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Safe drinking water across species: A review of key quality parameters for humans, livestock and laboratory animals

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Abstract

Access to safe drinking water is critical for maintaining the health and productivity of humans, companion animals, and livestock. This review outlines essential physical, chemical, microbial, and organic parameters used to assess water quality and their relevance to public and veterinary health. Key physical parameters such as color, turbidity, taste, and odor serve as initial indicators of water acceptability. Chemical properties, including pH, alkalinity, total dissolved solids (TDS), electrical conductivity (EC), and mineral composition (e.g., calcium, magnesium, fluoride), influence water's palatability, metabolic safety, and long-term usability. Notably, elevated TDS and nitrates can impair kidney function, growth, and reproductive health in both humans and animals. Microbial assessments focus on coliforms and *E. coli*, indicative of fecal contamination, while protozoa and viruses present further risks of gastrointestinal and systemic infections. Organic contaminants, including natural organic matter (NOM), industrial pollutants, and contaminants of emerging concern (CECs) such as pharmaceuticals and microplastics, represent growing challenges to water safety. Measurement techniques span from field-based digital testing (e.g., AmiciSence meters) to advanced lab-based methods like ICP-MS and AAS. Species-specific tolerance levels are discussed, highlighting that livestock tolerate higher TDS than humans or pets. The review emphasizes the necessity of regular monitoring, adherence to standards like BIS IS 10500:2012 and WHO guidelines, and the importance of tailored water treatment and policy interventions. Safe water is not only a public health imperative but also essential for sustainable animal agriculture and ecological balance.

Keywords: Water quality assessment, drinking water standards, human and animal health, physicochemical and microbial parameters

Introduction

Access to safe and high-quality drinking water is fundamental for the health and productivity of humans, companion animals, and livestock. Water serves not only as a medium for hydration but also as a critical vehicle for essential mineral intake and physiological homeostasis. Contaminated or imbalanced water can cause acute or chronic health problems, affect feed intake, productivity in livestock, and even alter metabolic and reproductive functions in animals. This review outlines the key physicochemical parameters used to assess water quality and discusses their implications across species.

Water quality is evaluated using a mix of physical, chemical, and bacteriological parameters as per BIS IS 10500:2012 standards^[1].

- **Physical:** Colour, appearance, odour and turbidity
- **Chemical:** pH, EC, TDS, alkalinity, hardness, fertility and minerals like Ca, Mg, Cl, F, NO₃, SO₄, Fe.
- **Microbial parameters:** Total microbial load, Total coliforms and *E. coli* (cfu/100 ml), tested via membrane filtration technique.
- **Other organic contaminants:** Natural organic matter (NOM), Industrial organic contaminants and Contaminants of emerging concern (CEC).

Water quality analysis carried out systematically by instrumental techniques ^[2, 3]. The analysis should be carried out immediately within 3-6 hours for physical and microbial parameters and later on for other organic contaminants and minerals estimation, water samples dispatched in air tight bottles to the laboratory with ICP-MS and GC-MS facility.

Physical Parameters

Colour, Appearance, Turbidity, Odour and Taste: these are organoleptic type of physical parameters assessed by observation through human senses and to detect water samples with desirable or undesirable qualities. Water should be colourless, odourless, and clear appearance. Taste varies from place to place depending on types of salts present and total dissolved solids (TDS). Discolouration of water may indicate organic contamination, metals (iron, manganese), or microbial growth. Turbidity should be below 5 NTU for safety and acceptance ^[4].

Chemical Parameters

pH: pH is a measure of hydrogen ion concentration and reflects the acidity or alkalinity of water. pH measured by AmiciSense digital water quality tester 10 in 1 meter with calibration function and also with pH meter available in labs. Ideal pH for drinking water lies between 6.5 and 8.5. Water with low pH may corrode pipes, leach toxic metals and cause acidosis in consumers, while high pH affects palatability and digestion in humans and animals ^[5] and also leads to skin irritation and alkalosis ^[6].

