# Review of the Effects of Water Characteristics and Quality on Human Health

## Ezugwu, Maryann Ogoamaka[1], Akhimien Faith Osarumwense[2]

[1,2] Department of Civil Engineering, Gen. Abudulsalami A. College of Engineering, Igbinedion University, Okada.

**ABSTRACT:** This paper reviews water quality parameters and their health effects on humans with the objective of enlightening the public on drinking water guidelines, the focal point and protection measures. It is also intended to help evade the health catastrophe that manifests as a result of ingesting water containing substances in excess concentration of recommended limits. Sources of water are reviewed, including rain water, surface water and groundwater. The presence and level of the biological, physical and chemical constituents referred to as water parameters which determine its suitability for drinking were also reviewed. Biological parameters are microorganisms, while physico-chemical parameters include temperature, color, dissolved solids, cations, etc. Drinking water quality standards as well as the health impacts of water quality parameters were discussed. Some of the health impacts include water borne diseases, organ failures, cancer, neurological damage, etc. The paper concludes that microorganisms and chemical constituents in drinking water sources and supply can directly or indirectly impair the use of the water for human consumption. Recommendations were made including the disinfection of drinking water sources to prevent growth of disease causing organisms, hand washing to prevent infections including Covid 19 virus and laboratory assessment of water quality parameters to ascertain their conformity with drinking water standards.

**KEY WORDS:** Drinking Water, Health Effects, Quality, Water Standards

## INTRODUCTION

Drinking water is one of the most essential, inevitable and indispensable natural resources needed for life existence and man's survival (Subramani *et al.,* 2005, Nwankwoala *et al.,* 2012). It is needed for daily use by all living organisms including plants, animals and human beings. Due to its unique properties, water serves multiple uses. Water is used for drinking, irrigation, transportation, recreation, washing, cooking, industrial activities and many more. Therefore, it is absolutely essential for life. Human beings depend on water at all developmental stages and activities (Srivastava, 2015). All water including drinking water, contain naturally occurring substances which are categorized into physical, chemical and biological constituents (characteristics). The level and type of the substances in the water determine its suitability for any purpose. The level and presence of physicochemical and biological parameters (substances) are expected to be within the recommended (maximum permissible) limits set by regulatory bodies to protect human health. Within this recommended range, substances (parameters) will not pose any health threat to water consumers, but deviation from the limit in excess of the recommended level, will result in human health catastrophe. The biological properties of water indicate the presence of micro-organisms such as viruses, bacteria, fungi, protozoa etc. These organisms are naturally present in water and consequently lead to water related diseases, especially when in contact with contaminated and untreated sources. Any water source serving consumption purpose should be devoid of these microorganisms or be disinfected in order to avert health dangers associated with drinking microbial-contaminated water. Health risks and challenges involved by ingesting a biologically polluted water are enormous, leading to outbreak of diseases within a particular community or even death. The physicochemical properties are made up of parameters such as, temperature, colour, odour, suspended solids, dissolved solids, bicarbonates, chlorides, sodium, nitrates, sulphates, calcium, magnesium, potassium, etc. These substances are naturally found in drinking water sources in amount that may or may not be detrimental to human health especially when consumed without proper treatment. Water is pure in its own nature, but the pathway on earth imparts additional impurities and contaminants found in it. Human and man-made activities also contribute contaminants prevalent in water (Peavy *et al.,* 1985; Venkateswaran & Deepa, 2015). The presence of contaminated substances and impurities in water can impair its intended use. Therefore, it is imperative to study water with intent to ascertain its quality and impacts on human health and environment. These impurities found

in water may be inform of suspended or dissolved solids. Dissolved materials consist of molecules or ions that are held by the molecular structure of the water which can only be assessed through laboratory analysis. Therefore water quality of drinking sources is a worldwide concern and very important for public health (Levallios & Villanueva, 2019). Understanding water characteristics with reference to its quality and health implications, will definitely help to curb both short and long term diseases incurred as a result of drinking contaminated water. The aim of this paper is to review water characteristics and its quality with the objectives of outlining the implications associated with water quality parameters in excess of the recommended range on human health. It will also raise awareness and enlighten the public. Narsimha *et al.,* 2013 stated that the backbone for prevention, protection and control of water -borne and related diseases lies in proper management of drinking water which directly empowers sustainable economy and development.

## SOURCES OF WATER

Water occur and circulate on the earth surface through hydrological cycle and a process called precipitation. Precipitation is the release of saturated water vapor from the atmosphere to the earth surface in forms of rain, hail, sleet, drizzle, etc. (Reddy, 2008). The various places on the earth surface from which this water can be collected or extracted for human use depicts its source. Sources of water include rain water, surface water and ground water.

### Rain Water

Rain water is a natural and major source of water supply in most rural areas. And for such areas, it might be the only source of water for drinking and other purposes. Therefore, it can be properly harvested, collected and stored for desired purposes. It is usually collected from building roofs and land surfaces (Agunwamba, 2000). Rainwater that is collected and stored correctly is safe, economical and also sustainable (Srivastava, 2015). Rain water is soft and most suitable for laundry purposes. It offers a better washing efficiency. It is free and requires no elaborate purification works. No transmission and distribution network is required. It causes no calcification in washing machines. Although it may be corrosive due to its travel surface.

