Defence Life Science Journal, Vol. 01, No. 2, September 2016, pp. 113-126, DOI : 10.14429/dlsj.1.10739

REVIEW PAPER

Emerging Potable Water Technologies

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ABSTRACT

Water is essential to keep up life, especially safe drinking water is one of the first priorities. As water quality is important, many nations endeavor to guard the water and to increase access to potable water. Fortification of water supplies from contamination is the earliest stripe of defence. Water purification is very important aspect, presently there are number of drinking water technologies available mostly based on ion exchange, ultra filtration and reverse osmosis techniques, but still about five million people die annually from water born diseases. The objective of this review is to provide direction on the chemical safety of drinking-water and also monitoring of chemicals in drinking-water. Water treatment potential technologies can solve diverse drinking water issues in case of chemical contamination, which is the second objective. The purpose of this review is to make survey of currently available and future emerging technologies for drinking water. Several purification techniques have been adopted to meet the standards. There is a necessity of wide-ranging global approach to tackle the problem of water pollution devastating thousand of lives annually rather than to develop nuclear and biological weapons. This document will also be useful to public health authorities, those responsible for setting standards and for surveillance of drinking-water quality, and to water supply agencies responsible for water quality management.

Keywords: Water quality, water born pathogens, water purification technologies, waste water treatment

1. INTRODUCTION

Water is an essential resource for life on earth and available freshwater resources are emerging as a limiting factor not only in quantity but also in quality for human development and ecological stability in a growing number of locations. Securing adequate freshwater quality for both human and ecological needs is thus an important aspect of integrated environmental management and sustainable development[1]. The world is facing a global water crisis. Already, deficiencies in water supply and water quality are causing widespread human sufferings. About 1.1 billion people lack access to clean water, and 2.6 billion do not have access to improved sanitation facilities. Everyday, 4500 children throughout the world die from escapable diseases caused by the lack of clean water and sanitation. China, India, and the United States are all facing major shortages of freshwater, and water pollution is having serious impacts on public health and the environment in both China and India. Major investments in science and technology are required to address the water issues of the future. A new generation of innovative, small-scale technologies is needed to prevent and control pollution and to restore watersheds. Creative, collaborative approaches to addressing the world's decline in freshwater resources are urgently needed[2].

Of the 326 million cubic miles of water on earth, only about 3 per cent of it is fresh water; and 3/4 of that is frozen. Only 1/2 of 1 per cent of all water is underground; about 1/50th of 1 per cent of all water is found in lakes and streams. Water is absolutely vital for sustaining the life of living beings. Just like the surface of the Earth, major constituent of human body is water. The average adult contains 40 quarts to 50 quarts of water. The water in our body must be renewed every 10-15 days. With the intake of foods such as fruits and vegetables, we are receiving water, even then it is required to drink at least 6 glasses of water daily to enable our body to function properly; water is the base for all physical functions.

Water is generally classified into two groups: Surface water and ground water. Surface water is a general term describing any water body that is found flowing or standing on the earth's surface, such as streams, rivers, ponds, lakes and reservoirs[3]. This water is usually not very high in mineral content, and many times it is called soft water. Surface water is exposed to many different contaminants, such as animal wastes, pesticides, insecticides, industrial wastes, algae and many other organic materials. Even surface water found in a pristine mountain stream possibly contains Giardia or Coliform from the fecal materials. Ground water is defined as all sub-surface water including soil water, deeper vadose zone water, and unconfined and confined aquifer waters[4]. This water is trapped beneath the ground. Because of the many sources of recharge, ground water may contain any or all of the contaminants found in surface water as well as the dissolved minerals. Most water resources models focus explicitly on water systems and represent socio-economic and environmental changes as external drivers[5]. Potable/Drinking water is water of sufficiently high quality

Received : 13 May 2016, Revised : 27 August 2016
Accepted : 04 September 2016, Online published : 07 October 2016

that it can be consumed or used without risk of immediate or long term harm. Source protection is almost invariably the best method of ensuring safe drinking-water. These improved drinking water sources include household connection, public standpipe, borehole condition, protected dug well, protected spring, and rain water collection. Sources that don't encourage improved drinking water includes: Unprotected wells, spring, rivers or ponds, vender-provided water, bottled water (consequential of limitations in quantity, not quality of water), and tanker truck water.

Over large parts of the world, humans have inadequate access to potable water and use sources contaminated with disease vectors, pathogens or unacceptable levels of dissolved chemicals or suspended solids. Such water is not potable and drinking or using such water in food preparation leads to widespread acute and chronic illnesses and is a major cause of death in many countries. To provide drinking water to the affected population (AP) is a challenge due to severe contamination and lack of access to infrastructure but availability in different country[6]. An onsite treatment system for the AP is a more sustainable solution than transporting bottled water[7]. Keeping purification tablets on hand in an emergency preparedness kit is also an excellent idea. After major storms and hurricanes, citizens should wait to be assured that their water is potable, in case sewage pipes have ruptured and contaminated the water supply. In developing nations, many non-governmental organisations (NGOs) are working to improve water quality conditions, along with other basic sanitation. Unfortunately, even in areas where the water is known to be unsafe, people may drink it anyway, out of desperation. Boiling water may not remove heavy/ heavy metal contaminants, but it can neutralise most bacteria and viruses which may be present. Water can also be treated with chemicals such as bleach, which sometimes come in the form of tablets for field and camping use.

2. WATER POLLUTION

Water is the universal solvent; it picks up particles and minerals from the air in the form of rain. As soon as, it hits the ground it captures minerals from the soil and rock upon which it lands. It makes its way into streams and rivers, carrying soil from the mountains to the sea. Water pollution is a leading cause of death worldwide, and transmits or supports numerous debilitating diseases to populations forced to drink contaminated water. As of today, some 1.1 billion planetary inhabitants do not have access to clean drinking water, and 2.6 billion do not have sanitation services[8]. Chemicals in water used for drinking or bathing result in direct exposure to humans and, if doses of chemicals derived from these activities are sufficiently high; these exposures can lead to toxic effects. Chemical contamination of groundwater has occurred as a result of poor chemical disposal practices in the past or the leaking of storage vessels such as underground tanks and landfills[9]. Several recent studies have revealed that emerging pathogens or chemicals (e.g., viruses, algal toxins, disinfection by products) may be present in natural or treated water bodies. These emerging contaminants, which have not historically been considered as pollutants, have now become prominent agents of concern to public health specialists and environmental engineers and scientists[10].