Alkalinity

Alkalinity refers to the water's buffering capacity against acids and is primarily due to bicarbonates, carbonates, and hydroxides and is estimated by N/50 sulphuric acid titrimetric method. Water with moderate alkalinity (100-200 mg/L as CaCO₃) is preferred ^[1]. High alkalinity may cause gastrointestinal upset in sensitive species ^[7].

Total Dissolved Solids (TDS)

TDS encompasses all dissolved minerals, salts, and organic matter in water. TDS measured by AmiciSense digital water quality tester/Elico EC meter calibrated with KCl solution. TDS can also be measured by the formula ^[8].

$TDS = \text{Electrical conductivity} \times 0.65$.

For human consumption, TDS < 500 mg/L is desirable, if there are no alternative sources of water, upto 1000mg/L is acceptable. However consumption of such high TDS water for long time leads to dehydration, digestive problems and kidney dysfunction ^[9]. In livestock, levels up to 3000 mg/L may be tolerated by ruminants, though productivity may decline ^[10]. Elevated TDS affects taste, causes diarrhea, and may result in mineral imbalances ^[11].

Electrical Conductivity (EC)

EC indicates the water's ability to conduct electricity, directly related to its ion content. EC measured by AmiciSense digital water quality tester/Elico EC meter calibrated with KCl solution. Water with EC < 1500 $\mu\text{S}/\text{cm}$ is considered acceptable for most species. EC values are often used as a quick screening tool to estimate TDS ^[8].

Resistance

Electrical resistance is inversely related to conductivity and can also reflect water purity measured by AmiciSense digital water quality tester. High resistance (low conductivity) suggests demineralized water, which may not be suitable for long-term consumption due to potential mineral deficiencies ^[12].

Hardness

Water hardness results from dissolved calcium and magnesium. Water hardness, particularly total hardness, is estimated using a formula based on a titration method with EDTA (ethylenediaminetetraacetic acid), using Eriochrome Black T (EBT) indicator with ammonia buffer to signal the endpoint ^[13]. The general formula is

$$\text{Hardness (mg/L as CaCO}_3\text{)} = \frac{(\text{Volume of EDTA} \times \text{Molarity of EDTA} \times 100.09)}{\text{Volume of water sample.}}$$

For the EDTA method, this formula is applied to determine total hardness, and then a separate calculation is done for permanent hardness (after boiling the water sample).

Another method of estimation of total hardness is after measuring the concentration of calcium and magnesium ions in a water sample.

$\text{Total Hardness (mg/L as CaCO}_3\text{)} = (\text{Ca}^{2+} \text{ concentration in mg/L} \times 2.5) + (\text{Mg}^{2+} \text{ concentration in mg/L} \times 4.1)$.

Moderate hardness (60-120 mg/L as CaCO₃) is beneficial, while extremely hard water (>300 mg/L) may cause scaling, and very soft water (<30 mg/L) can lead to electrolyte imbalance ^[14].

Fertility

In the context of water quality, "fertility" refers to the presence of nutrients—particularly nitrates, phosphates, and potassium—that can influence both soil fertility and water's potential to support microbial growth. Nitrate levels above 40 mg/L (BIS 10500:2012) are considered hazardous, especially to infants and young animals. Elevated nitrate intake has been implicated in methemoglobinemia ("blue baby syndrome") and is associated with other serious health outcomes, including increased risk of certain cancers (via bacterial conversion to N-nitroso compounds), hypertension, central nervous system birth defects, diabetes, spontaneous abortions, respiratory infections, and impaired immune function. ^[15]

Fertility in drinking water is assessed by analyzing parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), sodium absorption ratio (SAR), and alkalinity to determine nutrient load and its potential impact on microbial proliferation. In this study, fertility was measured using the AmiciSense digital water quality tester, which provides a scale ranging from 0 to 3. A reading of 0 indicates the water lacks sufficient nutrients to support microbial life and maintains a stable pH upon storage. Conversely, a reading of 3 indicates that the water contains sufficient nutrients, on storage these nutrients can promote microbial growth, leading to visible gas bubble formation, pH fluctuations, oxygen depletion, and biofilm formation. These changes signify deterioration in stored water quality, rendering it unsuitable for safe drinking.