### Surface Water

Surface water is accumulated water body in a particular area with an open surface. It includes rivers, lakes, ponds, streams, oceans, etc. This particular water is an open source on land surface and very susceptible to contamination and quality deterioration by human and animal activities. They are mostly harnessed for water supply in urban areas by state water co-operations due to its sustaining perennial condition. Also due to lack of proximity, it requires more piping network, treatment system, storage facilities and professional skills, to design and construct water supply system to communities. These factors directly spike the cost of construction of water supply system and such projects can only be financed or sponsored by federal or state government. Surface water is the major sources of water supply, in some areas (Kumar *et al.,* 2009; Avvannavar & Shrihari, 2008)

### Ground Water

Groundwater is formed by rainfall which infiltrates into the ground through the pores of rock and soil to underground water table (Arora, 2007). Groundwater exists in pore spaces of soil and rock sediments and are fully saturated (Todd and Mays, 2000; Mahalingam *et al.,* 2014). It varies in quality depending on the geological conditions of the soil through which it passes through or flows (Ocheri *et al.,* 2014). It includes wells, boreholes, etc. It can be abstracted from the aquifer by means of hand dug well and boreholes at various depths (Ezomo *et al.,* 2013). Hand dug wells are manually sited by individuals to meet their domestic water demands. Siting of boreholes within a community or home requires proper geological and geophysical investigation of viable aquifer before drilling to guide against influences of seasonal variations on water level and yield. Conversely, improper siting of boreholes may lead to its failure or insufficient water abstraction during the dry season. Singh *et al.* (2011) reported that groundwater are mainly utilized in areas with shortages or no supply of water from water board.

## WATER CHARACTERISTICS

Water characteristics are constituents in water which are of biological, physical or chemical origin. In laboratory investigation and analyses, they are referred to as water parameters. Their level of concentrations in a water sample denote the degree of water quality and it's suitability for desired purposes. Assessment of water quality is a true reflection of water characteristics.

### Biological Water Characteristics

Biological water characteristics are micro-organisms that live in water and undergo some vital processes such as reproduction and growth. These microorganism are so diminutive and can only be identified or seen with the aid of a microscope. They include bacteria, algae, crustaceans, fungi, protozoa, rotifers, and virus.

### a. Bacteria

They are unicellular or single cell microorganisms varying from 0.5 to 3.0 microns in size and without chlorophyll, sensitive to temperature and pH (Agunwamba, 2000). They cannot be seen with the naked eye with some being pathogenic (disease causing) while others are harmless (Linsley *et al.,* 1992). There are aerobic, anaerobic and facultative types. Waterborne pathogenic bacteria are causes of gastrointestinal disorder in humans (Peavy et al, 1985) Typhoid fever and cholera are also diseases transmitted via these disease causing bacteria, salmonella type and vibrio comma respectively.

### b. Algae

Algae are single celled photosynthetic plants that predominates mostly in surface water (Linsley *et al.,* 1992). Their presence cause taste and odour problems in water (Agunwamba, 2000). They can alter and affect the growth of certain kind of fish and other aquatic organisms as well as the use of that water for recreational activities and other beneficial uses.

### c. Virus

Viruses are ultramicroscopic, intracellular and obligate parasites that requires a host to live in and of about 20 to 200 millimicrons in diameter smaller than bacteria in size (Agunwamba, 2000; Peavy *et al.,* 1985). They are mostly pathogenic and reproduce within cells of bacteria, plants or humans. They manifest their ability by destroying or damaging the host cells. Polio-myelitis and infectious hepatitis are caused by viral pathogens found in contaminated water.

### d. Protozoa

Protozoa are single cell eukaryotic micro-organisms which reproduce by binary fission without cell walls and the majority of protozoa are aerobic or facultative, anaerobic and chemo.-heterotrophic (Linsley *et al.,* 1992). They feed on bacteria and other microscopic organisms and are therefore essential in the purification of streams and in the operation of biological treatment processes because they maintain a natural balance among the different group of microorganisms. Quite a number of them are also pathogenic e.g., giardia lambia.

### e. Fungi

Fungi are multicellular, aerobic, non-photosynthetic, heterotrophic, eukaryotic organisms (DEFRA, 2011). Most fungi obtain their food from dead organic plants and matter (saprophytes). They can grow in low pH environment and extreme conditions unlike bacteria and are responsible for the cause of taste and odour in water (Agunwamba, 2000; Linsley *et al.,* 1992).

### f. Helminths

Helminths can also be called parasitic worms which involve two or more hosts, e.g., human, aquatic species such as snail or insects and they pose their own hazards on individuals that had contact with untreated or contaminated water ( Peavy *et al.,* 1985).

These micro-organisms and many more such as rotifiers and crustaceans (e.g., crabs, lobsters etc,.) signify the bacteriological contamination of a water source and the presence of disease-causing organisms often referred to as pathogenic organisms. These organisms, either by ingestion or physical contact through water, result in water related diseases such as water borne, water-washed, water-based and insect-vector diseases.

Water borne diseases are caused by the presence of pathogenic bacteria in drinking water source of which the spontaneous effect results in outbreak of diseases such as cholera, typhoid fever, dysentery and diarrhea. About 525,000 children lose their life due to diarrhea and there are nearly 1.7 billion cases of childhood diarrhoeal disease every year (WHO, 2017). Contaminated drinking water is estimated to

cause 485,000 diarrhoeal deaths each year (WHO/UNICEF, 2020). Outbreaks of water borne diseases in a community must be seriously avoided and curbed due to its consequential health implication and impact on the masses (WHO, 2011).

Diseases such as, trachoma, leprosy, tuberculosis, whooping cough, tetanus and diphtheria, skin infections are regarded as water scarce diseases. They are predominantly found in areas with water scarcity and very poor hygiene and environmental sanitation. Their transmission will be reduced by increasing the volume of water used for hygienic purposes (Agunwamba, 2000).

Aquatic organisms that spend part of their life cycle in the water and another part as parasites of animals cause water based diseases. These organisms can thrive in either polluted or unpolluted water. They include guinea worm (dracunculiasis), paragomimiais, and schistosomiasis (bilharzia). These diseases are caused by a variety of flukes, tapeworms, roundworms and tissue nematodes, often collectively referred to as helminthes that infect humans. Although they are usually not fatal but they can be extremely painful, prevent people from working and sometimes make movement impossible.

Millions of people suffer from infections that are transmitted by vectors-insects or other animals capable of transmitting an infection such as mosquitoes and tsetse-flies, that breed and live in or near both polluted and unpolluted water (Agunwamba, 2000). Such vectors infect humans with malaria, yellow fever, sleeping sickness and filariasis.