In this chapter, a very brief overview is given of our present knowledge about the presence of emerging pollutants and micro-pollutants in the aquatic environment[11]. Nitrogen and phosphorus are the two main plant nutrients acting as polluting agents. If plant nutrients get into water, they stimulate the growth of algae and other water plants. When these plants die and decay, they consume oxygen, just like any other organic waste. The excess plant growth caused by fertilisation and subsequent build up of dead plant matter is called eutrophication. If the oxygen level drops even a small amount, desirable species of fishes, such as trout and bass, will be replaced by less desirable species such as carp and catfish. If the oxygen level drops low enough, all species of fishes, crayfishes, shrimp, and other organisms may die.

Demand for water is growing at an alarming rate since the water lable is diminishing day by day. India's water crisis is predominantly a manmade problem. India's climate is not particularly dry, nor it lacks water bodies viz., rivers, lakes and streams.

2.1 Organic Pollutant

Organic waste comes from domestic sewage, agricultural runoff, feedlot operations, and industrial waste of animals and plants origin, such as from a paper mill. Domestic sewage is the largest and most wide spreaded source of organic waste. Bacteria can efficiently break down organic waste. However, bacterial action also removes oxygen from the water. Because fishes and other forms of aquatic life depend on dissolved oxygen, the bacterial action necessary to break down the waste damages the aquatic environment. If organic waste consumes oxygen at a rate greater than it can be replenished, then anaerobic bacteria dominate the decay process. Anaerobic decomposition by bacteria is smelly and aesthetically unpleasant. Emerging organic contaminants (EOCs) detected in groundwater may have adverse effects on human health and aquatic ecosystems[12]. The presence of these synthetic chemicals adversely affects fishes and other aquatic life. Many researchers think that some synthetic chemicals mimic natural hormones, disrupting growth and reproductive cycles in affected populations.

Organic water pollutants include: detergents, disinfection by-products, food processing waste, which can include oxygen-demanding substances, fats and grease, insecticides and herbicides, a huge range of organohalides and petroleum hydrocarbons and chemical warfare agents (CWAs).

Chemical warfare agent is a substance which is intended for use in military operations to kill, seriously injure or incapacitate people because of its highly poisonous and physiological effects. Common examples are nerve agents, sulphur mustard, cyanides and phosgene. These agents either prevent the normal functioning of the humans or may cause death depending upon the extent of exposure. Two most important classes are:

(a) Sulphur mustard: It is a blister agent causing blisters on skin after exposing to living beings[13]. The blisters are very aching like thermal burns and takes more time to heal and can propel the body into a mortal shock condition. These agents on inhalation affect upper respiratory tract as well as the lungs and producing pulmonary edema.

(b) Nerve agents: Basically these are organic phosphorous compounds. They affect the central nervous system. Nerve agents are thousand times more lethal than blister agents. They are hazardous in their liquid and vapour states and can cause death within minutes after exposure to skin, eyes and lungs. These agents first were developed by the German scientists in 1930[14].

2.2 Inorganic Chemicals

The most common ions as dissolved inorganic water contaminants or impurities are: Ca^{++}, M_g^{++}, Na^+, Fe^{++}, Mn^{++}, HCO_3^{--}, Cl^-, SO_4^{--}, NO_3^-, CO_3^{--}, PO_4^{---} and heavy metal ions. These electrically charged dissolved particles make ordinary natural water, a good conductor of electricity. Conversely, pure water has a high electrical resistance, and resistance is frequently used as a measure of its purity.

2.2.1 Arsenic

Arsenic toxicity is a significant threat to human health. Arsenic contamination of ground water has been found to cause adverse effects on human body at levels as low as 0.01 mg/L. Over a period of weeks, it causes skin lesions, peripheral neuropathy and anemia, lung and skin cancer. Long term ingestion causes Gangreen of the extremities; black foot disease. As (III) is regarded to be more toxic in comparison to As (V) because of its solubility and mobility.

2.2.1 Asbestos

Six minerals have been characterised as asbestos: chrysotile, crocidolite, anthophyllite, tremolite, actinolite and amosite. Asbestos is commonly found in domestic water supplies through pipes. It causes carcinogenicity.

2.2.3 Barium

Barium is present in the earth's crust in a concentration of 0.50 g/Kg and the mineral barytes, and barium sulphate are the commonest sources.

2.2.4 Beryllium

Beryllium can enter the water system through weathering of rocks in ground aquifers, atmospheric fallout on rain water collection systems and industrial and municipal discharges.

2.2.5 Selenium

Dietary selenium levels of 5 mg/kg of food or more may cause chronic intoxication.

2.2.6 Manganese

Long term ingestion of manganese toxicants affect the central nervous system and this leads to death. Manganese toxicity has been found to result in acute effects on lungs, liver, central nervous system, and blood circulatory system of the body.

2.2.7 Nickel

Nickel is present in the effluents of silver refineries, electroplating, zinc base casting and storage battery industries. Higher concentration of nickel causes cancer of lungs, nose and bone.

2.2.8 Zinc

Zinc is mainly used in the process of galvanisation of iron, manufacturing of zinc white and several useful alloys such as brass, German silver, delta metal. Long term ingestion of zinc causes gastrointestinal distress and diarrhea.

2.2.9 Silver

The levels of silver in drinking water should not exceed 1 ppb. In industry, silver is used in the manufacturing of various silver based chemicals.

2.2.10 Mercury

Environmental contamination caused by mercury is a serious problem worldwide. Mercury can also enter into the living being through food chain and accumulate into the body in larger extent. The major sources of mercury pollution in environment are industries. Methyl mercury causes deformities in the off springs, mainly affecting the nervous system (teratogenic effects). It is responsible for mental retardation in children, cerebral palsy and convulsions. Mercury also brings about genetic defects causing chromosome breaking and interference in cell division, resulting in abnormal distribution of chromosome.

2.2.11 Cyanide

Cyanide is a common name for compounds containing the cyanide group (-C≡N). Cyanide most commonly occurs as hydrogen cyanide and its salts such as sodium and potassium cyanide. Cyanide is released into the environment from numerous sources including both man-made and natural. Free cyanides are quickly absorbed by inhalation, ingestion, or contact with the skin. It is then bound to a cytochrome oxidase enzyme involved in respiration and thus inhibits the ability of cells to use oxygen.

2.2.12 Per Chlorate

Per chlorate is not only a known health hazard for humans but also one of the persistent inorganic pollutants. Regrettably, there is no single technology that is perfect for complete perchlorate removal or reduction, although correlative studies are still in process[23].

2.2.13 Fluoride

Consumption of excess fluoride in water may causes dental fluorosis or tooth decay if the level of fluoride is below than 0.5 ppm. Fluoride contamination in groundwater may be (i) Manmade: through industry, (ii) Natural: by dissolving rocks having fluorite, appatite and cryolite.

