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Education on Drinking Water Quality and Its Health Impacts among Students and Community People

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Abstract The health troubles due to poor drinking water quality are huge. The impact of increasing developmental activities, pollution and over-exploitation are altering the distribution of safe water. Besides this, the non-uniform distribution of rainfall due to changing climatic conditions aggravated the trouble. Both point and non-point sources of pollution affect the drinking water quality dominantly. The lack of education and awareness among community people and students about the drinking water quality are also key issues for health problems due to the consumption of contaminated water. Therefore, the knowledge of drinking water quality including health hygiene and sanitation aspects among students and community people is an urgent need. The present paper highlights the need of education about water quality, significant scientific information about the selected drinking water quality parameters, reasons of water quality deterioration, its health impacts etc.

Keywords: *education, students, community people, water quality, health impacts*

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1. Introduction

Water with safe quality is essential not only to survive the humans but for the proper development of ecosystem. Deterioration of drinking water quality has become a serious issue due to some anthropogenic behavior including increase in population, mismanaged agricultural and industrial activities. Besides this, some climatic factors also affect the hydrological cycle. Consequently, human interventions and natural processes affect the quality of ground water as well as surface water also. Domestic manners, mining, power generations, forestry practices etc. are also responsible to create the changes in physical, chemical and biological properties of water [1]. It has been reported that more than 80% untreated sewage in developing nations is discharged directly in water bodies [2]. People nearby contaminated sites and consumers of untreated drinking water are mainly affected with water borne diseases. Water with degraded quality may also impact the crop productivity and food security. According to United Nations, approximately 700 million people suffer today from water scarcity problem in 43 countries. It is estimated that 1.8 billion people will be affected with absolute water shortage by the year 2025 [3].

Human health is directly related with safe drinking water consumption. Ingestion of contaminated drinking water may create several health related problems. Sometimes, it may cause serious issues even death also. In this regard, the students and community people as the main part of society may play a key role in the better understanding of water quality issues. There are many parameters including physico-chemical and bacteriological parameters to judge the quality of drinking water for which certain guidelines has been issued by various authorities like World Health Organization [4], United Nations Environment Protection Agency (USEPA) [5], Bureau of Indian Standard [6] etc. Various water quality parameters can be analyzed in laboratory and also in fields. The knowledge of these water quality parameters has become indispensable to each people before its consumption [7-29]. Therefore, the present paper explains the knowledge of some important physico-chemical and bacteriological drinking water quality parameters and related health issues.

2. Education on Drinking Water Quality Parameters

The physico-chemical and biological characteristics of water define the overall quality of water and suitability for any specific application like drinking, irrigation etc. The knowledge of these water quality characteristics is essential before its consumption. The standard guideline values of these water quality parameters have been decided by certain authorities for different uses. In this paper various important drinking water quality characteristics such as pH, Total dissolved solids (TDS), Turbidity, Total hardness, Alkalinity, Chloride (Cl^-), Sulphate (SO_4^{--}), Nitrate (NO_3^-), Iron (Fe), Calcium (Ca), Magnesium (Mg), Fluoride (F^-), Arsenic (As), Chromium (Cr), Microorganisms/Pathogens in Drinking Water including Fecal coliform and Total Coliform have been described considering the reasons of their occurrence in drinking water, their health impacts etc.

2.1. pH

According to American Public Health Association 2005, each step of water supply and waste water treatment process either water softening, acid base neutralization, precipitation, coagulation, disinfection or corrosion control depends on pH. Importantly, the alkalinity and the acidity of a water sample are the acid and base neutralization capacity and generally represented in terms of milligrams $CaCO_3$ per liter [30]. The pH value of any water body significantly depends on the temperature of the water body and varies according to the temperature variation of the aquatic body [31]. pH is actually the presence of hydrogen ions (H^+) in the sample. The value of pH varies from 0 to 14. Water samples with a pH lower than 7.0 are considered as acids whereas the samples with a pH more than 7.0 up to 14.0 are considered as alkaline in nature. pH 7.0 has been considered as neutral value of pH. The alkaline nature of water may be due to the presence of carbonates and bicarbonates of lime-stones from nearby rocks where as the acidic nature of water body may be due to the presence of humic acid produced by the decay of forest vegetation. According to Kaul and Handoo [32], higher pH of water increases the metabolic activities of autotrophs. Autotrophs receive the carbon dioxide and release the oxygen. Thus decrease the hydrogen ion concentrations and affects the pH.