Microbial or bacteriological analysis of water involves the estimation and isolation of microorganisms present in the water sample. Each of these organisms are individually screened and detected through specific techniques which is time consuming and expensive (Peavy *et al.,* 1985). In addition, they cannot easily be handled in laboratory and are relatively difficult to isolate and identify, hence the use of indicator organisms. Indicator organisms comprise faecal and total coliform generally referred to as coliform organisms. They are more numerous, less harmful and easily tested for. Their presence indicates and signifies that contamination has occurred which originates from human and animal intestines as well as the presence of pathogenic organisms (Weiner & Matthews, 2003). Drinking water source is tested for these coliform bacteria to ensure absence or presence of water borne pathogens and the suitable treatment where necessary (Parker *et al.,* 2010)

**Physical Water Characteristics**

Physical water characteristics are regarded as those characteristics that can be identified through human senses i.e., sight, smell, touch and taste. They include temperature, turbidity, suspended solids, colour, taste and odour.

**a. Temperature:**

Temperature of water determines its suitability for human use, industrial application and aquatic ecosystem functioning (Subramani *et al.,* 2012). To a large extent, it governs the biological species present and their rates of activities (Al-Layla *et al.,* 1978). It has effect on most chemical reactions that occur in natural water systems and solubility of gases in water (Peavy *et al.,* 1985).

**b. Turbidity**

Turbidity is a measure of the extent to which light is either absorbed or scattered by suspended material in water. It is cloudy and prevents visibility (Agunwamba, 2000). The colloidal materials associated with turbidity provide adsorption sites for chemicals and biological organisms that may be harmful and cause undesirable taste and odour (WEC, 2008). Therefore, turbidity is one of the primary parameter for assessing drinking water quality (Parker *et al.,* 2010).

**c. Suspended solids**

Solids in water can be in suspended or dissolved forms. Suspended solids in water can be observed with the naked eye. It consists of inorganic and organic materials, resulting from the erosive action of water flowing over surfaces. It is aesthetically displeasing; provide adsorption (attachment of particles to the surfaces or in the pores) sites for chemical and biological agents. Suspended solids may harbor disease causing organisms (Peavy *et al.,* 1985).

**d. Tastes and Odour**

Drinking water should be free of taste and odour (Linsley *et al.,* 1992). At the point of water usage, these two parameters should not be noticed (Sincero & Sincero, 2006). Tastes and odour are caused by organic decomposition of materials and volatile chemicals. They are aesthetically displeasing and odour producing substances may be carcinogenic (Peavy *et al.,* 1985).

### e. Colour

Drinking water must be colourless (Agunwamba, 2000). Decaying organic matter such as leaves, weeds impart colour to water which is objectionable not only for health reasons but for aesthetics as well (Sincero & Sincero, 2006). Coloured water is generally not accepted by people and is unsuitable for industrial uses and drinking.

### Chemical Water Characteristics

Chemical water characteristics are mostly dissolve solids in water. It relates to the solvent capacity of a water source or sample. Chemical characteristics comprise organic and inorganic constituents, which are soluble and present in water. They include, total dissolved solids, alkalinity, hardness, fluorides, metals, organics and nutrients. Theses parameters are of a major and serious concern in water quality. Their degree in water determines the level of pollution or purity of the water source and suggest the water source suitability for human consumption without any impediment to health.

### a. pH

pH is one of the most important operational water quality parameter which determines the suitability of water for various purposes with the optimum pH ranging from 7 – 8.5.  It determines the acidic and alkaline nature of water (Ramesh & Elango, 2006).        Water with low pH (<6.5) could be acidic, soft and corrosive. The recommended level for human use is 6.5 – 8.5. Above or below this stipulated range directly poses health risk and other secondary influences.

### b. Electrical Conductivity (EC)

Electrical conductivity is the capacity of electrical current to pass through the water and it is directly related to concentration of ionized substances in that water (Singh and Khan, 2011). Excess of it reduces the osmotic activity of plants and therefore interferes with water absorption and nutrients from the soil.

### c. Total Dissolved Solid (TDS)

TDS in water represent dissolve substances both organic and inorganic constituents soluble in water. It indicates the general nature and extent of contaminant in water (Ramesh & Elango, 2006). High level of TDS reflects higher dissolution of substances in the water. According to Linsley *et al.,* 1992, total dissolved solids in a water sample is equal to 0.55 – 0.7(conductivity value of the water).

### d. Total Hardness

Total Hardness in water is primarily caused by the presence of calcium and magnesium, anions such as carbonate, bicarbonate, chloride and sulphate in water. Water with hardness above 200mg/l may cause scale formation in the distribution system, boilers and irrigation pipes (Ishaku *et al.,* 2011). Water Hardness limits its use for domestic, industrial and agricultural activities. Hard water requires considerable amounts of soap to produce foam or lather. Hardness due to bicarbonate is called carbonate hardness generally known as temporary hardness, while permanent hardness are caused by non-carbonate ions (Parker *et al.,* 2010).

### e. Alkalinity

Alkalinity defines the capacity of water to neutralize acid (Nicholas, 2007). The measurement of alkalinity and pH is needed in drinking water. Parker *et al.,* (2010) stated that Alkalinity measurement is important to determine water stability. It equally imparts a bitter taste to water (Peavy *et al.,* 1985)

### f. Cations

Cations include Calcium ($Ca^{2+}$), Magnesium ($Mg^{2+}$), Sodium ($Na^+$), Potassium ($K^+$), Iron($Fe^{2+}$), Manganese($Mn^{2+}$), Aluminum, etc. Some of the substances are introduced to aquifers by rainwater. Dissolved Calcium and Magnesium in water are the two most common minerals that make water hard. The hardness of natural water varies considerably.

Sodium is a nontoxic metal abundant in earth crust, highly reactive and found in natural waters. High concentration in water can cause a bitter taste and as well pose health risk to kidney and cardiac patients (Peavy *et al.,* 1985).

