
3. reducing the susceptibility of formulations (especially liquids, ointments, lotions, and creams) to microbial contamination, and
4. providing a tool for the rationale for reducing the frequency of microbial limit testing and screening for objectionable microorganisms for product release and stability testing using methods contained in the general test chapter *Microbial Enumeration Tests* (61) and *Tests for Specified Microorganisms* (62).

Reduced water activity (a_w) will greatly assist in the prevention of microbial proliferation in pharmaceutical products; and the formulation, manufacturing steps, and testing of nonsterile dosage forms should reflect this parameter.

Low water activity has traditionally been used to control microbial deterioration of foodstuffs. Examples where the available moisture is reduced are dried fruit, syrups, and pickled meats and vegetables. Low water activities make these materials self-preserved. Low water activity will also prevent microbial growth within pharmaceutical drug products. Other product attributes, for example, low or high pH, absence of nutrients, presence of surfactants, and addition of antimicrobial agents, as well as low water activity, help to prevent microbial growth. However, it should be noted that more resistant microorganisms, including spore-forming *Clostridium* spp., *Bacillus* spp., *Salmonella* spp. and filamentous fungi, although they may not proliferate in a drug product with a low water activity, may persist within the product.

When formulating an aqueous oral or topical dosage form, candidate formulations should be evaluated for water activity so that the drug product may be self-preserving, if possible. For example, small changes in the concentration of sodium chloride, sucrose, alcohol, propylene glycol, or glycerin in a formulation may result in the creation of a drug product with a lower water activity that can discourage the proliferation of microorganisms in the product. This is particularly valuable with a multiple-use product that may be contaminated by the user. Packaging studies should be conducted to test product stability and to determine that the container–closure system protects the product from moisture gains that would increase the water activity during storage.

Reduced microbial limits testing may be justified through risk assessment. This reduction in testing, when justified, may entail forgoing full microbial limits testing, implementing skip-lot testing, or eliminating routine testing.

Nonaqueous liquids or dry solid dosage forms will not support spore germination or microbial growth due to their low water activity. The frequency of their microbial monitoring can be determined by a review of the historic testing database of the product and the demonstrated effectiveness of microbial contamination control of the raw materials, ingredient water, manufacturing process, formulation, and packaging system. The testing history would include microbial monitoring during product development, scale-up, process validation, and routine testing of sufficient marketed product lots (e.g., up to 20 lots) to ensure that the product has little or no potential for microbial contamination. Because the water activity requirements for different Gram-reactive bacteria, bacterial spores, yeasts, and molds are well described in the literature,¹ the appropriate microbial limit testing program for products of differing water activities can be established. For example, Gram-negative bacteria including the specific objectionable microorganisms, *Pseudomonas aeruginosa*, *Escherichia coli*, and *Salmonella* species will not proliferate or survive in preserved products with water activities below 0.91, while Gram-positive bacteria such as *Staphylococcus aureus* will not proliferate below 0.86, and *Aspergillus niger* will not proliferate below 0.77. Furthermore, even the most osmophilic yeast and xerophilic fungi will not proliferate below 0.60, and they cannot be isolated on compendial microbiological media.¹ The water activity requirements measured at 25° for the growth of a range of representative microorganisms are presented in *Table 1*.

Table 1. Water Activities (a_w) Required to Support the Growth of Representative Microorganisms

Bacteria	Water Activity (a_w)	Molds and Yeast	Water Activity (a_w)
<i>Pseudomonas aeruginosa</i>	0.97	<i>Rhizopus nigricans</i>	0.93
<i>Bacillus cereus</i>	0.95	<i>Mucor plumbeus</i>	0.92
<i>Clostridium botulinum</i> , Type A	0.95	<i>Rhodotorula mucilaginosa</i>	0.92
<i>Escherichia coli</i>	0.95	<i>Saccharomyces cerevisiae</i>	0.90
<i>Clostridium perfringens</i>	0.95	<i>Paecilomyces variotti</i>	0.84
<i>Lactobacillus viridescens</i>	0.95	<i>Penicillium chrysogenum</i>	0.83
<i>Salmonella</i> spp.	0.95	<i>Aspergillus fumigatus</i>	0.82
<i>Enterobacter aerogenes</i>	0.94	<i>Penicillium glabrum</i>	0.81
<i>Bacillus subtilis</i>	0.90	<i>Aspergillus flavus</i>	0.78

¹ J. A. Troller, D. T. Bernard, and V. W. Scott. Measurement of Water Activity. In: *Compendium of Methods for the Microbiological Examination of Foods*. American Public Health Association, Washington, DC, 1984 pp.124–134.

