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Expert consensus

Expert Meeting Group Report

1.1 DEFINITIONS AND SCOPE

1.1.1 Drinking-water

WHO considers that “drinking-water” should be “suitable for human consumption and for all usual domestic purposes including personal hygiene.” Diverse regulatory agencies adopt similar definitions. Drinking-water should therefore be suitable for consumption, washing/showering and domestic food preparation. In human health terms, exposure to water and its constituents can occur through ingestion, contact and aerosol inhalation.

Drinking-waters should be safe for lifetime use, taking account of differing sensitivities that occur across life stages, but all are not necessarily suitable for individuals suffering from certain specific immunocompromising disorders.

Piped drinking-water supplies typically involve source abstraction, treatment and distribution. The latter may include ancillary devices at domestic or institutional levels, such as softeners, activated carbon treatment, vending

machines, dispensers, etc. Drinking-waters also include those obtained from non-piped sources, such as from springs and community wells, in bottles and as ice.

The control of faecal contamination in drinking-water systems and sources, where it occurs, is of primary importance. Faecal-specific indicator bacteria such as *E. coli* are the parameters of first importance in monitoring faecal pollution.

1.1.2 Heterotrophic plate count

Heterotrophs are broadly defined as microorganisms that require organic carbon for growth. They include bacteria, yeasts and moulds. A variety of simple culture-based tests that are intended to recover a wide range of microorganisms from water are collectively referred to as “heterotrophic plate count” or “HPC test” procedures. Accordingly, the terms “heterotroph” and “HPC” are not synonymous.

There is no universal “HPC measurement.” Although standardized methods have been formalized, HPC test methods involve a wide variety of test conditions that lead to a wide range of quantitative and qualitative results. Temperatures employed range from around 20 °C to 40 °C, incubation times from a few hours to seven days or a few weeks, and nutrient conditions from low to high. The test itself does not specify the organisms that are detected.

Only a small proportion of the metabolically active microorganisms present in a water sample may grow and be detected under any given set of HPC test conditions, and the population recovered will differ significantly according to the method used. The actual organisms recovered in HPC testing can also vary widely between locations, between seasons and between consecutive samples at a single location.

Microorganisms recovered through HPC tests generally include those that are part of the natural (typically non-hazardous) microbiota of water; in some instances, they may also include organisms derived from diverse pollutant sources.

1.1.3 Microbial growth in water

Microorganisms will normally grow in water and on surfaces in contact with water as biofilms. Growth following drinking-water treatment is normally referred to as “regrowth.” Growth is typically reflected in higher HPC values measured in water samples. Elevated HPC levels occur especially in stagnant parts of piped distribution systems, in domestic plumbing, in bottled water and in plumbed-in devices, such as softeners, carbon filters and vending machines.

The principal determinants of regrowth are temperature, availability of nutrients and lack of residual disinfectant. Nutrients may derive from the water body and/or materials in contact with water.

1.1.4 Use of HPC in water management

HPC testing has a long history of use in water microbiology. At the end of the 19th century, HPC tests were employed as indicators of the proper functioning of processes (and of sand filtration in particular) and thereby as indirect indicators of water safety. Use as a safety indicator declined with the adoption of specific faecal indicator bacteria during the 20th century.

HPC measurements nevertheless continue to figure in water regulations or guidelines in many countries. HPC measurements are used:

- to indicate the effectiveness of water treatment processes, thus as an indirect indication of pathogen removal;
- as a measure of numbers of regrowth organisms that may or may not have sanitary significance; and
- as a measure of possible interference with coliform measurements in lactose-based culture methods. This application is of declining value, as lactose-based culture media are being replaced by alternative methods that are lactose-free.

1.2 USES IN PIPED WATER SUPPLIES

1.2.1 Water safety plans

There is an increasing trend towards application of a comprehensive “water safety plan” (WSP) approach to drinking-water supply safety management. This approach is applicable throughout the water supply, from catchment to consumer.

It has been proposed that the WSP approach be included in the next (third) edition of WHO *Guidelines for Drinking-water Quality* and that this would entail five components:

- (1) health-based targets based upon public health protection and disease prevention;
- (2) system assessment to determine whether the water supply chain (up to the point of consumption) as a whole can deliver water of a quality that meets the defined targets;

- (3) monitoring of the steps in the supply chain that are of particular importance in securing safe drinking-water;
- (4) management plans documenting the system assessment and monitoring and describing action to be undertaken from normal conditions to extreme events, including documentation and communication; and
- (5) systematic independent surveillance that verifies that the above are operating properly.

Piped water systems of large buildings may incur greater growth than encountered elsewhere (because of storage tanks, extensive internal distribution networks and temperature-related growth). The principal health concerns in these networks are cross-connections and growth of *Legionella* bacteria, which are not detected by the HPC test procedures. General water safety is ensured by maintenance protocols, regular cleaning, temperature management and maintenance of a disinfectant residual. For these reasons, authorities responsible for building safety should provide advice and require specific water management safety plans.