Iron is found naturally in water, soil, rocks and can also be released in water through other man-made activities such  as in industrial wastes, corrosion of metals containing iron,  refining of iron ore, etc.  It can be present in soluble and insoluble form known as ferrous and ferric iron respectively. Drinking water containing ferrous iron can be colourless and clear which render water turbid when exposed

to air resulting in a precipitate called ferric iron (Agunwamba, 2000). For good health, average concentration level is needed. However, excess of it, can damage blood vessels, kidney, liver and can even cause death (SIC, 2007).

Manganese and iron impart brownish colour to water and are therefore objectionable (Sincero & Sincero, 2006). Their concentration in water determines the amount of organic matter present (Agunwamba, 2000). Excess concentration level of manganese in drinking water can led to neurological disorder (NIS, 2007).

Potassium is an essential water parameter that is not often found in drinking water, at concentration that may pose health risk. However, intake of excess potassium can result in kidney problems, diabetes, hypertension, heart diseases and may also cause immature kidney functions in infants (WHO, 2009)

### g. Anions

Anions include bicarbonate ($HCO_3^-$), sulphate ($SO4^{2-}$), chloride ($Cl^-$), nitrate ($NO_3^-$), phosphate ($PO_4^{3-}$) and fluoride. They are introduced to aquifers through rainwater (Younger, 2007). They are beneficial in irrigation practices especially in the presence of calcium (Nas, 2009).

High concentration of chloride indicates high degree of pollution (Bartram & Balance, 1996). Sources of Chloride in natural water may include sewage discharges and industrial effluents, dissolution of salts deposits, oil well operations.

Nitrates occur naturally in water due to break down of organic compounds containing nitrogen in oxygen presence (Gama, 2017). High level of nitrogen in water is directly linked with agricultural activities involving excessive use of fertilizers (Perera *et al.,* 2014), fertilizer manufacturing industries, leakage of sewage systems into water bodies, etc. It can be naturally removed from water through denitrification process.

Phosphate is mostly used in fertilizer for soil supplement and is released into surface water through runoff. Fluoride is associated with sedimentary or igneous rock, seldom found in small quantities in ground and surface water. High concentration in drinking water causes discolouration of teeth, bone fluorosis and other skeletal abnormalities (Peavy *et al.,* 1985).

### h. Heavy Metals

Heavy metals such as barium, arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd), chromium (Cr), zinc (Zn), nickel (Ni), copper (Cu), and silver, etc. are very toxic and poisonous in small or low concentrations to both human and aquatic organisms. They are hazardous even in very minute concentrations thus posing serious health risk (Peavy *et al.,* 1985). Arsenic is colourless, tasteless and odourless in water and can be found naturally in water and soils through weathering actions (Srivastava, 2015). Zinc and Copper in synergy may be toxic to biological species in small amount (Peavy *et al.,* 1985)

### DRINKING WATER QUALITY STANDARDS

Drinking water quality standards are standards set to ensure the protection and safety of human health in regard to water consumption (NIS, 2007). The advancement of knowledge of the nature and effects of various contaminants in water has brought about regulatory bodies setting recommended (maximum allowable) limits for each water parameter especially water desired for drinking purposes. The quality of water is assessed and evaluated based on the concentration level or degree of these parameters in water (WHO, 2003). The quality of water is regarded as satisfactory when the concentration level of parameters investigated are less than the maximum allowable limits. These recommended standard limits are set based on their implication on human health. Excess of the recommended or allowable limits is a strong indication of health risk for consumers. World Health Organization (WHO) guideline is a backbone from which other regulatory bodies adopted their guideline (Peavy *et al.,* 1985)

Nigerian Standard for Drinking Water Quality (NSDQW) was also established to ensure the protection of consumers in Nigeria. This standard sets maximum allowable limits of drinking water parameters in Nigeria anchored on WHO guideline. The Nigerian Standard for Drinking Water Quality covers all drinking water except mineral water and packaged water. The standard applies to drinking water supplied by state water agencies, community water systems; water vendors and water tankers; public or privately owned establishments, privately owned drinking water system and use solely for the family residence (NSDWQ, 2007). Table 2 captured NSDWQ, WHO and European Union (EU) maximum allowable limits for water quality parameters.

## HEALTH IMPACTS OF WATER QUALITY PARAMETERS

Excess concentration of some water quality parameters in drinking water sources expose consumers to serious health risks and challenges which may be spontaneous or accumulate for a future manifestation. The health implication and impact of these water quality parameters especially when the maximum allowable limit has been exceeded cannot be over emphasized for preventive and protective measures. The biological indicators can seriously lead to outbreak of water related diseases within a community that might even result to death. A healthy society and people lead to a better development. Suspected cases of 42,466 (forty-two thousand, four hundred and sixty- six) cholera outbreak in 2018 were reported by the Nigerian Centre for Disease Control (NCDC) included 830(eighty hundred and thirty) deaths from 20states in Nigeria. Such cases of cholera outbreaks have also been reported in previous years by the Federal Ministry of Health (NCDC, 2019). Furthermore, a total of 5,853 (Five thousand, eight hundred and fifty-three) cases of salmonella typhoid fever were reported in Pakistan from November 2016 to February, 2019, and such cases are prevalent also in parts of Africa (WHO EMRO, 2019). One of the United Nation goals is to ensure clean water and sanitation of which importance has been revealed by Covid 19 pandemic. According to United Nations, nearly 1,000 children die due to preventable water and sanitation-related diarrheal diseases (UN, 2015).

The health effect of chemical substances consumed through drinking water manifest after a prolonged exposure and accumulation which conversely hide the potential source of exposure. Kidney failures, liver and cardiovascular diseases are woven with consumption of contaminated food, drinks and water. However, some of the guidelines and standards for drinking water are established as basis for the protective and precautionary measures to be taken against adverse health impacts of these water parameters on human and environment at large (WHO, 2021). The degree of the presence of these contaminants is determined by laboratory analysis aimed at providing a consensus description of the water quality. Table 1 is the summary of diseases on human beings as a result of consuming contaminated untreated water sources harbouring micro-organisms. Table 2 reveals the maximum allowable limits of physical and chemical water quality parameters set by NSDWQ, WHO and EU as well the health impact, if the recommended limits are exceeded.