Table 1. Water Activities (a_w) Required to Support the Growth of Representative Microorganisms (continued)

Bacteria	Water Activity (a_w)	Molds and Yeast	Water Activity (a_w)
<i>Micrococcus lysodeketicus</i>	0.93	<i>Aspergillus niger</i>	0.77
<i>Staphylococcus aureus</i>	0.86	<i>Zygosaccharomyces rouxii</i> (osmophilic yeast)	0.62
<i>Halobacterium halobium</i> (halophilic bacterium)	0.75	<i>Xeromyces bisporus</i> (xerophilic fungi)	0.61

Pharmaceutical drug products with water activities well below 0.75 (e.g., direct compression tablets, powder and liquid-filled capsules, nonaqueous liquid products, ointments, and rectal suppositories) would be excellent candidates for reduced microbial limit testing for product release and stability evaluation. This is especially true when pharmaceutical products are made from ingredients of good microbial quality, when manufacturing environments do not foster microbial contamination, when there are processes that inherently reduce the microbial content, when the formulation of the drug product has antimicrobial activity, and when manufacturing sites have an established testing history of low bioburden associated with their products. Table 2 contains suggested microbial limit testing strategies for typical pharmaceutical and over-the-counter (OTC) drug products based on water activity. Other considerations, as listed above, would be applied when setting up the microbial limits testing program for individual drug products because water activity measurements cannot solely be used to justify the elimination of microbial content testing for product release.

Similar arguments could be made for the microbial limits testing of pharmaceutical ingredients. However, this would require pharmaceutical manufacturers to have a comprehensive knowledge of the pharmaceutical ingredient manufacturer's manufacturing processes, quality programs, and testing record. This could be obtained through a supplier audit program.

Table 2. Microbial Limit Testing Strategy for Representative Pharmaceutical and OTC Drug Products Based on Water Activity

Products	Water Activity (a_w)	Greatest Potential Contaminants	Testing Recommended
Nasal inhalant	0.99	Gram-negative bacteria	TAMC,* TCYMC, absence of <i>S. aureus</i> and <i>P. aeruginosa</i>
Hair shampoo	0.99	Gram-negative bacteria	TAMC, TCYMC, absence of <i>S. aureus</i> and <i>P. aeruginosa</i>
Antacid	0.99	Gram-negative bacteria	TAMC, TCYMC, absence of <i>E. coli</i> and <i>Salmonella</i> spp.
Topical cream	0.97	Gram-positive bacteria	TAMC, TCYMC, absence of <i>S. aureus</i> and <i>P. aeruginosa</i>
Oral liquid	0.90	Gram-positive bacteria and fungi	TAMC and TCYMC
Oral suspension	0.87	Fungi	TAMC and TCYMC
Topical ointment	0.55	None	Reduced testing
Lip balm	0.36	None	Reduced testing
Vaginal and rectal suppositories	0.30	None	Reduced testing
Compressed tablets	0.36	None	Reduced testing
Liquid-filled capsule	0.30	None	Reduced testing

* TAMC = Total aerobic microbial count; TCYMC = Total combined yeast and mold count.

[NOTE—The water activities cited in Table 2 for the different dosage forms are representative, and companies are urged to test their individual products before developing a testing strategy.]

Water activity, a_w , is the ratio of vapor pressure of H_2O in product (P) to vapor pressure of pure H_2O (P_o) at the same temperature. It is numerically equal to 1/100 of the relative humidity (RH) generated by the product in a closed system. RH can be calculated from direct measurements of partial vapor pressure or dew point or indirect measurement by sensors whose physical or electric characteristics are altered by the RH to which they are exposed.

The relationship between a_w and equilibrium relative humidity (ERH) is represented by the following equations:

$$a_w = P/P_o \text{ and } ERH(\%) = a_w \times 100$$

The a_w measurement may be conducted using the dew point/chilled mirror method.² A polished, chilled mirror is used as the condensing surface. The cooling system is electronically linked to a photoelectric cell into which light is reflected from the condensing mirror. An air stream, in equilibrium with the test sample, is directed at the mirror which cools until condensation occurs on the mirror. The temperature at which this condensation begins is the dew point from which the ERH is determined. Sample preparation should be considered as it may affect the water activity level of the material tested. Commercially available instruments using the dew point/chilled mirror method or other technologies need to be evaluated for suitability, validated, and calibrated when used to make water activity determinations. These instruments are typically calibrated using saturated salt solutions at 25°, as listed in Table 3.

² AOAC International Official Method 978.18. In: *Official Methods of Analysis of AOAC International*, 17th edition, AOAC International, Gaithersburg, Maryland.

Table 3. Standard Saturated Salt Solutions Used to Calibrate Water Activity Determination Instruments

Saturated Salt Solutions	ERH (%)	a _w
Potassium sulfate (K ₂ SO ₄)	97.3	0.973
Barium chloride (BaCl ₂)	90.2	0.902
Sodium chloride (NaCl)	75.3	0.753
Magnesium nitrate [Mg(NO ₃) ₂]	52.9	0.529
Magnesium chloride (MgCl ₂)	32.8	0.328

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