1.2.2 Water quality targets

There is no evidence, either from epidemiological studies or from correlation with occurrence of waterborne pathogens, that HPC values alone directly relate to health risk. They are therefore unsuitable for public health target setting or as sole justification for issuing “boil water” advisories. Abrupt increases in HPC levels might sometimes concurrently be associated with faecal contamination; tests for *E. coli* or other faecal-specific indicators and other information are essential for determining whether a health risk exists.

1.2.3 Validation and verification

Experience suggests that HPC monitoring can be used in drinking-water supplies along with other information for validation¹ and verification² of

¹ *Validation* is an investigative activity to identify the effectiveness of a control measure. It is typically an intensive activity when a system is initially constructed or rehabilitated. It provides information on reliably achievable quality improvement or maintenance to be used in system assessment in preference to assumed values and also the operational criteria required to ensure that the control measure contributes to effective control of hazards.

² In addition to operational monitoring of the performance of the individual components of a supply system, it is necessary to undertake final *verification* for

treatment process performance and other applications. These may include the following:

- HPC measurements can be used to monitor the performance of filtration or disinfection processes.
- In piped distribution systems, HPC measurements are assumed to respond primarily to (and therefore provide a general indication of) distribution system conditions. These arise from stagnation, loss of residual disinfectant, high levels of assimilable organic carbon in the water, higher water temperature and availability of particular nutrients. In systems treated by chloramination or that contain ammonia in source waters, measurement of a variety of parameters, including HPC, but especially including nitrate and nitrite (which are regulated for health protection), can sometimes indicate the possible onset of nitrification.
- HPC values are also used in verification (and by some authorities also for validation) of efficacy of cleaning in diverse applications, including beverage vending machines, food processing and preparation facilities and medical devices. These applications of HPC have not been considered in this review.

1.2.4 Aesthetic quality

Drinking-water must be aesthetically acceptable as well as safe. Aesthetic acceptability is directly relevant to health, since rejection of safe, but unacceptable (undesirable), water may lead users to consume acceptable but potentially unsafe alternative waters. HPC testing may be used in investigating aesthetic quality, and it is used by some authorities as a marker for some of the underlying causes of some aesthetic problems.

reassurance that the system as a whole is operating safely. Verification may be undertaken by the supplier or by an independent authority or a combination of these, depending on the administrative regime in a given country. It can include testing for faecal indicator organisms, pathogens and hazardous chemicals.

1.3 USES IN NON-PIPED AND OTHER WATER SUPPLIES

1.3.1 Bottled water

Bottled (“packaged”) water is considered drinking-water under some regulatory schemes and as a food in others. Some authorities distinguish between natural mineral water and other bottled waters. The WHO *Guidelines for Drinking-water Quality* are referred to directly in international norms (Codex Alimentarius Commission) and are considered applicable to bottled waters.

Bottled waters represent a specific growth situation for microbial flora. Bottled waters may derive from “pristine” sources (“natural mineral water”) or from processed waters. They may contain or have added carbon dioxide that will restrict growth potential, but typically no long-lasting disinfectant residual is present. The finished product will often be exposed to elevated (ambient) temperatures over a period of days to weeks before consumption.

Microorganisms naturally occurring in water are a normal part of the microbiota of bottled waters that meet appropriate safety norms. Levels of HPC recovered from bottled water post-distribution may therefore sometimes be significantly higher than those found in municipal water supplies in distribution.

Microbial safety for bottled waters is best pursued by a WSP approach (as summarized in section 1.2.1). *Pseudomonas aeruginosa* and HPC values are used by some as process management indicators in bottled water production and not as health risk indicators.

1.3.2 Plumbed-in devices

Bacterial growth occurs in plumbed-in domestic water devices (including water softeners, carbon filters, etc.) and plumbed-in commercial devices, such as beverage vending machines. HPC values in water samples typically increase in such devices. Increases of HPC (due to growth) in these devices therefore do not indicate the existence of a health risk, as long as the entry water meets acceptable microbial water quality norms (e.g., WHO *Guidelines for Drinking-water Quality*). Appropriate maintenance of these devices is required for aesthetic reasons (see section 1.2.4) — for example, per manufacturers’ recommendations. Plumbed-in devices in health care facilities are considered in section 1.4.5.

1.3.3 Conveyances

Water systems on conveyances such as ships and aircraft present specific challenges to water safety management. These include both physical characteristics (extensive complex piping in confined space, physical

movement) as well as organizational issues, such as multiple responsible parties in different locations and at different stages of delivery.

In general, the potential roles for HPC in water safety management in conveyances are similar to those elsewhere (see section 1.2.1). HPC measurements alone are unsuitable for use in independent surveillance by, for example, port health authorities where series results are unavailable; faecal indicator bacteria measurements are essential in this role. This issue is dealt with in the WHO *Guide to Ship Sanitation* and *Guide to Hygiene and Sanitation in Aviation*, which are currently in revision.

When drinking-water is stored in tanks in conveyances, microbial growth invariably occurs. If HPC testing is conducted, the counts measured will often exceed those normally found in piped distribution systems. Obtaining a high count by the HPC test may indicate the need to examine procedures for taking on water, maintenance of the system and disinfection.