**Table 1:** Impacts of Microbial Organisms on Human Heath

| Organisms | Type of Organisms | Disease(s) caused on Humans |
|---|---|---|
| Bacteria | Vibro Comma | Cholera |
| | Salmonella typhi | Typhoid fever, Enteric Fever |
| | Salmonella typhi(A,B,C) | Paratyphoid (Enteric Fever) |
| | Francisella tularensis | Tularemia (deer fly fever) |
| | Leptospirae | Leptospirosis weil's disease, swineherd's disease, hemorrhagic jaundice |
| | Shigella (flexneri, sonnei dysenteriae, boydii) | Shigellosis (bacillary dysentery) |
| | Campylobacter, Clostridium perfringens and botulinum, Yersinia enterocolitica, Staphylococcus, E Coli O157:H7 | Gastroenteristis |
| | Legionella | Pneumonia like pulmonary disease |
| Viruses | Enteric cytopathogenic human orphan (ECHO) | Aseptic meningitis , epidermic exanthem, infantile diarrhea. |
| | Poliomyelitis (3 types) | Acute anterior poliomyelitis, infantile paralysis |
| | Hepatitis A viruses | Hepatitis |
| Protozoa | Entamoeba histolytica | Amebiasis (amebic dysentery, Amebic enteritis Amebic colitis) |
| | Giardia Lamblia | Giardiasis (giardia enteritis Lambliasis) |

| Helminths | Cryptosporidum | Cryptosporidiasis |
| --- | --- | --- |
|  | Dracunculus medinensis | Dracontiasis (dracunculiasis, dracunculosis; medina; serpent, dragon or guinea worm infection) |
|  | Echinococcus | Echinococcosis (hydatidosis, granulosus; dog tapeworm) |
|  | Schistosomas( Mansoni; Japonicum; Haematobium) | Schistosomiasis (bilharziasis or Bill Harris or Blood fluke disease).s |

Adapted from Peavy *et al.,* 1985; Linsley *et al.,* 1992, Weiner & Matthews, 2003.

**Table 2:** Water quality parameters and human health implications.

| S/N | Parameters | Unit | Maximum Permitted by NSDWQ, WHO, EU | Health Impacts |
| --- | --- | --- | --- | --- |
| 1. | pH | - | 6.5-8.5 | Water with a low pH are acidic, soft and could be corrosive. The water could leach metal ions such as iron, manganese, copper, lead and zinc to the aquifer, plumbing fixtures and piping. It can contain elevated level of toxic metals which are cancerous and detrimental to health (WEC, 2008). |
| 2. | Total Dissolved Solids | mg/L | 500 | Water containing more than 500mg/l of TDS causes gastrointestinal irritation (Jain *et al.,*2003) |
| 3. | Conductivity | µS/cm | 250 - 1000 | None |
| 4. | Total Hardness (as $CaCO_3$) | mg/L | 150 | Water exceeding the limit of 300mg/l is considered to be very hard and may cause heart disease and kidney problems (WHO, 2006). |
| 5. | Aluminum (Al) | mg/L | 0.2 | Potential Neuro-degenerative disorders (NIS,2007) |
| 6. | Arsenic (As) | mg/L | 0.01 | Cancer of the skin, lungs, bladder, kidney, diabetes, gastrointestinal symptoms, cardiovascular diseases, rapid poisoning and death, (NIS, 2007, Srivastava, 2015; IPCS, 2021) |
| 7. | Barium | mg/L | 0.3 - 0.7 | Hypertension (NIS, 2007) |
| 8. | Cadmium (Cd) | mg/L | 0.003 – 0.005 | Toxic to the kidney, cadmium exposure in drinking water sources causes liver and kidney damage, renal dysfunctioning and bone degeneration. It is a human carcinogen (NIS, 2007; IPCS, 2021) |
| 9. | Chloride (Cl) | mg/L | 250 | None |
| 10. | Chromium ($Cr^{6+}$) | mg/L | 0.05 | Cancer (NIS, 2007) |
| 11. | Copper ($Cu^{2+}$) | mg/L | 1 - 2 | Gastrointestinal disorder, high concentration of copper in water sources can causes nausea, diarrhea, eyes, nose and mouth irritation. It may also lead to kidney failure and death as well (Ravindra *et al.,* 2015) |
| 12. | Cyanide (CN-) | mg/L | 0.01 – 0.07 | Very toxic to the thyroid and the nervous system |
| 13. | Fluoride (F-) | mg/L | 1.5 | Fluorosis, Skeletal tissue (bones and teeth) morbidity (Peavy *et al.,* 1985; NIS, 2007;; Srivastava, 2015). While dental caries or tooth decay results as a result of absence of fluoride in drinking water(Sincero & Sincero, 2006) |