Both the acidic and alkaline water are harmful for human health. Industrial contamination also changes the pH of water body. Trivedy and Goel, 1986 reported that high pH favors the formation of trihalomethanes which are toxic and carcinogenic substances for the living beings [33]. Higher pH of water makes it bitter in taste, affects digestive system as well as mucous membrane, reduces the effectiveness of its disinfection by chlorine etc. [34]. The determination of pH of water samples can be done by the electrometric principle through the determination of H^+ ions by potentiometric measurement [30]. BIS has decided the pH range as 6.5 to 8.5 for drinking water [6].

2.2. Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) include the inorganic salts mostly calcium, magnesium, sodium, potassium, bicarbonates, chlorides and sulfates along with small amounts of organic matter which are dissolved in water. The TDS in drinking water i.e. in both surface and ground water come from natural or anthropogenic sources or both such as industrial waste water, sewage, urban run-off and chemicals used in treatment process of water [4,35]. Generally, the concentration of TDS in drinking water may vary significantly in different geological regions due to the differences in the solubilities of the minerals of the concerned rocks [30]. Besides, the higher amount of TDS in drinking water may also occur due to soil weathering, leaching and percolation of dissolved ions from waste dumps and industrial discharges etc. Higher amount of TDS changes the corrosion properties of water, its hardness and taste. Though, the higher amount of TDS in drinking-water may be disagreeable to the consumers but no reliable data on probable health effects due to TDS is available [30,36]. As per BIS, 500 mg/l is the desirable limit for TDS whereas 2000 mg/l is the permissible limit in drinking water [6].

2.3. Turbidity

Turbidity is an appearance of the optical property due to which the light propagates with scattering and absorption instead of transmission without any change in its direction. If the higher intensity of scattered light occurs then the turbidity value would be higher [30]. Turbidity in water occurs due to suspended material, colloidal matter, finely divided inorganic or organic matter. Particulate matters including the attached micro-organisms like bacteria, viruses and protozoa which are threat to human health increase the problem of turbidity in surface water whereas clay or chalk particles or the precipitation of non-soluble reduced iron and other oxides creates the turbidity problem in ground water [4,37,38]. Higher values of turbidity indicates the higher content of suspended soilds mainly due to the contamination from soil run-off, bathing, laundering and sand dredging [39] which may vary in water body due to various natural incidents such as heavy precipitation, spring snow melt, flood, weathering of rocks etc. or waste water discharges. On the other hand, the most common causes of turbidity in ground water and surface water are planktons and soil erosion due to logging, mining, urbanizations etc. Higher turbidity in water bodies may reduce the effectiveness of disinfection through providing the protection for microorganisms. Therefore, more chemical disinfection is required before public supply. The consumption of turbid water may create the health related problems like nausea, cramps, diarrhea headaches including gastrointestinal problem [40] and other water borne diseases. The turbidity of water sample can be calculated by Nephelometric method [30].The turbidity range i.e. 1-5 NTU has been determined for drinking water [6].

2.4. Total Hardness

The hardness of water was explained as the capacity of water to precipitate the soap. Dissolved polyvalent metallic ions, mainly calcium and magnesium cations from sedimentary rocks, seepage and runoff from soils are responsible for water hardness [4]. Some researchers have reported that total hardness in water principally occurred due to calcium and magnesium salts derived from dissolved limestone or industrial effluents [35,41,42]. Besides the carbonate and biocarbonate ions, chloride and sulphate anions also cause the hardness difficulty in water. In addition, high temperature, evaporation of water, rock weathering and addition of calcium and magnesium salts through plants and living organisms are found as contributing factors for hardness of water. Pawar et al. (2014) reported that the hardness in water body may be attributed due to the dissolution of $CaCO_3$, magnesium calcite etc [43].

Now more scientifically, it has been explained as the sum of calcium and magnesium concentrations in terms of Calcium carbonate in mg/l [30]. When numerically:

i) Hardness > sum of Carbonate and Bicarbonate alkalinity then hardness equivalent to Total Alkalinity = Carbonate harness (Temporary). Excess hardness is known as noncarbonate hardness (Permanent).
ii) Hardness < or = Sum of Carbonate and Bicarbonate alkalinity then, all hardness = Carbonate hardness. In this case the noncarbonate hardness would be absent.