1.3.4 Other water exposure media

Swimming pools and spas are outside the scope of this report. They are dealt with in the WHO *Guidelines for Safe Recreational Water Environments*. The role of HPC in humidifiers and air cooling systems is also outside the scope of this report.

1.4 HEALTH ASPECTS

1.4.1 Exposure

Exposure to general HPC microbiota is far greater through foodstuffs than through drinking-water. Levels of exposure regarded as acceptable from foods are much greater than those regarded as acceptable from drinking-water. Limited data are available with which to characterize exposure to specific microorganisms through these two routes. Exposure to HPC microbiota also occurs through air and other environmental sources.

1.4.2 Epidemiology

Some epidemiological studies have been conducted into the relationship between HPC exposures from drinking-water and human health effects. Other studies relevant to this issue include case-studies, especially in clinical situations, and compromised animal challenge studies using heterotrophic bacteria obtained from drinking-water distribution systems. The available body

of evidence supports the conclusion that, in the absence of faecal contamination, there is no direct relationship between HPC values in ingested water and human health effects in the population at large. This conclusion is also supported indirectly by evidence from exposures to HPC in foodstuffs, where there is no evidence for a health effects link in the absence of pathogen contamination.

There are a small number of studies that have examined possible links between HPC and non-intestinal outcomes in general populations. The conclusions of these studies do not support a relationship.

1.4.3 Health effects — specific organisms

Information on the association of specific HPC microbiota with health effects may be derived from epidemiological studies, including outbreak investigations, or from risk assessments.

Bacteria typically described as “opportunistic pathogens” that may be recovered among HPC microbiota include strains of *Pseudomonas aeruginosa*, *Acinetobacter* spp., *Aeromonas* spp., *Klebsiella pneumoniae*, etc. There is no evidence of an association of any of these with gastrointestinal infection through the waterborne route among the general population.

There are opportunistic pathogens that may regrow in water but that are not detected in HPC measurements, including strains of *Legionella* and non-tuberculous mycobacteria. The public health significance of inhalation exposure to some legionellae has been demonstrated.

There is no evidence that HPC levels *per se*, as measured by established procedures, have a direct relationship to the likely presence of, or act as indices for the numbers or presence of, regrowth organisms such as legionellae, *P. aeruginosa* and non-tuberculous mycobacteria.

1.4.4 Populations at increased risk (including sensitivity through life stages)

Specific strains of microbial species that may be a part of HPC microbiota can cause infection in certain vulnerable people (e.g., the immunocompromised and those with indwelling urinary catheters, intravenous catheters, continuous ambulatory peritoneal dialysis, etc.). Most infections due to these organisms are from non-water sources (endogenous microbiota, cross-infection from other persons in health care wards or the general environment). However, there have been a number of outbreaks reported where the investigations may implicate the water supply. The implication for infections of immunocompromised patients in the general community is unclear.

There are increasing numbers of persons who are immunocompromised to various degrees and types living in communities, including some patients discharged to “home care.” Normal “drinking-water” is not always suitable for all such individuals for all uses (e.g., wound irrigation). This relates to water safety in general and not to growth or HPC organisms in particular. Advice should be provided by public health authorities to at-risk groups in general and by practitioners responsible for individuals discharged to home care.

Where the drinking-water supply meets international norms such as the WHO *Guidelines for Drinking-water Quality*, only those people with severe changes from normal, as determined by their physicians or medical agencies (e.g., an absolute neutrophil count $<500/\mu\text{l}$), are considered immunosuppressed to the extent that they may require specially processed drinking-water.

1.4.5 Health care facilities

Health care facilities include hospitals, health centres, dialysis facilities and dental facilities. These facilities represent a general area of concern for infection control because of the potentially increased susceptibility of the associated population and their risk of infection from organisms growing in their environment.

Health care facilities should have WSPs as part of their infection control strategy. Such plans may be generic (e.g., applicable to health centres in general) or specific when applied to a larger built environment (e.g., many hospitals and nursing homes). Such plans should address microbial growth in addition to control of external contamination by *Pseudomonas aeruginosa* and *Legionella* and should include ancillary equipment such as shower heads and medical devices, such as dialysis units and dental water dispensing equipment, that involve patient contact.

1.5 OUTSTANDING QUESTIONS AND RESEARCH

The state of the evidence indicates that any further research on HPC in general should focus on its use for process management and control applications as described in section 1.2 and is not a high priority for public health protection.

Because of ongoing interest, further research in this area is likely to occur. It may usefully focus on:

- specific heterotrophic organisms of potential concern for human health, along with developments of future molecular techniques that may provide additional public health information;

- the immunocompromised (especially infection control in health care facilities and susceptible persons in the public at large);
- non-ingestion exposures (including aerosol exposure and hypersensitivity reactions) and roles of amoebae in biofilms;
- *Pseudomonas aeruginosa*, which are common in the environment and are occasionally found in drinking-water — they are sometimes associated with wound and other infections in high-risk populations;
- additional research on conditions and routes of exposure and control methods (when appropriate); and
- susceptible populations of relevance to exposure from drinking-water.

The potential role of heterotrophic bacteria in preventing or reducing colonization of water system components by organisms of human health concern also merits further research.

1.6 REFERENCES

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