| 14. | Hydrogen Sulphide ($H_2S$) | mg/L | 0.05 | None |
|---|---|---|---|---|
| 15. | Iron ($Fe^{2+}$) | mg/L | 0.2 – 0.3 | Excess concentration of iron in drinking water can damage blood vessels, kidney, liver, heart, pancreas for individuals with mutated genes and even cause death, while its deficiency enhances lead absorption and toxicity (SIC, 2007; Dalton, 2013). |
| 16. | Lead (Pb) | mg/L | 0.01 | Cancer, interference with Vitamin D metabolism, affect mental development in infants, toxic to the central and peripheral nervous systems. High levels of lead contamination in a child can result in convulsions, irreversible neurological damage, organ failure, coma and ultimately death. Also, moderate to low levels of exposure may alter physical and mental development, inhibit growth, decrease attention span and hearing, and cause learning disabilities. In older men and women, lead can increase blood pressure (Ravindra *et al.,* 2015; IPCS, 2021). |
| 17. | Magnesium ($Mg^{2+}$) | mg/L | 0.20 | Consumer acceptability (NIS, 2007), high concentrations of magnesium in drinking water causes laxative effect and osmotic diarrhea (USEPA, 2009). |
| 18. | Manganese ($Mn^{2+}$) | mg/L | 0.05 – 0.5 | Neurological disorder (NIS, 2007). |
| 19. | Mercury (Hg) | mg/L | 0.001 | Affects the kidney and central nervous system, Pregnant mothers exposed to toxic mercury either through water or consumption of contaminated fish are liable to born physically and mentally deformed babies i.e., it is a threat to child development in the womb (Ravindra *et al.,* 2015; IPCS, 2021). |
| 20. | Nickel (Ni) | mg/L | 0.02 | Possible becoming carcinogenic (NIS, 2007). |
| 21. | Nitrate ($NO^3$) | mg/L | 50 | Cyanosis, and asphyxia (blue-baby syndrome) in infants under 3 months (Sincero & Sincero, 2006; NIS, 2007). |
| 22. | Nitrite ($NO^2$) | mg/L | 0.2 – 0.5 | Cyanosis, and asphyxia (blue-baby syndrome) in infants under 3 months , Higher concentration of Nitrite causes illness known as infant methemoglobinemia,( i.e., a blood disorder in which too little oxygen is delivered to body cells), very unhealthy for pregnant women and even livestock (Nas, 2009; Balakrishnan *et al.,* 2011 and Gama,2017) |
| 23. | Sodium ($Na^+$) | mg/L | 200 | High concentration of sodium in water can affect individuals suffering from heart, kidney, or circulatory ailments and such elevate their blood pressure (Sincero & Sincero, 2006; Peavy *et al.,* 1985) |
| 24. | Sulphate ($SO^4$ ) | mg/L | 100 – 500 | Excessive amount of sulphate in water causes cathartic or laxative effect on consumers (Sincero & Sincero, 2006). |
| 25. | Zinc (Zn) | mg/L | 3 | Zinc exposure in high concentration causes cholesterol and anemia problems in adults, nausea and vomiting in children, etc. (WHO, 2017). |

| 26. | Total Coliform count | cfu/mL | 10 | Indication of faecal contamination (NIS, 2007). |
|---|---|---|---|---|
| 27. | Thermo tolerant Coliform or *E.coli* | cfu/100mL | 0 | Urinary track infections, bacteraemia, meningitis, diarrhea, (one of the main cause of morbidity and mortality among children), acute renal failure and haemolytic anaemia (NIS, 2007). |
| 28 | Faecal streptococcus | cfu/100mL | 0 | Indication of recent faecal contamination (NIS, 2007). |
| 29. | Clostridium perfringens spore | cfu/100mL | 0 | Index of intermittent faecal contamination (NIS, 2007). |

Adapted from NIS, 2007.

**RELEVANCE OF CLEAN WATER TO COVID 19 PREVENTION**

COVID 19 (Coronavirus disease 2019) is an infectious viral disease, identified in Wuhan City of Hubei province of China with symptoms of common cold, cough, tiredness, breathlessness, chest pain, body and muscle pain, headache, runny nose, loss of taste and smell, etc. which may appear 2 to 14 days upon exposure (Kandora,2020; UNICEF,2020). It spreads when respiratory droplets from an infected person get into the nose, eyes or even mouth of people close by. It can also be contacted when people touch surfaces that are contaminated with the virus and without washing their hands, touch their mouth, nose or eyes. It may actually survive on surfaces for few hours to several days, although disinfectants can kill it (Kandora, 2020). It is referred to as a pandemic because of its global spread and lack of people's immunity.

According to NCDC (2021), 164,756 cases have been confirmed, 154963 cases have been discharged and 2,062 deaths have been recorded in 36 states and the Federal Capital Territory.

This infection and spread can be prevented when people have access to clean water and regularly engage in hand washing for at least 20 seconds with soap and water or use an alcohol based sanitizer (NCDC, 2021). Wearing of nose masks and safe distancing are also preventive measures to avoid contracting the virus. Touching of eyes, nose or mouth should be avoided. Stay at home and also seek medical attention when unwell and exhibiting symptoms.

**CONCLUSION**

The presence and level of physical, biological and chemical constituents in water referred to as water parameters determine its suitability for drinking purpose. Biological parameters in drinking water sources and supply can directly or indirectly impair the use of that water for human consumption. Their presence in drinking water outside health risk can also cause other problems such as aesthetic and technical problems e.g., corrosion in pipes (Boe-Hansen, 2002). To overcome these problems and challenges, it is therefore imperative that drinking water sources should be tested for specific pathogens that can endanger human health. Detection of some bacteria signifies faecal contamination of water sources and presences of enteric pathogens. These pathogens give rise to outbreaks of water related diseases. One of the measures enlisted by NCDC in control of infectious diseases is to ensure that drinking water are boiled, filtered and properly preserved or stored safely in a very clean container (NCDC, 2020).

Physical water quality parameters are more or less for aesthetical consideration and an indirect indication of level of dissolved constituents present in the water.

Chemical water quality parameters predominate and as such directly determine the level of pollution or purity of water for human consumption. The complexities of water quality can be simplified in understanding of these parameters and their contaminated or pollution index that are not permitted in drinking water. A critical concern must be observed especially to some water quality parameters needed in human body at some profitable level such as iron, sodium, fluoride. Of course, excess of such parameters have also been seen

to mobilize human health hazard. Heavy (toxic) metals e.g., lead, cadmium, arsenic have been seen to be a death sentence, therefore, they must be critically assessed in any water serving for human consumption. The concentration of these substances in water is a worldwide concern and should be critically and carefully handled because of its stringent and immediate serious health impact on the human health in its minute level. Access to clean water and regular hand washing prevent spread and risk of infection from COVID 19 virus.