Hardness of water is categorized [44] as:

Water having the Calcium Carbonate value (mg/l)	Category
< below 60 mg/l	Soft water
Between 60–120 mg/l	Moderately hard
Between 120–180 mg/l	Hard
> 180 mg/l	Very hard

Hard water may causes some potential health impacts like kidney stone problem, cardiovascular disease, childhood atopic dermatitis, bone mineral density, diabetes, heart disease etc. [45]. The EDTA titration method is a suitable method for the determination of hardness in water in laboratory [30]. The desirable and permissible limits of total hardness for drinking water are 200 and 600 mg/l, respectively [6].

2.5. Alkalinity

The alkalinity of water is defined as its capacity to neutralize an acid which is a summation of all the titratable bases specially carbonate, bicarbonate, hydroxide present in water including borates, phosphates, silicates and other bases if present [30]. The alkalinity in water may be derived from dissolved rocks, salts or sediments [46] and the concentration of alkalinity in water increases with the increasing amount of dissolved carbonates and bicarbonates [47]. Higher concentration of alkalinity imparts bitter taste to water [48]. The determination of alkalinity of water sample can be performed through titration method in laboratory [30]. According to BIS, 200 and 600 mg/l values are fixed as desirable and permissible limits for drinking water samples, respectively [6].

2.6. Chloride

Chloride in the form of chloride ion generally occurs in all kinds of natural water as one of the major inorganic anions. WHO (2006) reported that the chloride ions in drinking water mainly come from natural sources, weathering, sewage and industrial effluents, urban runoff having de-icing salt and saline intrusion etc [49]. Some other researchers also explained that the mixing of sewage and leaching from waste dumping sites created the salty taste in water [30,43,50]. Extreme chloride concentrations raise the rate of corrosion of metals in the water distribution system which leads to the increased concentrations of metals in drinking water supply [49]. Though, higher level of chloride in water is considered as an indication of pollution, which is ascribed due to high organic waste received from animals [51]. Exceeded concentration of chloride ion in water indicates the degree of pollution in relevant water body. When chloride concentration is about 100 mg/l in water, it is usually associated with cations viz. Na, K and Ca which produces salty taste in water [52].

Argentometric method is found as suitable and popular in laboratories for 0.15 – 10 mg/l concentration range in clear water samples whereas potentiometric method was reported as suitable method for colored and turbid samples [30]. The values for concentration of chloride in drinking water have been provided as 250 and 1000 mg/l as desirable and permissible limits [6].

2.7. Sulphate

Sulfate naturally occurs in several minerals and is also being used commercially in chemical industries. Finally, the industrial wastes merge in water body. The wastes from mine drainage also contribute a higher amount of sulfate through pyrite oxidation process. Therefore, the large amount of sulfate occurs in ground water. Very high level of sulfate may create a laxative effect in unaccustomed consumers [30,49,53,54,55]. The concentration of sulphate is possibly derived from dissolution process of gypsum salt. Generally, sulphate is a non toxic anion in water quality. Drinking water with higher amount of magnesium or sodium sulphates may cause intestinal discomfort, diarrhea, consequently dehydration and cathartic effect as described by Heizer et al. [56] and Zarei & Bilondi [57]. The laxative effect is most commonly felt by the people not accustomed to drinking water with amount of these chemicals [30,49]. Due to air pollution, the acid rain or snow with sulfur compounds flowed into water bodies and increase the sulphate contents. As per APHA, ion chromatographic method and capillary ion electrophoresis are applicable when sulfate concentration is > 1.0 mg/l, gravimetric method is suitable for the concentration > 10 mg/l and turbidimetric method is useful for 1 - 40 mg SO_4^{2-}/litre concentration [30]. According to BIS, the guideline values for sulfate are decided as 200-400 mg/l as DL and PL values [6].

2.8. Nitrate

Nitrate occurs in the environment as a part of the nitrogen cycle. Usually, the amount of nitrate remains low in groundwater and surface water. Nitrate is main inorganic fertilizer in agriculture. Thus, the leaching and runoff from agricultural field or contamination from domestic sewage and animal wastes as a result of the oxidation of ammonia contribute the nitrate content in to the aquatic system [43,49,58,59,60]. The amount of nitrate in water system is an indicator of degree of organic pollution [35,61,62]. The mobility of nitrate in ground water system is high due to its solubility and anionic form. Moreover, the concentration of nitrate in water body is largely varies from place to place and season to season depending on the precipitation received, soil type and mostly exceeded in growing season during a large application of nitrogenous fertilizers. Finally, it occurs in surface, sub-surface and ground waters [63].