2.2.14 Oil Pollution

Oil pollution can enter water through bilge flushing, from accidental or deliberate discharge from ships, or from accidental spills of crude oil during transport. Water polluted by oil greatly damages aquatic life and other wildlife such as birds that depend on the water for food and nesting areas.

2.2.15 Radioactive Materials

Radioactive waste comes from: a) the mining and processing of radioactive ores, b) the refining of radioactive materials, c) the industrial, medical, and research uses of radioactive materials, and d) nuclear-powered reactors. The two most common radioactive materials found in water are strontium-90 and radium-226.

3. STANDARDS OF POTABLE WATER

Water-testing standards are available for the determination of various conventional parameters, the quantification of inorganic or organic water ingredients, microbiological examination, biodegradability or ecotoxicity testing, and for ecological and morphological assessment of water bodies. It mainly focuses on the activities of the European Committee for Standardisation (CEN) and the International Organisation for Standardisation (ISO) in this field. Principles and procedures of standardisation are outlined. Important issues here are validation of methods and estimation of variability of results[15]. Drinking-water supply and quality both have important impacts upon health and socio-economic development and therefore, remain important components of the poverty cycle[16].

3.1 Permissible Limits

As shown in Table 1.

3.2 WHO's Guidelines

For drinking-water quality, setup in Geneva, 1993, are the International Standard for drinking-water safety as mentioned in Table 2.

4. TECHNOLOGIES FOR DETECTION AND IDENTIFICATION

Water to be used for drinking and cooking must be of high quality. It must meet or exceed the bacteriological and chemical requirements of Indian Standards, both the EPA Interim Primary and Secondary Drinking Water Regulations, WHO standards, etc. Only 1/2 of 1 per cent (0.875 gallons per person per day) of the total water supplied 175 gallons per person per day by a community is used for drinking and cooking purpose. The remaining amount (over 174 gallons per person per day) is used for a variety of purposes such as sprinkling lawns and irrigation, flushing toilets, fighting fires, cleaning streets, as well as utility commercial and industrial uses within the community. Of course, many commercial establishments (laundries, beauty salons, car washes, etc.), industries (for rinsing and specific processes), and institutions (hospitals, for example for laboratory use, hemodialysis, etc.) will want to provide extremely high quality water of different types for specific applications at the point of use.

4.1 Qualitative Detection

Different qualitative parameters of water samples (waste and potable) that includes the physical parameters (TDS, pH, color, turbidity, specific conductance) and chemical parameters (BOD, COD, DO, Metal ion concentration.) were measured using the available standard methods in the laboratory. Comparison of the caboratory treated water with the International Standard Potable water (World Health Organisation Standard, WHO) as well as with the raw waste water are also included to get a good effective representation of the study.

The aim of this review is to examine methods currently in use or which can be proposed for the monitoring of coliforms in drinking water. This review shows that even though many innovative bacterial detection methods have been developed, a few of the methods have the potential for becoming standardised methods for the detection of coliforms in drinking water samples[17].

The key to continuing improvements in environmental quality is the availability of precise information that is representative of the quality of water bodies. These include sensors, field test kits, passive samplers, biological early warning systems, biomarkers, and ecological indices. It is important that further work is carried out to demonstrate the utility and reliability of these emerging tools in laboratory and field trials alongside classical methods. This will be necessary to provide regulators with a range of well characterised tools to enable them to select the most appropriate solution for any specific applications[18].

The concentrations of the toxic metals like arsenic, cadmium, lead, barium, chromium, cyanide were decreased significantly during the laboratory treatment and the values of their final concentration were found to be within the permissible limit.

4.2 Quantitative Detection

Water samples from a local water treatment plant were analysed, using gas chromatography Fourier transform ion cyclotron resonance mass spectrometry (GC/FT−ICR MS), to identify potential disinfection byproducts (DBPs). Both liquid−liquid extraction (LLE) and solid-phase microextraction (SPME) techniques were used for sample preparation prior to GC/MS analyses[19].

Quantitative microbial risk assessment (QMRA) is increasingly applied to estimate drinking water safety. In QMRA the risk of infection is calculated from pathogens concentrations in drinking water, water consumption and dose response relations. Pathogens concentrations in drinking water are generally low and monitoring provides little information for QMRA. Therefore, pathogen concentrations are monitored in the raw water and reduction of pathogens by treatment is modelled stochiometrically with Monte Carlo simulations.

4.3 Online Drinking Water Quality Monitoring

This review covers the most recent advancements occurred in the areas of on-line SPE–LC–MS and biosensors, discusses and compares the main strengths and limitations of the two approaches, and examines their most relevant applications to the analyses of emerging contaminants in environmental waters. Biosensors are, in addition, relatively cheap and fast, which make them ideally suited for routine testing and screening of samples; however, in most cases, they can not compete yet with on-line SPE procedures in terms of accuracy, reproducibility, reliability (confirmation) of results, and capacity for multi-analytes determination[20].

Table 1. Drinking Water Specification: IS: 10500, 1992 (Reaffirmed 1993)

Sl. No.	Parameter	Desirable limit	Undesirable effect outside the desirable limit	Permissible limit in the absence of alternate source
1.	pH	6.5 – 8.5	Affect the mucous membrane and or water supply system	No relaxation
2.	Colour (Hazen Unit)	5	Consumer acceptance decreases	25
3.	Odour	Unobjectio-nable		
4.	Taste	Agreeable		
5.	Turbidity (NTU)	5	Consumer acceptance decreases	10
(in mg/L)				
6.	Total hardness as $CaCO_3$	300	Encrustation in water supply structure and adverse effects on domestic supply	600
7.	Iron as Fe	0.30	Affect taste and appearance, adverse effect on domestic uses and water supply structures and promotes iron bacteria.	1.0
8.	Chlorides as Cl^-	250	Affect taste , corrosion, and palatability	1000
9.	Residual (Free Chlorine)	0.20		
Desirable characteristics				
10.	Dissolved solids	500	Palatability decreases & may cause gastro intestinal irritation	2000
11.	Calcium as Ca	75	Encrustation in water supply structure & adverse effects	200
12.	Magnesium as Mg^{++}	30	--	100
13.	Copper as Cu^+/Cu^{++}	0.05	Astringent taste, discoloration and corrosion of pipes and fittings	1.5
14.	Manganese as Mn^{++}	0.1	Affect taste and appearance, adverse effect on domestic uses and water supply structures	0.3
15.	Sulphate as SO_4^{--}	200	Gastro intestinal irritation when magnesium and/or sodium are present	400
16.	Nitrates as NO_3^-	45	methanemoglobinemia takes place	100
17.	Fluoride as F^-	1.0	High fluoride may cause fluorosis	1.5
18.	Phenolic compounds as C_6H_5OH	0.001	Objectionable taste & odour	0.002
19.	Mercury as Hg^{++}	0.001	Water becomes toxic	No relaxation
20.	Cadmium as Cd^{++}	0.01	Water becomes toxic	No relaxation
21.	Selenium as Se^{++}	0.01	Water becomes toxic	No relaxation
22.	Arsenic as As^{+++}	0.05	Water becomes toxic	No relaxation
23.	Cyanide as CN^-	0.05	Water becomes toxic	No relaxation
24.	Lead as Pb^{++}	0.05	Water becomes toxic	No relaxation
25.	Zinc as Zn^{++}	5	Astringent taste & an opalescence in water	15
26.	Anionic detergents as MBAS	0.2	A light froth in water	1.0
27.	Chromium as Cr^{6+}	0.05	Carcinogenic	No relaxation
28.	Ploynuclear aromatic hydrocarbons as PAH	--	May be carcinogenic	--
29.	Mineral Oil	0.01	Undesirable taste and odour after chlorination take place	0.03
30.	Pesticides	Nil	Toxic	0.001
31.	Radioactive materials a) α emitters Bq/1, Max b) β emitters Pci/1	----	----	0.1/Lit
32.	Alkalinity	200	Taste becomes unpleasant	600
33.	Aluminum as Al^{+++}	0.03	Cause dementia	0.2
34.	Boron asB^{+++}	1	--	5