## RECOMMENDATION

Disinfection of drinking water sources should be encouraged to prevent growth of disease causing organisms and fight against the spread of water borne diseases that are prevalent in various regions and communities.

Enlightenment and awareness programs on water quality should be continuously empowered and spread to all nooks and crannies of the society.

Private and public supply agencies should regularly monitor and assess water qualities through analysis in recognized and approved water laboratories.

Federal and State government should establish water testing laboratories' across states and federation for proximity and affordability.

Boiling of drinking water as a home remedy especially to curtail outbreak of water borne diseases should be encouraged.

Regular and frequent hand washing should be encouraged to help prevent infections including Covid 19 virus and the spread of pathogens (WHO, 2020)

## REFERENCES

1. Agunwamba, J.C. (2000): "Water Engineering System" Immaculate publication Limited, Enugu,   Nigeria.pp96.
2. Al – Layla, M. A., Ahmed S., and Middlebrooks, E. (1978): "Water Supply Engineering Design". Ann Arbor Science Publishers Inc. Ann Arbor Michigam, pp 279.
3. Arora, K.R. (2007) "Irrigation, Water Power and Water Resources Engineering". Fourth Reprint Edition. A.K. ain for Standard Publishers Distribution 1705-B, Nai Sarak Delhi-110006. Pp133-167.
4. Avvannavar, S.M. & Shrihari, S. (2008): "Evaluation of Water Ouality Index for Drinking Purposes for River Netravathi, Mangalore, South India". Environmental Monitoring and Assessment, Vol. 143: pp 279-290.
5. Balakrishnah, P.; Saleem, A. & Mallikarjun, N.D. (2011): "Groundwater Quality Mapping Using Geographic Information Systems (GIS): A case     study of Gulbarga City, Karnataka, India" African Journal of Environmental Science and Technology. Vol. 5, No 12. pp 1069- 1084.
6. Bartram, J. & Balance, R. (1996) "Water Quality Monitoring - A Practical Guide to the Design and Implementation of Freshwater Quality Studies and Monitoring Programmes" Published on behalf of United Nations Environment Programme and the World Health Organization. ISBN 0 419 22320 7 (Hbk) 0 419 21730 4 (Pbk)
7. Boe-Hansen, R. (2002) "Microbial growth in drinking water distribution systems" Environment and Resources Technical Unversity of Denmark.
8. Dalton, J. (2013) "Groundwater News". Dales water services. www. Dales.water. co.uk.   Accessed February 2017.
9. DEFRA. (2011) "A Review of Fungi in Drinking Water and The Implications For Human Health" Bio intelligence Service. Accessed March, 2017.
10. Ezomo, F.O., Biose, O & Ajieh, M. U. (2013): "Evaluation of Groundwater in Uromi, Edo State, Nigeria."International Journal of Scientific & Engineering Research, Vol. 4, Issue 3. ISSN 2229 – 5518. www.ijser.org. Accessed on 8th April,2016.
11. GAMA. (2017) "Groundwater Information Sheet" State Water Resources Control Board Division of Water Quality GAMA Program, Geo-Tracker. Accessed  March, 2021.
12. IPCS-International Program on Chemical Safety (2021) "Health Impacts of Chemicals" https://www.who.int/ipcs/assessment/public_health. Accessed March, 2021.

13. Ishaku, J.M.; Ahmed, A.S. & Abubakar, M.A. (2011):"Assessment of Groundwater quality Using Chemical Indices and GIS Mapping in Jada. Journal of Earth Sciences and Geotechnical Engineering. Vol. 1 No 1. pp. 35-60.

14. Jain, C.K.; Kumar, C.P. & Sharma, M.K.(2003): "Groundwater Qualities of Ghataprabha Command Area Karnataka". Indian Journal of Environmental Ecoplan. Vol. 7, Issue 2. pp 251-262.

15. Kandora, A (2020) "Coronavirus cause: Origin and how it spreads" Medical news Today. www.medicalnewstoday.com.Accessed April, 2021

16. Kumar, V. (2007): "Optimal contour mapping of Groundwater levels using Universal Kriging" Hydrological Sciences Journal. Vol. 52 No 5.pp 1039 – 1049.

17. Kumar, S.; Bharti, V. K.; Singh, K. B. and Singh, T. N. (2009): "Quality Assessment of Potable Water in the Town of Kolasib, Mizoram (India)". Journal of Environmental Earth Sciences, 61, pp 115-121

18. Levallois P. & Villanueva C.M.(2019) "Drinking Water Quality and Human Health:An Editorial". International Journal of Environment Research anf Public health. Volume 16 (8)

19. Linsley, R.K., Franzini, J.B., Freybery, D.L. & Tchobanoglous, G. (1992): "Water Resources Engineering". Fourth Edition, McGraw-Hill Book Co. Singapore. pp 123 - 125

20. Mahalingam, B.; Ramu; Magdum, D.B. & Jayashree, P. (2014): "Assessment of Groundwater Quality Using GIS Techniques: A Case study of Mysore City". International Journal of Engineering and Innovative Technology (IJEIT) Vol. 3, Issue 8.

21. Nas, B. (2009): "Geostatistical Approach to Assessment of Spatial Distribution of Groundwater Quality" Polish Journal of Environmental Studies, Vol. 18, No6. pp.1073- 1082.

22. Narsimha, A., Sudarshan, V., Srinivasulu, P., Anitha, N. & Parameshwar, V. (2013): An integrated approach to assess the quality of groundwater in part of cheralapally area, Rangareddy District, Andhra Pradesh, India. Pelagia Research Library. Advances in Applied Science Research, Vol. 4, issue 1, pp 244-233.

23. NCDC (2019) "Cholera". www. Ncdc.gov.ng/disease/info. Accessed April, 2021.

24. NCDC (2020) "Ten Essential measures to prevent infectious Disease outbreaks during flooding" www.ncdc.gov.ng/news/268. Accessed April, 2021.