Mineral Composition

Minerals such as calcium, magnesium, sodium, potassium, iron, zinc, and fluoride contribute to water's nutritional value. Their deficiency or excess can lead to disorders like osteopenia, dental fluorosis, or salt toxicity^[16].

To estimate minerals in drinking water, a range of analytical techniques can be used, from simple titration methods to advanced, lab-based instrumental methods such as inductively coupled plasma analysis (ICP-MS), atomic absorption spectroscopy (AAS), Ion chromatography (IC). For a single test of multiple minerals, a lab analysis is the most comprehensive option. The best method depends on the required accuracy and the specific minerals of concern.

Microbial contaminants

Bacteria

These are organisms present in water include bacteria found in human and animal feces that can contaminate water. Water born diseases caused by bacteria include diarrhea, cholera and typhoid. Presence of coliforms indicates that other harmful bacteria are found in water, *Escherichia coli* (E coli) test is preferred to confirm whether the coliform is of fecal origin or not. The presence of E coli renders the water unfit for drinking purposes^[17].

Protozoa

Water-transmitted enteric protozoal diseases, such as giardiasis, cryptosporidiosis, amoebiasis, balantidiasis, and infections with *Cyclospora* and *Microsporidia*, are caused by protozoan parasites transmitted through contaminated water and cause diarrheal illness. Transmission occurs when people ingest parasitic cysts or oocysts, often from unsafe drinking water^[18]. To identify water-transmitted enteric protozoal diseases, medical and environmental laboratories primarily use microscopic, immunologic, and molecular methods^[19].

Virus: Water transmitted viral pathogens having health significance are adenovirus, astrovirus, hepatitis A and E viruses, rotavirus, norovirus and other calici viruses^[20].

Other organic contaminants

Natural organic matter (NOM)

Originates in water due to the biological degradation of plant and animal products. NOM is the measure of total organic carbon (TOC) in water, which is mostly in solution form. The portion that can pass through a 0.45 µm filter membrane is called dissolved organic carbon (DOC). Organic matter plays an important physical and chemical characteristics of water and may cause the regrowth of pathogens^[21].

Natural organic matter (NOM) in water is estimated using methods like Total Organic Carbon (TOC) analysis, UV-Vis spectroscopy (measuring UV absorbance), and other chemical oxygen demand tests such as BOD and COD^[22].

Industrial organic contaminants

These emerge from industrial activity, agricultural lands (fertilizers and pesticides), livestock farming, over flowing sewers and defective waste treatment plants. They may include pharmaceuticals, bodycare products, polychlorinated biphenyls (PCB) benzene, toluene, xylene, polyvinyl chloride (PVC), styrene, volatile organic compounds (VOCs) and tetrachloroethylene^[23].

Contaminants of emerging concern (CEC)

CEC are present in environment are created by anthropogenic activity. These contaminants include pharmaceuticals,

bodycare products and nano particles. Others include surfactants and plasticizers such as 4-nonylphenol (NP), 4-octylphenol (OP) and bisphenol A (BPA), in addition to perfluorinated substances, such as perfluorooctane sulfonate (PFOS) and perfluorooctanoate (PFOA)^[24, 25].

Species-Specific Considerations

- **Humans:** Sensitive to microbial and chemical contaminants. RO water is often low in minerals, requiring remineralization.
- **Companion Animals (Dogs, Cats):** Affected by high TDS and nitrates; chronic exposure can affect renal health.
- **Livestock (Cattle, Poultry, Swine):** Tolerate broader ranges in TDS (upto 3000mg/L) and pH (6.5 to 8.5) but sensitive to nitrates (>44mg/L), sulphates (<500mg/L), and salinity (<3000mg/L)^[14].

Conclusion

Water quality assessment is a multidimensional approach involving physical, chemical, and sometimes microbiological parameters. Ensuring safe and mineral-balanced water is crucial not only for human health but also for maintaining productivity and well-being in animals. Regular monitoring and adherence to BIS, WHO, and species-specific standards are essential.

Conflict of Interest

Not available

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Not available

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