Table 2. WHO's Guidelines

Element/ substance	Symbol / formula	Normally found in fresh /surface / ground water	WHO guidelines
Aluminium	Al		0.2 mg/l
Ammonia	NH_4	< 0.2 mg/l (upto 0.3 mg/l in anaerobic	No guideline
Antimony	Sb	< 4 µg/l	0.005 mg/l
Arsenic	As		0.01 mg/l
Asbestos			No guideline
Barium	Ba		0.3 mg/l
Berillium	Be	< 1 µg/l	No guideline
Boron	B	< 1 mg/l	0.3 mg/l
Cadmium	Cd	< 1 µg/l	0.003 mg/l
Chloride	Cl		250 mg/l
Chromium	Cr^{+3}, Cr^{+6}	< 2 µg/l	0.05 mg/l
Colour			Not mentioned
Copper	Cu		2 mg/l
Cyanide	CN^-		0.07 mg/l
Dissolved oxygen	O_2		No guideline
Fluoride	F^-	< 1.5 mg/l (up to 10)	1.5 mg/l
Hardness	mg/l $CaCO_3$		No guideline
Hydrogen sulfide	H_2S		No guideline
Iron	Fe	0.5 - 50 mg/l	No guideline
Lead	Pb		0.01 mg/l
Manganese	Mn		0.5 mg/l
Mercury	Hg	< 0.5 µg/l	0.001 mg/l
Molybdenum	Mb	< 0.01 mg/l	0.07 mg/l
Nickel	Ni	< 0.02 mg/l	0.02 mg/l
Nitrate and nitrite	NO_3, NO_2		50 mg/l total N_2
Turbidity			Not mentioned
pH			No guideline
Selenium	Se	< 0.01 mg/l	0.01 mg/l
Silver	Ag	5 – 50 µg/l	No guideline
Sodium	Na	< 20 mg/l	200 mg/l
Sulfate	SO_4		500 mg/l
Inorganic tin	Sn		No guideline
TDS			No guideline
Uranium	U		1.4 mg/l
Zinc	Zn		3 mg/l

Organic Compounds: Pesticides		Formula	WHO guidelines
Alachlor		$C_{14}H_{20}ClNO_2$	20 µg/l
Aldicarb		$C_7H_{14}N_2O_4S$	10 µg/l
Aldrin and dieldrin		$C_{12}H_8Cl_6$ / $C_{12}H_8Cl_6O$	0.03 µg/l
Atrazine		$C_8H_{14}ClN_5$	2 µg/l
Bentazone		$C_{10}H_{12}N_2O_3S$	30 µg/l
Carbofuran		$C_{12}H_{15}NO_3$	5 µg/l
Chlordane		$C_{10}H_6Cl_8$	0.2 µg/l
Chlorotoluron		$C_{10}H_{13}ClN_2O$	30 µg/l
DDT		$C_{14}H_9Cl_5$	2 µg/l
1,2-Dibromo-3-chloropropane		$C_3H_5Br_2Cl$	1 µg/l
2,4-Dichlorophenoxyacetic acid (2,4-D)		$C_8H_6Cl_2O_3$	30 µg/l
1,2-Dichloropropane		$C_3H_6Cl_2$	No guideline
1,3-Dichloropropane		$C_3H_6Cl_2$	20 µg/l
1,3-Dichloropropene		$CH_3CHClCH_2Cl$	No guideline
Ethylene dibromide (EDB)		$BrCH_2CH_2Br$	No guideline
Heptachlor and heptachlor epoxide		$C_{10}H_5Cl_7$	0.03 µg/l
Hexachlorobenzene (HCB)		$C_{10}H_5Cl_7O$	1 µg/l
Isoproturon		$C_{12}H_{18}N_2O$	9 µg/l
Lindane		$C_6H_6Cl_6$	2 µg/l
MCPA		$C_9H_9ClO_3$	2 µg/l
Methoxychlor		$(C_6H_4OCH_3)_2CHCCl_3$	20 µg/l
Metolachlor		$C_{15}H_{22}ClNO_2$	10 µg/l
Molinate		$C_9H_{17}NOS$	6 µg/l
Pendimethalin		$C_{13}H_{19}O_4N_3$	20 µg/l
Pentachlorophenol (PCP)		C_6HCl_5O	9 µg/l
Permethrin		$C_{21}H_{20}Cl_2O_3$	20 µg/l
Propanil		$C_9H_9Cl_2NO$	20 µg/l
Pyridate		$C_{19}H_{23}ClN_2O_2S$	100 µg/l
Simazine		$C_7H_{12}ClN_5$	2 µg/l
Trifluralin		$C_{13}H_{16}F_3N_3O_4$	20 µg/l
Chlorophenoxy herbicides (excluding 2,4-D and MCPA)	2,4-DB	$C_{10}H_{10}Cl_2O_3$	90 µg/l
	Dichlorprop	$C_9H_8Cl_2 0_3$	100 µg/l
	Fenoprop	$C_9H_7Cl_3O_3$	9 µg/l
	MCPB	$C_{11}H_{13}ClO_3$	No guideline
	Mecoprop	$C_{10}H_{11}ClO_3$	10 µg/l
	2,4,5-T	$C_8H_5Cl_3O_3$	9 µg/l

The United States and Singapore involved in the development and deployment of on-line monitoring technology for the detection of contaminants in water[21].