Higher concentration of nitrate in drinking water is a serious health problem due to its conversion into nitrite and nitrite is very toxic in the digestive system of human infants. The nitrite is capable to oxidize the hemoglobin of the blood to methaemoglobin, which is unable to transport oxygen in the body. Methaemoglobinaemia i.e. blue-baby syndrome occurs in bottle-fed infants under 3 months of age after reduction of oxygen in their transport system of body when methaemoglobin concentration reaches 10% or more of normal methaemoglobin. Thus, methaemoglobinaemia creates cyanosis i.e. bluish discoloration of the skin and mucous membranes and also creates asphyxia at higher concentrations [49,64,65]. Higher quantity of nitrate create the risk of respiratory tract infections and goiter development in children [66,67], high probability of bladder and ovarian cancer, insulin dependent diabetes mellitus and genotoxic effect at chromosomal level [68], detrimental effects on pregnant women and babies less than six months old [69], digestive disorders [70] etc. The desirable limit of nitrate in drinking water is 45 mg/l with no relaxation for permissible limit [6].

Nitrate can be analyzed in water samples using ultra-violet method, ion chromatography, capillary ion electrophoresis as well as by using specific methods, which depends on the various concentration ranges of nitrate, like nitrate electrode method, cadmium reduction method, hydrazine reduction method etc. [30].

2.9. Iron

Iron as an essential element occurs in drinking water supplies. Normally, a slight concentration of iron is found in water but its chemical forms are not easily absorbable in human body. Rock weathering and galvanization of plumbing pipes are the main sources which are accountable to discharge the iron in water sources [71]. Hematite, taconite, magnetite, pyrite, goethite, and siderite are the major iron occurring minerals in the nature [14,30]. Usually, the groundwater possesses the iron in dissolved ferrous ion form which is not exposed to oxygen. Upon exposure to air, the dissolved ferrous ions change into the insoluble ferric state Fe^{3+} with a reddish brown to black rust formation in water sources [30].

Iron is helpful in human body systems like oxygen transport in blood, metabolism of neurotransmitters, DNA synthesis and oxidative phosphorylation. The major part of iron is present in hemoglobin, myoglobin, heme-containing enzymes etc. [72]. Though, iron itself is not a detrimental element, but USEPA [73] have considered iron as a secondary pollutant which causes disagreeable taste, color, odor, corrosion problem, foaming, or staining [74]. No treatment method has been found to be effective for all forms of iron. Idoko [75] reported that the long-term exposure of iron through drinking water may cause serious liver related diseases. Moreover, numerous women are facing the anemic condition due to poor bioavailability of nutritional iron. Iron insufficiency is the common disorder in childhood and pregnancy.

Various analytical methods like capillary electrophoresis (CE) [76], flame (FAAS) [77] and electrothermal atomic absorption spectrometry (ETAAS) [78], UV-Vis spectrophotometry [79], ICP and ion chromatography (IC) [80] and inductively coupled plasma-mass spectrometry (ICP-MS) [81] have been used for the determination of iron in different water samples. 0.30 mg/l value is the desirable limit as per BIS with no relaxation in permissible limit [6].

2.10. Calcium

Usually, drinking-water comes from surface sources like streams, lakes, rivers, from groundwater sources like wells or directly from rain. In nature, the calcium occurs in water supplies in the form of calcite (Calcium carbonate), dolomite (Calcium magnesium carbonate), gypsum, gypsiferous shale etc. Besides this, calcium compounds after application in pharmaceuticals, photography, lime, de-icing salts, fertilizers, pigments etc. move towards the fresh water resources through drainage and runoff [30]. Some advanced techniques like desalination, melting of ice, recovery of used water by membranes have also been employed for drinking water purposes. Several epidemiological investigations on the possible associations between the risk of gastrointestinal tract cancers and minerals in drinking-water, in particular hardness, have been well reported [82]. Commonly, calcium occurs in water due to leaching of calcium rich mineral rocks i.e. lime stone or mineralization of organic matter by the bacteria. Studies showed that in similar geographical locations, the mineral contents can vary markedly for groundwater system. Besides, different geographic and anthropogenic factors also affect the calcium amount in drinking water [83]. The amount of calcium in natural water bodies occurs due to various geographical structures. The calcium is a significant determinant of water hardness and functions as a pH stabilizer due to its buffering nature. Calcium is an essential element for human body specially for bones, teeth, soft tissues and in numerous metabolic activities of the body [84]. Trivedy and Goel [85] explained that the calcium ion in natural water usually varies from 10 – 100 mg/l depending on rock type of the areas. The long term ingestion of calcium might increase the blood calcium level i.e. creates the problem of hypercalcemia [4,86] while, insufficient ingestion of calcium increased the risks of osteoporosis, nephrolithiasis, colorectal cancer, coronary artery disease, insulin resistance hypertension, stroke etc. [82]. The DL and PL guideline values for calcium in drinking water are provided as 75-200 mg/l by BIS [6].