25. NCDC (2021) "Coronavirus Covid -19 Microsite" https://Covid 19.ncdc.gov.ng. Accessed April,2021

26. Nicholas, P.C. (2007): Handbook of Water And Waste Water Treatment Technologies." Butterwofih-Heinemann, 225 Wildwood Avenue, USA. pp 10 -13.

27. NIS (2007) "Nigerian Standard for Drinking Water Quality"ICS 13.060.20.

28. Nwankwoala, H.O., Eludoyin, O.S. & Obafemi, A.A. (2012): "Groundwater Quality Assessment and Monitoring Using Geographic Information Systems (GIS) In Port Harcourt, Nigeria." Ethiopian Journal of Environmental Studies and Management (EJEM) Vol. 5, No 4 pp.583- 5967.

29. Ocheri, M.I.; Odoma, L.A. & Umar, N.D. (2014): "Groundwater Quality in Nigeria Urban Areas: A Review". Global Journal of Science Frontier Research: Environment and Earth Science. Vol. 14, Issue 3, version 1.0. ISSN 2249-4626.

30. Parker, R., Morris N., Fair F.N & Bhatia S.C. (2010) "Waste Water Engineering" First Edition, CBS publishers & Distributors PVT, LTD, New Delhi, India. Pp 63 – 72.

31. Peavy, H. S., Rowe, D. R., & Tchobanoglaus, G. (1985). Environmental Engineering. International Edition, McGraw-Hill Book Co. Singapore. pp 12 – 56.

32. Perera, P.A.C.T; Sundarabarathy, T.V; Sivananthawer, T. & Edirisinghe, U. (2014) Seasonal Variation of Water Quality Parameters in Different Geomorphic Channels of the Upper *Malwathu Oya* in Anuradhapura,Sri Lanka. Tropical Agricultural Research Vol. 25 (2): 158 – 170 (2014).

33. Ramesh, K. & Elango, L. (2006). "Groundwater Quality Assessment in Tondiar Basin". International Journal of Environmental Pollution Vol. 26(6): pp 497-504.

34. Reddy, R. J. P. (2008) "A Textbook of Hydrology"2nd Edition, University Science Press, Boston USA.pp 96 – 159.

35. SIC (2007) "Fact Sheet: Iron For Private Water and Health Regulated Public Water Supplies" Government of Saskatchewan, Water Information website, www.SaskH20.ca. Accessed November, 2017.

36. Sincero, A.P & Sincero, G.A (2006) "Environmental Engineering, A Design Approach" Eastern Economy Edition, Prentice, Hall of India. pp 7 – 55.

37. Singh, P. & Khan, I.A. (2011). "Groundwater Quality Assessment of Dhankawadi ward of Pune by Using GIS." International Journal of Geomatics and Geosciences Vol. 2, No. 2.pp 688 - 703

38. Srivastava, S (2015): "Environment and Ecology" S.K. Kataria & Sons, New Delhi-110002. Pp 82 – 83, 199 – 202.

39. Subramani, T., Elango , L. & Damodarasamy, S.R. (2012). " Groundwater Quality and its Suitability for Drinking and Agricultural Use Chithar River Basin, Tamil Nadu" India. Environmental Geology, (47): pp 1099-1110.

40. Todd, D.K. & Mays, L.W. (2005). "Groundwater Hydrology" Third edition, John Wiley and sons, Inc. United States of America. pp. 329 – 386.

41. UN (2015) "Clean water and Sanitation". www.un.org/sustainabledevelopment/waterand sanitation. Accessed April, 2021.

42. UNICEF (2021) "What you need to know about the coronavirus" www.unicef.org/nigeria/what-need-know-about-coronavirus. Accessed April,2021.

43. USEPA (2009) "Groundwater and Drinking water" www. Epa.gov. Accessed February, 2017.

44. Venkateswaran, S. & Deepa, S. (2015): "Assessment of Groundwater Quality using GIS Techniques in Vaniyar Watershed, Ponnaiyar River, Tamil Nadu". Aquatic Procedia 4,pp 1283 – 1290.

45. Weiner, R.F & Matthews, R. A. (2003) "Environmental Engineering" Fourth Edition, Butterworth-Heinemann, Amsterdam Boston London. pp. 81 – 105.

46. WEC (2008): Wilkes University Center for Environmental Quality, Environmental Engineering and earth sciences. www. Water research . com

47. WHO (2003): "Manual of Basic Technique for a Health labouratory" World Health Organization, 2nd edition, Geneva.

48. WHO (2009): "Potassium in Drinking water" WHO/SDE/WSH/09.01/7 www.who.int/water sanitation…/potassium.pdf. Accessed November, 2017.

49. WHO (2006): "Guidelines for drinking water quality" electronic resource; Incorporation 1st and 2nd addenda v.1 Recommendations, 3rd edition, Geneva, 515

50. WHO (2009): "Calcium and Magnesium in Drinking water, Public Health Significance" Printed in Spain.

51. WHO (2011): "Guidelines for drinking water quality" Fourth edition. www. Unicef.org. January, 2017.

52. WHO (2017): "Zinc in Drinking water" WHO/SDE/WSH/03.04/17 www.who.int/water sanitation…/zinc.pdf. Accessed November, 2017.

53. WHO (2017) "Facts Sheets- Diarrhoeal Diseases" www. Who.intl. Accessed March, 2021.

54. WHO (2021): "Guidelines for drinking water quality" Fourth edition. www. Unicef.org. Accessed April, 2021.

55. WHO EMRO (2019): "Weekly Epidemiological Monitor".Volume 12, Issue 6.

56. WHO (2020): "Hand Hygiene Day" www.who.int/news-room/event/details/2020/05/05/default-calender/hand washing. Accessed April, 2021.

57. WHO/UNICEF(2020): "Drinking Water" www.who.int/news-room/facts-sheets. Accessed April, 2021.

58. Younger, P.L. (2007): "Groundwater in the Environment: An Introduction" 1st edition Blackwell publishing 350 Main Street, Malden, MA 02148-5020, USA., pp74 -106.