Recently developed online sensor technologies allow water utility managers to continuously monitor physico-chemical water quality indicators in their drinking water distribution systems, almost in real-time.

- Statement of work
- Determine the sensitivity and long-term reliability of commonly used water quality sensors.
- Identify water quality parameters changes in response to

Disinfectants and disinfectant by-products

Group	Substance		Formula	WHO guidelines
Disinfectants	Chloramines		$NH_nCl(3\text{-}n)$ n = 0, 1 or 2	3 mg/l
	Chlorine		Cl_2	5 mg/l
	Chlorine dioxide		ClO_2	No guideline
	Iodine		I_2	No guideline
Disinfectant by-products	Bromate		BrO_3^-	25 µg/l
	Chlorate		ClO_3^-	No guideline
	Chlorite		ClO_2^-	200 µg/l
	Chlorophenols	2-Chlorophenol (2-CP)		
		2,4-Dichlorophenol (2,4-DCP)		
		2,4,6-Trichlorophenol (2,4,6-TCP)		
	Formaldehyde		HCHO	900 µg/l
	MX (3-Chloro-4-dichloromethyl-5-hydroxy-2(5H)-furanone)		$C_5H_3Cl_3O_3$	No guideline
	Trihalomethanes	Bromoform	$CHBr_3$	100 µg/l
		Dibromochloromethane	$CHBr_2Cl$	100 µg/l
		Bromodichloromethane	$CHBr\ Cl_2$	60 µg/l
		Chloroform	$CHCl_3$	200 µg/l
	Chlorinated acetic acids	Monochloroacetic acid	$C_2H_3ClO_2$	No guideline
		Dichloroacetic acid	$C_2H_2Cl_2O_2$	50 µg/l
		Trichloroacetic acid	$C_2H\ Cl_3O_2$	100 µg/l
	Chloral hydrate (trichloroacetaldehyde)		$CCl_3\ CH(OH)_2$	10 µg/l
	Chloroacetones		C_3H_5OCl	No guideline
	Halogenated acetonitriles	Dichloroacetonitrile	C_2HCl_2N	90 µg/l
		Dibromoacetonitrile	C_2HBr_2N	100 µg/l
		Bromochloroacetonitrile	$CHCl_2CN$	No guideline
		Trichloroacetonitrile	C_2Cl_3N	1 µg/l
	Cyanogen chloride		ClCN	70 µg/l
	Chloropicrin		CCl_3NO_2	No guideline

the presence of contaminants such as microbes, heavy metals, corrosion by-products and organic compounds.

- Establish baseline and threshold values for water quality using online data from small distribution systems.
- Develop a protocol for quick identification of drinking water problems using online sensor systems.

5. WATER PURIFICATION TECHNIQUES AND TECHNOLOGIES

The main focus of this article is to evaluate the social, economic and political feasibilities of providing water purification technologies to rural areas of developing countries. The findings of this research can serve as the basis for private investors interested in entering this market. Four representative regions were selected for the study. Economic, demographic, and environmental variables of each region were collected and analysed along with domestic markets and political information. Rural areas of the developing world are populated with poor people unable to fulfill the basic needs for clean water and sanitation. These people represent an important group of potential users. Due to economic, social, and political risks in these areas, it is difficult to build a strong case for any business or organisation focusing on immediate returns on capital investment. A plausible business strategy would be to approach the water purification market as a corporate responsibility and social investing in the short term. This would allow any organisation to be well positioned once the economic ability of individuals, governments, and donor agencies are better aligned[22].

Because each purification technology removes a specific type of contaminant, none can be relied upon to remove all contaminants to the levels required for critical applications. A well-designed water purification system uses a combination of purification technologies to achieve final water quality. Each of the purification technologies must be used in an appropriate sequence to optimise their particular removal capabilities.

5.1 Distillation

Distillation is probably the oldest method of water purification. Water is first heated to boiling. The water vapor rises to a condenser where cooling water lowers the temperature so the vapor is condensed, collected and stored. Most contaminants remain behind in the liquid phase vessel. Organics such as herbicides and pesticides, with boiling points lower than 100 °C cannot be removed efficiently and can actually become concentrated in the product water. Another disadvantage is cost. Distillation requires large amounts of energy and water. Distilled water can also be very acidic, having a low pH, thus should be contained in glass and often called "hungry" water. It lacks oxygen and minerals and has a flat taste, which is why it is mostly used in industrial processes.

In this study, the feasibility of the direct contact membrane distillation (DCMD) process to recover arsenic, uranium and fluoride contaminated saline ground waters was investigated. The ability to utilise the low grade heat sources makes the DCMD process a viable option to recover potable water from a variety of impaired ground waters[23].

5.2 Ion Exchange

The ion exchange process percolates water through bead-like spherical resin materials (ion-exchange resins). Ions in the water are exchanged for other ions fixed to the beads. The two most common ion-exchange methods are softening and deionisation. Softening is used primarily as a pretreatment method to reduce water hardness prior to reverse osmosis (RO) processing. The softeners contain beads that exchange two sodium ions for every calcium or magnesium ion removed from the "softened" water.

Deionisation (DI) can be an important component of a total water purification system when used in combination with other methods such as RO, filtration and carbon adsorption. DI beads exchange either hydrogen ions for cations or hydroxyl ions for anions. The cation exchange resins, made of styrene and divinylbenzene containing sulfonic acid groups, will exchange a hydrogen ion for any cations they encounter (e.g., Na^+, Ca^{++}, Al^{+++}). Similarly, the anion exchange resins, made of styrene and divinylbenzene containing quaternary ammonium groups, will exchange a hydroxyl ion for any anions (e.g., Cl^-). The hydrogen ion from the cation exchanger unites with the hydroxyl ion of the anion exchanger to form pure water. Therefore, the main advantage of ion-exchange resins is it removes dissolved inorganics effectively and regenerated (reverse of purification) easily. Inspite of this, it shows poor removal capacity for pyrogens or bacteria.

5.3 Carbon Adsorption

Activated carbon is created from a variety of carbon-based materials in a high-temperature process that creates a matrix of millions of microscopic pores and crevices. One pound of activated carbon provides anywhere from 60 to 150 acres of surface area. The pores trap microscopic particles and large organic molecules, while the activated surface areas cling to, or adsorb, small organic molecules. The ability of an activated carbon filter to remove certain microorganisms and certain organic chemicals, especially pesticides, chlorine by-product and trichloroethylene depends upon several factors, such as the type of carbon and the amount used, the design of the filter and the rate of water flow, how long the filter has been in use, and the types of impurities the filter has previously removed.