Atomic absorption spectrometric method and inductively coupled plasma method are useful methods for the determination of calcium in fresh water samples [11,24,26,28,29,30]. EDTA titrimetric method is also useful for calcium determination in water samples [11,24,26,28,29,30]. Reverse osmosis, electrodialysis, ion exchange method and chemical softening treatment are useful methods for calcium reduction in fresh water samples [30].

2.11. Magnesium

Importantly, magnesium is an essential element which occurs in chlorophyll and RBCs. Besides this, magnesium in general occurs in all kinds of natural water along with calcium. Though, its concentration remains usually lesser than the amount of calcium. Large amount of magnesium in drinking water may be attributed due to minerals such as dolomite, magnesite in many sedimentary rocks [30,44,82]. In addition, magnesium also comes from fertilizer, alloys, flash photography, drying agents, pharmaceuticals etc. Magnesium sulphate is used in beer breweries, while magnesium hydroxide is applied as a flocculant in waste water treatment plants. Calcium and magnesium play important roles in bone structure, muscle contraction, nerve impulse transmission, blood clotting and cell signaling [82]. The DL and PL limits are 30 and 100 mg/l as per BIS, respectively [6].

Concentration of magnesium in drinking water more than 125 mg/l may creates cathartic and diuretic problems [30]. The high concentration of magnesium in drinking water creates the irregular heartbeat, low blood pressure, slow breathing, and death whereas the low concentration of magnesium is associated with hypertension, metabolic syndrome, increased vascular reactions, coronary heart disease, type 2 diabetes mellitus etc. Besides this, the deficiency of magnesium affects the neurological and neuromuscular function of the body which results into anorexia, muscular weakness, lethargy and unsteady gait [82]. Atomic absorption spectrometric method and ICP-MS are useful methods for the analytical determination of magnesium in fresh water samples [11,24,26,28,29,30].

2.12. Fluoride

Generally, Fluoride occurs in surface and ground water sources due to geological, industrial and other anthropogenic developmental activities. The water sources are connected with various types of rocks, volcanic activities, industrial and agricultural activities which are directly responsible for fluoride amount in groundwater. Crystalline rocks, sedimentary rocks, and metamorphic rocks increase the fluoride concentration in groundwater system [12,87]. Although, lower fluoride concentration is necessary for the proper development of bones and teeth but higher fluoride concentration in drinking water creates the problem of fluorosis in humans. Several studies have established that ingestion of drinking water having high fluoride concentrations causes severe health troubles such as dental and skeletal fluorosis [12,88,89,90]. BIS [6] and WHO [4] have decided the standard limit of fluoride concentration in drinking water as 1.5 mg/L (maximum).

Colorimetric i.e. SPADNS technique is the popular method of fluoride determination in fresh water and waste water samples in laboratories among many available methods [12,30]. Besides SPADNS method, Ion Selective Electrode Method [91], Spectrophotometric determination [26], Ion Chromatography [92], High-performance liquid chromatography with hydride generation-atomic fluorescence spectrometry [93], High-performance liquid chromatography-inductively coupled plasma mass (ICP) spectrometry [94], Non-chromatographic hydride generation-atomic fluorescence spectrometry [24] etc. were also reported for fluoride determination.