Adsorption on Carbon is a widely used method of home water filter treatment because of its ability to improve water by removing disagreeable tastes and odors, including objectionable chlorine. Activated carbon effectively removes many chemicals and gases, and in some cases it can be effective against microorganisms. Only a few carbon filter systems have been certified for the removal of lead, asbestos, cysts, and coliform. There are two types of carbon filter systems, each with advantages and disadvantages: granular activated carbon, and solid block carbon. These two methods can also work along with a reverse osmosis system, which is as follows :

There have been significant advances in the development and application of treatment processes to control off-flavor problems in drinking water in the past few years. A new treatment process for controlling nitrification in distribution systems is introduced which has the potential to dramatically reduce the problems of chlorinous odor complaints from customers[24]. The adsorption process on carbon is controlled by the diameter of the pores in the carbon filter and by the diffusion rate of organic molecules through the pores. The rate of adsorption is a function of the molecular weight and the molecular size of the organics. Certain granular carbons effectively remove chloramines. Carbon also removes free chlorine and protects other purification media in the system that may be sensitive to an oxidant such as chlorine. Carbon is usually used in combination with other treatment processes. The placement of carbon in relation to other components is an important consideration in the design of a water purification system.

5.4 Micro porous Basic Filtration

There are three types of microporous filtration: depth, screen and surface. Depth filters are matted fibers or materials compressed to form a matrix that retains particles by random adsorption or entrapment. Screen filters are inherently uniform structures which, like a sieve, retain all particles larger than the precisely controlled pore size on their surface. Surface filters are made from multiple layers of media. When fluid passes through the filter, particles larger than the spaces within the filter matrix are retained, accumulating primarily on the surface of the filter. The distinction between filters is important because these three serve very different functions. Depth filters are usually used as prefilters because they are economical to remove 98 per cent of suspended solids and protect elements downstream from fouling or clogging. Surface filters remove 99.99 per cent of suspended solids and may be used as either prefilters or clarifying filters. Microporous membrane (screen) filters are placed at the last possible point in a system to remove the last remaining traces of resin fragments, carbon fines, colloidal particles and microorganisms.

5.5 Ultra Filtration

A micro porous membrane filter removes particles according to pore size. By contrast, an ultra filtration (UF) membrane functions as a molecular sieve. It separates dissolved molecules on the basis of size by passing a solution through an infinitesimally fine filter. The ultra filter is a tough, thin, selectively permeable membrane that retains most macromolecules above a certain size including colloids, microorganisms and pyrogens. Smaller molecules, such as solvents and ionised contaminants, are allowed to pass into the filtrate. Thus, UF provides a retained fraction (retaintates) that is rich in large molecules and a filtrate that contains few, if any, of these molecules. Ultra filters are available in several selective ranges. In all cases, the membranes will retain most, but not necessarily all, molecules above their rated size.

A new concept for household and large-scale safe drinking water production is presented. Raw water is successively filtered through a series of sand and iron filters. Sand filters mostly remove suspended particles (media filtration) and iron filters remove anions, cations, micro-pollutants, natural organic matter, and micro-organisms including pathogens (reactive filtration). Accordingly, treatment steps conventionally achieved with flocculation, sedimentation, rapid sand filtration, activated carbon filtration, and disinfection are achieved in the new concept in only two steps[25].

5.6 Reverse Osmosis

The important purification step is reverse osmosis (RO). RO removes 90 to 99 per cent of all the contaminants found in water except cyanide which is removing around 25 per cent. So, it is called the heart of any well designed water purification system. It is economical method. Reverse osmosis is highly effective in removing several impurities from water such as total dissolved solids (TDS), turbidity, asbestos, lead and other toxic heavy metals, radium, and many dissolved organics. The process will also remove chlorinated pesticides and most heavier-weight VOCs. The pore structure of RO membranes is much tighter than UF membranes. RO membranes are capable of rejecting practically all particles, bacteria and organics of >300 Daltons molecular weight (including pyrogens). In fact, reverse osmosis technology is used by most leading water bottling plants. Osmotic pressure drives water through the membrane; the water dilutes the more concentrated solution; and the end result is equilibrium. In recent years, considerable interest has been given to using nanofiltration (NF) in lieu of reverse osmosis (RO) for water reclamation applications[26].

Desalination by reverse osmosis (RO) has become the most cost-effective process to convert seawater into freshwater for potable use at large scale[27]. The recent advances in reverse osmosis technology are related to the major issues of concern in this rapidly growing desalination method. These issues include membrane fouling studies and control techniques, membrane characterisation methods as well as applications to different water types and constituents present in the feed water. Finally, future research trends and needs relevant to RO are highlighted[28].

In water purification systems, hydraulic pressure is applied to the concentrated solution to counteract the osmotic pressure. Pure water is driven from the concentrated solution and collected downstream of the membrane. Because RO membranes are very restrictive, they yield slow flow rates. Storage tanks are required to produce an adequate volume in a reasonable amount of time. RO also involves an ionic exclusion process. Only solvent is allowed to pass through the semi-permeable RO membrane, while virtually all ions and dissolved molecules are retained (including salts and sugars). The semi-permeable membrane rejects salts (ions) by a charge phenomena action: the greater the charge, the greater the rejection. Three alternative desalination technologies– membrane distillation, forward osmosis, and capacitive deionisation are also reviewed, and issues surrounding their industrial implementation discussed[29]. Reverse osmosis and activated carbon filtration are complementary processes. Combining of both processes results in the most effective treatment against the broadest range of water impurities and contaminants.

Tajura seawater desalination plant is the largest operating reverse osmosis plant in Libya with capacity of 10,000 m^3/d. It utilised a double pass of spiral-wound polyamide membranes. The first pass utilised polyamide membranes to desalt seawater and the second pass was used further to desalt the product of the first stage for industrial utilisation.

5.7 Ultraviolet Radiation

Ultraviolet radiation has widely been used as a germicidal treatment for water. Mercury low pressure lamps generating 254 nm UV light are an effective means of sanitising water. The adsorption of UV light by the DNA and proteins in the microbial cell results in the inactivation of the microorganism (bacteria, some algae and protozoa). Recent advances in UV lamp technology have resulted in the production of special lamps which generate both 185 nm and 254 nm UV light. This combination of wavelengths is necessary for the photooxidation of organic compounds. With these special lamps, total organic carbon (TOC) levels in high purity water can be reduced to 5 ppb.

6. STANDARD OPERATING PROCEDURES FOR POTABLE/DRINKING WATER

Standard operating procedures (SOP) are required for screening risk assessment on municipal drinking water supply and water resources. This SOP focuses on determining the suitability of municipal drinking water supply and other water resources. In addition, it provides procedures for certifying the potability of drinking water sources.

(i) Access to water supply: All urban households have access to safe water either through a piped system, a hand pump, or a tube well.

(ii) Chemical terrorism (threats to water supplies) by introducing toxic chemicals: Sabotaging of water supply under terrorist chemical attack is a real possibility to block the access to the potable water and make the population ill if the water thus contaminated is used for drinking. Therefore, defence of water against chemical attack comprising of prevention, detection and identification, warning and reporting, 24x7 monitoring and surveillance of water resources against the chemical hazards, physical protection, purification, medical management of the casualties due to ingestion of distributed chemically contaminated water, incident management, restoration of normalcy, deterrence, training, etc is needed.

(iii) Water Protection: Water must be protected from chemical contamination. Procedures for subsistence protection must be a part of operational plans and SOPs at all levels of water service operations.

(iv) Inspection of contaminated water: Various equipments are used for preliminary inspection of water such as: Water Poison Detection Kit, Gas Chromatography for organic volatile and non volatile compounds and Gas Chromatography Mass Spectrometry.

(v) Water purification: Potential water purification technologies are based on ion exchange process, ultrafiltration, revers osmosis, ultraviolet, etc.. Purification through the systems based on reverse osmosis and carbon columns is suitable for NBC agents.

Final certification should be granted only after the results of complete chemical analyses as represented in Table 3.

Table 3. Final certificate

Potable water sampling field data sheet	
Section I – Administrative Data	**Section II- Field Data**
1.Sample ID:	14. Sample Collectors Name:
2. Location:	15. Sample Collectors Phone No:
3. Operation:	16.Water Source:
4.Sampling Date:	17. Water Type:
5. Sampling Time:	18. Sample Quantity:
6. Collecting Unit:	19. Sampling Device:
7. Unit Spec ID:	20.Sample Kit Type: Deployment/WPDK/Other
8. Mission ID:	21. Initial pH:
9. Shipping ID:	22. Water Temperature: ºC
10. Lab ID:	23.Conductivity: mV
11. Job No.:	24.Turbidity: NTU
12. Project No:	25. Free Available mg/L chlorine
13. Sample Notes:	26. Total Dissolved solids: mg/L
14.Sample Collectors Name:	GEOLOCATION
15. Sample Collectors Phone No:	27. Latitute:
	28. Longitude:
	29. MGRS.
	30. Field Notes:

7. CURRENT TRENDS IN WATER RESEARCH

The existing water treatment processes and their importance in terms of quantity, quality and cost of water produced as well as their environmental impact are illustrated. That includes a survey of the current desalination techniques in use and an overview of possible future technologies, aiming at solving different water issues.

In recent years, semiconductor photocatalytic process has shown a great potential as a low-cost, environmental friendly and sustainable treatment technology to align with the 'zero' waste scheme in the water/waste water industry.

This review presents the findings of an international study into the state of the art in this field.

7.1 UV-protected Granulated Activated Charcoal Bed

This innovative method has been developed at the U.S. National Aeronautics and Space Administration (NASA) Johnson Space Center. Charcoal is an effective water-purification material that can adhere (adsorb on its surface) diverse classes of inorganic, organic or biological contaminants. The process extends the active life of the charcoal through the use of ultraviolet light that inhibits the growth of microbes on the carbon surface while disinfecting and purifying the water passing through the tubing. Unlike chlorinated disinfectants, UV light does not leave residual matter, which helps to prolong the life of the active charcoal bed.

7.2 Titanium Dioxide and UV Light as the Purifier

More than 20 years ago, Japanese scientists illustrated that anatase, a naturally occurring mineral that is a form of titanium dioxide or TiO_2 is an efficient disinfectant when subject to ultraviolet radiation. Under such conditions, TiO_2 produces reactive oxygen and free radicals that kill bacteria, fungi and viruses in a brief time. TiO_2 a mineral found in abundance in nature. The addition of TiO_2 and the shining ultraviolet rays purifies the water though 'photo catalysis'. A decade ago, the first International Conference on TiO_2 Photo catalytic Purification and Treatment of Water, highlighting the advantages of using TiO_2 and UV-light to purify, took place in Canada. Since that conference, several improvements have made the TiO_2 photo catalysis method even simpler and more effective.

A flexible, uniform and multifunctional TiO_2 nanowire membrane was fabricated successfully using a hydrothermal method. XRD results indicate that it consists of anatase TiO_2 and $Na_2(Ti_6O_{13})$ titanate. The nanowire membrane proves to have remarkable potential for water and wastewater purification, and could be used to eliminate other foulants such as microorganisms and trace organics. A removal rate of 100 per cent and 93.6 per cent for Humic acid and TOC were achieved respectively[30]. Current advances in the technology such as tailor-design of TiO_2 materials at the nanoscale and simultaneous generation of hydroxyl radicals and sulfate radicals are of high interest and are also discussed[31].

7.3 TiO_2 and Sunlight to Purify Water

While TiO_2 is an inexpensive and non-toxic substance used to purify water, it does have some disadvantages. First, because it is suspended as a powder in water, it must subsequently be filtered. Second, TiO_2 uses ultraviolet light and most of the sun's light that falls on earth is above this range. To solve these drawbacks, a research team in Germany sought to immobilise the catalyst as coatings on glass using a process (sol-gel transformation) that produces solids from liquid solutions. Such coatings could be used as effectively and for longer periods without filtering. The researchers improved the light absorption character of TiO_2 by adding small quantities of iron oxide (Fe_2O_3) into the TiO_2 grid. This allowed the use of direct sunlight instead of UV-light. In experimental tests, the composite TiO_2 (Fe_2O_3 catalyst coated on glass), together with the use of sunlight, proved successful, opening the possibility of much broader use.

7.4 Electrochemical Activation

In this method, electrical energy instead of light is used for purification. The catalyst is not TiO_2 alone, but a mixture of oxides of various metals (such as Ru, Ir, Pt and Ti) that are coated on the surface of electrodes. The electrodes are placed on either side of a vessel that is divided into two sections by a vertical diaphragm (ceramic, coated with other oxides) which separates the water contained in the two chambers. Rain water passes through one of these anode chambers to a second vertical chamber that contains replacement-free and regeneration-free catalyst granules. The latter oxidises all organic and biological substances and decontaminates the water. The outflow is then fed into the other chamber of the electrolytic column, while a direct current electrical energy, generated by car battery, passes through. The electrochemical activation (double layer intensification) is intense enough to purify even the most obdurate pollutant. A business group from Estonia has commercialised the purifier as a low cost, easy-to-maintain purification device that provides drinking water which meets World Health Organisation (WHO) standard. The system yields 120 l/h, consumes small amounts of energy and the cartridge does not require to be replaced for years.