2.13. Arsenic

Arsenic occurs in nature in the form of sulfide minerals like pyrite. The alloys of arsenic with lead are being used in storage batteries, and ammunition [30]. Arsenic is a very toxic and broadly scattered metal in nature. It occurs in the form of inorganic as well as organic compounds. In natural water, toxic metal arsenic comes from the natural minerals and other chemical compounds such as insecticides and herbicides due to weathering of the arsenic containing minerals and anthropogenic activities. It has been reported that Bangladesh ranked first throughout the world for arsenic pollution in drinking water followed by India and China. Reports [95,96] have explained that arsenic species come into water system mainly through pesticides, industrial effluents, wood preservative agents and mining activities. Normally, the inorganic arsenic species may be present in unpolluted fresh water in the form of arsenate and arsenite but organic arsenic compound usually does not occur in unpolluted fresh water [30]. Various forms of arsenic show different chemical and toxic properties. APHA [30] and Samanta et al. [97] explained the descending toxicity order of different arsenic species as AsH_3 >Arsenite > Arsenate > organic acids of arsenic.

The arsenic compounds are responsible for many types of health diseases like keratosis, skin lesions, bladder cancer and lung cancer [30,95,98]. Suzuki and his research group [99] have reported that the effects of inorganic arsenic species on the bladder of rats and mice after intake of arsenic contaminated water. In India, the skin troubles in West Bengal state have been occurred due to arsenic contamination in drinking water [10]. USEPA [98] has decided the 10 ppb standard limit for arsenic in drinking water.

The electrothermal atomic absorption spectrometric method was found as suitable method for the determination of arsenic in the absence of interferences in natural water samples but hydride generation-atomic absorption method was found as method of choice when interferences were present in natural water samples. The ICP-emission spectroscopic method is appropriate for high concentration of arsenic (>50 µg/l) whereas ICP-MS method is helpful for lower amount of arsenic if chloride interference is absent [30]. BIS limits for total arsenic in drinking water are 0.01 and 0.05 mg/l [6].

2.14. Chromium

In natural deposits, chromium may occur in the form of complex cubic isomorphic minerals. Chromite ($FeCr_2O_4$) is the most common chromium-containing mineral. Usually, chromium occurs in two oxidation states in environment i.e. trivalent and hexavalent forms of chromium. Cr(III) form is the most stable form of chromium. In natural waters, Cr(III) occurs in the form of Cr_3^+, $Cr(OH)^{++}$, $Cr(OH)_2^+$, and $Cr(OH)_4^-$ whereas Cr(VI) exists as CrO_4^{2-} and $Cr_2O_7^{2-}$ [30]. The researchers [100,101,102] have reported that Cr (VI) is highly soluble and mobile in alkaline, oxic groundwater as well as its contamination may extend for a long distance with only limited decrease in concentration. Chromium has a wide range of industrial applications and is being used in alloys, electroplating and pigments. Cr(VI) has been found as harmful even in small ingestion quantity while Cr(III) form has been considered necessary for health. According to International Agency for Research on Cancer [103], the people residing nearby to anthropogenic sources of Cr(VI) may be exposed with the inhalation of Cr(VI) contaminated ambient air or ingestion of Cr(VI) contaminated drinking water. Chromium (VI) is very hazardous for the people who work in steel, textile industries. Main, health troubles due to Cr(VI) are skin rashes, ulcers in stomach, respiratory problems, weakened immune systems, kidney and liver damage, alteration of genetic material, cancer etc. [30,103]. The electrothermal atomic absorption spectrophotometric method has been found as suitable for the lower level detection of total chromium i.e. for < 50 µg/l while flame atomic absorption spectrophotometric and inductively coupled plasma techniques were reported for the determination of total chromium upto mg/l level in natural water samples. Furthermore, the colorimetric and ion chromatographic methods were also found suitable for hexavalent chromium determination in natural water and waste water samples [30]. The desirable value of total chromium in drinking water is 0.05 mg/l with no relaxation in permissible limit [6].