7.5 Potable Reverse Osmosis Water Purifiers

Commercial companies now make small reverse osmosis devices for home use that can regularly produce 7 l/h of pure water from any type of water. The devices, which can be mounted on a wall, consume little electricity, use membranes that do not need replacement for 2 yr to 3 yr, and rely on filters that must be replaced just once a year. Larger units, designed to serve an apartment building with throughput rates of 100 l/h. These devices may prove attractive for middle- and upper-income homes or communities where water is hard or brackish.

7.6 Forward Osmosis

Forward osmosis (FO) is one of the unique and emerging technologies that can produce both clean energy and water driven by the osmotic pressure difference across a semi-permeable membrane. Therefore, this is an environmentally friendly industrial system without chemical discharging. Due to record high oil prices, FO based desalination has recently received worldwide attention[2-3] and because it operates without high pressures and high temperatures. Compared to traditional pressure-driven membrane processes, FO offers recognised advantages including high rejections of contaminants, low membrane fouling and potentially less operation energy[32].

7.7 Efficient Adsorbent Filters

Filtering water removes suspended particulate matter. The finer the filter, the more it can decontaminate and purify. Use of a membrane allows selective passage of water while preventing unwanted dissolved material from passing through. Water purification requires a quick-flow, corrosion-resistant, high-stability (in terms of pressure, temperature and contaminants) bactericidal and economical membrane filters. Here, advanced technology is formed–in place hyper filtration membrane. The technology has been used to treat creosote and pentachlorophenol (PCP) contaminated ground water[33].

7.8 Advanced Oxidation Processes

AOP is done by hydroxyl radicals (very reactive, and short-lived oxidants) which are produced in-situ using ultraviolet radiation/hydrogen peroxide, ozone/hydrogen peroxide, ultraviolet radiation/ozone, Fenton's reagent), titanium dioxide/ ultraviolet radiation, and through other means. This process is used to destroy specific pollutants that remain in wastewater after other treatment steps[34-35].

8. FUTURE EMERGING WATER TECHNOLOGIES

The English dictionary defines the word 'emerging' to mean, 'to rise out of a state of depression or obscurity; to come to notice; to reappear after being eclipsed.

Carbon nanotube (CNT) adsorption technology has the potential to support point of use (POU) based treatment approach for removal of bacterial pathogens, natural organic matter (NOM), and cyanobacterial toxins from water systems. Unlike many microporous adsorbents, CNTs possess fibrous shape with high aspect ratio, large accessible external surface area, and well developed mesopores, all contribute to the superior removal capacities of these macromolecular biomolecules and microorganisms.

Bottled water enjoys a booming business lately due to all of the water problems covered before. People drink it because of the improved taste, and that allows them to drink more water. Bottled water companies are allowed to sell water with a minimum level of contamination (bacteria, algae, dirt, lead, etc.). When the water tastes better, the public perceives it as purer.

Cost-effective health risk-mitigating measures, such as of solar disinfection applied to microbial-contaminated water stored in plastic bottles have been increasingly tested in developing countries adversely impacted by epidemic water-borne diseases. Public health concerns associated with chemical leaching from water packaging materials led us to investigate the magnitude and variability of antimony (Sb) and bromine (Br) leaching from reused plastic containers (polyethylene terephthalate, and polycarbonate) subject to UV and/or temperature-driven disinfection. The overall objective of this study was to determine the main and interactive effects of temperature, UV exposure duration, and frequency of bottle reuse on the extent of leaching of Sb and Bromine from plastic bottles into water[34]. Bottled waters are found to having numerous reported contamination problems, such as finding various chemicals, insects, algaes, bacteria, fingernails and even chewing gum! Because of the nature of the bottling and handling process, it is difficult to avoid casual contamination from different points in the process.

9. EMERGENCY RESPONSE TO WATER SECURITY

China has suffered frequent source water contamination accidents in the past decade, which has resulted in severe consequences to the water supply of millions of residents. The origins of typical cases of contamination are discussed in this paper as well as the emergency response to these accidents. To guarantee water security, China is trying to establish a rapid and effective emergency response framework, build up the capability of early accident detection, and develop efficient technologies to remove contaminants from water[36].

The availability of clean water is necessary for all aspects of food production, preparation, distribution and consumption. Nanotechnology shows great promise as a feasible means of treating both long-standing and emerging water contaminants, as well as enabling technologies such as desalination of seawater to increase water supply. However, some engineered nanomaterials could also become water pollutants that threaten public and ecosystem health. Accordingly, this paper considers both the applications and implications of nanotechnology within the context of water quality and water security for developing countries[37].

Around the world as countries are struggling to arrive at an effective regulatory regime to control the discharge of industrial effluents into their ecosystems. Considering that Industries comply with environmental regulations based on the level of enforcement and their ability to spend for waste treatment, this paper endeavours to sketch probable industrial effluent discharge scenarios under various market enforcement conditions and proposes possible strategies for effective regulatory regime in India.

10. CONCLUSION

Essential to the survival of all organisms, water has always been an important and life-sustaining drink to humans. Excluding fat, water comprises approximately 70 per cent of the human body by mass. It is a crucial component of metabolic processes and serves as a solvent for many bodily solutes. Health authorities have historically suggested at least eight glasses of water per day, British Dietetic Association recommends 1.8 l and the United States Environmental Protection Agency recommends 2.0 l per day.

Water problems can arise at four different points in the water supply cycle: at the source and resource, at the treatment stage, during distribution to the consumer's house, and within the household plumbing system. A problem with quality is defined as a failure of a water supply to meet the minimum standards laid down in the EC Drinking Water Directive or the USEPA national primary and secondary drinking water standards. However, drinking water should also be aesthetically pleasing to drink in terms of taste, odour, colour and clarity, and on a daily basis it is these four parameters that consumers use to assess whether their water is fit to drink. Water supply companies ensure the water that is supplied to consumers is of the highest quality by using a range of management systems. The most important are: water safety plans and water security plans. The threat of harmful contaminants in drinking water can no longer be reasonably ignored. Of course, municipal water treatment facilities have lowered the presence of many of the more harmful contaminants, and the EPA has set maximum contaminant levels, below which it is assumed that contaminants may be safely ingested into the body.

There are many home treatment alternatives that can purify drinking water to a greater extent than city treatment plants. Reverse osmosis and distillation, two of these alternatives, are moderately successful at removing some contaminants, but they are expensive and wasteful. Bottled water, besides being expensive and highly unfeasible as a main drinking water source, is not under the same government regulations as municipal water systems and may actually contain more contaminants than tap water. The absolute best technology now available for treating water and removing undesirable contaminants is water filtration. Water filters, when compared to any other water treatment alternative, will remove more contaminants and provide safer, healthier drinking water.

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