2.15. Microorganisms/Pathogens in Drinking Water

Communicable diseases due to pathogenic bacteria, viruses and parasites related with drinking-water have become very common. Waterborne pathogens may cause acute and also chronic health problems. The exposure of pathogens through drinking water mainly depends upon the dose, invasiveness, virulence of the pathogen as well as the immunity condition of the people [4,44]. The contamination of drinking water occurs due to the pathogens which have diverse properties, behavior and resistance also. According to WHO report [4,44], various pathogens such as bacteria, viruses, protozoa, helminthes, transmitted through drinking-water has been summarized as below:

Bacteria	**Viruses**	**Protozoa**	**Helminths**
Burkholderia pseudomallei	Adenoviruses	*Acanthamoeba* spp.	*Dracunculus medinensis*
Campylobacter jejuni, C. coli	Astroviruses	*Cryptosporidium hominis/parvum*	*Schistosoma* spp.
Escherichia coli – Pathogenic	Enteroviruses	*Cyclospora cayetanensis*	
E. coli – Enterohaemorrhagic	Hepatitis A virus	*Entamoeba histolytica*	
Francisella tularensis	Hepatitis E virus	*Giardia intestinalis*	
Legionella spp.	Noroviruses	*Naegleria fowleri*	
Leptospira	Rotaviruses		
Mycobacteria (nontuberculous)	Sapoviruses		
Salmonella Typhi			
Shigella spp.			
Vibrio cholerae			

2.15.1. Coliform Contamination

Coliform is usually occurred in the environment. The density of coliform group specially fecal coliform or *E. coli* bacteria represent the degree of pollution and finally the sanitary quality of water as well as the effectiveness of water treatment process. Besides the analysis of coliform indicators such as total coliform, fecal coliform and *E. coli*, some other microbial indicators as fecal streptococci, enterococci, *Clostridium perfringens*, *Aeromonas* have also been proposed as the indicators of drinking water quality [30].

Many waterborne diseases like diarrhea, dysentery, typhoid etc. may occur due to the contaminated water with bacteria, intestinal parasites, viruses and other harmful microorganisms [104]. Numerous researchers have established that drinking water polluted with human waste results into various waterborne diseases like diarrhea, dysentery, typhoid, nausea, gastroenteritis and hepatitis [105,106,107]. According to a WHO report [108], hazardous drinking water due to poor sanitation and hygiene is the main factor to several billion cases of diarrheal disease per annum. According to BIS, coliform contamination should be absent in drinking water [6].

2.15.1.1. Fecal Coliform

The fecal coliform, which is a group of bacteria, may occur in ambient water as a result of the overflow of untreated domestic sewage or nonpoint sources of human beings and waste of animals indicating the presence of sewage contamination into a water channel [109,110]. In addition, some practices like washing of animal waste into adjacent streams, livestock bathing in streams, dispersal of manure and fertilizer in the agricultural fields in monsoon periods can all contribute fecal coliform contamination in water bodies. The FC does not directly cause disease, but its high numbers indicate the presence of disease-causing agents. The utilization of FC polluted water may lead intestinal illness in users. Fecal streptococci and enterococci are also the indicator of fecal pollution in drinking water [30].

2.15.1.2. Total Coliform

Total coliform bacteria comprise a broad series of aerobic and facultative anaerobic, Gram-negative, non-spore-forming bacilli which are able to grow in the presence of *Escherichia coli* bacteria. Sewage, natural water, surrounding environment, leakages in water distribution pipes are main sources of Total coliform (TC) in water as per WHO [4,44]. Besides this, the some anthropogenic sources including agricultural run-off, effluent of septic or sewage discharges, infiltration of fecal matter of domestic or wild animal, etc. are also responsible for the total coliform contamination in surface and ground water both [4,44]. The occurrence of total coliforms in supply systems and in stored water discloses the regrowth and possible bio-film formation or contamination. The water borne diseases due to total coliform bacteria include gastrointestinal illness. However, USEPA has also told that the presence of total coliform in drinking water is a possible health concern. The report [111] reveals that the transmission of various pathogens causing water-borne diseases like diarrhea, cramps nausea and possibly jaundice etc., is associated with the ingestion of contaminated drinking water.

Thus, Bureau of Indian Standard [6] has fixed the guidelines that the fecal coliform and total coliform should be absent in drinking water and the presence of these organisms indicates inadequate treatment of water. Therefore, coliform bacteria should be absent instantaneously after disinfection of drinking water. Multiple tube dilution and membrane filter techniques are the main coliform detection methods in drinking water samples [30].

3. Conclusion

After the thorough study of various water quality parameters specially drinking water quality parameters, it is recognized that the human health is directly associated with it. The students and community people should be educated and aware about the water quality issues. There should be the knowledge that how the water quality problems may be combated i.e. the education on prevention of pollution, suitable water treatment processes, use of waste water after proper treatment, environment protection specially ecosystem etc. The students and community people may play an important role for the awareness about drinking water quality in society.

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