LABORATORY INVESTIG ND SOIL CONSOLIDATION BEHAVIOUR OF SOIL-ACTIVATED CARBON MIXTURE IN RIVERBANK FILTRATION SYSTEM

PIUS ANTONIO NG YEW SHANG

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FACULTY OF CIVIL ENGINEERING AND EARTH
RESOURCES UNIVERSITY MALAYSIA PAHANG

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ABSTRACT

Riverbank Filtration (RBF) is an alternative water treatment process that makes use of surface water that has naturally infiltrated into groundwater through rivers or bank(s) and is extracted by using pumping well. Conventional water treatment method uses both physical and chemicals like disinfectants and coagulants to control pathogens that result in a higher cost and the use of chemicals that can cause relative health problems. In riverbank filtration system, specific natural soil properties are needed to effectively filter and extract fresh water from underground sources. Such scarcity of having the ideal soil properties has prompt the application of artificial soil barrier as an alternative source for riverbank filtration to extract fresh water from underground sources. However, the removal of natural soil and replacement of artificial soil has disturbed the soils in the area which would result in soil consolidation and settlement, and hence the overall stability of the system. Therefore, this research is carried out to investigate the compressibility behaviour of the soils. Besides, it is also carried out to determine and compare the effectiveness of natural soil and mixture of natural soil and activated carbon in treating water.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

%	Percentage
kPa	kilo Pascal
kg	Kilogram
µm	Micrometer
mm	millimeter
m	meter
ml	milliliter
g	gram
N	Newton
°C	Degree of Celcius
s	second

LIST OF ABBREVIATIONS

Fig	Figure
UMP	Universiti Malaysia Pahang
BS	British Standard
ASTM	American Society for Testing and Materials

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Freshwater is a fundamental resource to mankind, integral to all ecological and societal activities such as transportation, industrial development, human activities, food and energy production and human health. According to UN-water statistics, the total volume of water on Earth is about 1.4 billion km^3 and only around 35 million km^3 or 2.5% of the total volume is fresh water (Shiklomanov, 1993). Of these freshwater resources, about 24 million km^3or 70% is in the form of ice and permanent snow cover in mountainous regions, such as in Antarctic and Arctic regions that are unreachable to humans. Only about 0.3% or an estimated 105 000 $km^3$of the world's freshwater are found in freshwater lakes and rivers that are accessible to humans. About one third of the world's population lacks sufficient access to safe drinking water and sanitation to meet their basic needs as well as approximately 900million people rely on unimproved drinking water supplies (WHO, 2008). The scarcity of freshwater supply has led nations to see access to water as a matter of national security and as such, researches has been done over the past years to grant access to more freshwater availability. As freshwater is a renewable but finite natural source, conventional water treatment method has been implemented to treat freshwater, mainly for drinking purpose. The application of conventional water treatment method however, has resulted in a higher cost as it uses both physical and chemicals like disinfectants and coagulants to control pathogens besides causing higher risk to human health. Riverbank filtration (RBF) on the other hand, has proven to be a lower cost and effective alternative water treatment method for drinking-water applications. In RBF water treatment technology, water is extracted from rivers using pumping well located in the adjacent alluvial aquifer whereby a series of physical, chemical and biological processes take place while travelling within the underground passage, which results in a higher water quality extracted, substituting conventional water treatment method (Jaramillo, 2011).

1.2 PROBLEM STATEMENT

In riverbank filtration system, specific natural soil properties are needed to effectively filter and extract fresh water from underground sources. Such scarcity of having the ideal natural soil properties has prompt the application of artificial soil barrier as an alternative source for riverbank filtration to extract fresh water from underground sources. However, the removal of natural soil and replacement of artificial soil has disturbed the original soils within the area which would result in soil consolidation and settlement and hence, the overall stability of the system. Therefore, this research is carried out to investigate the compressibility behavior of the soils. Besides, the research is also carried out to determine and compare the effectiveness of natural soil and mixture of natural soil and activated carbon to treat water.

1.3 OBJECTIVES OF THE STUDY

The objectives of the research are as follows:

i) To determine the effectiveness of natural soil in treating water.

ii) To determine the effectiveness of natural soil and activated carbon in treating water.

iii) To investigate the compressibility behavior of the soils.

1.4 SCOPE OF THE STUDY

This research focuses on two major aspects that may affect the performance of the RBF system. The two aspects are the effectiveness of natural soil and mixture of natural soil and activated carbon in treating water and the soil compressibility behavior that would affect the overall stability of the system. The soil sample for this research is taken from Tasik Chini and a total of 5 parameters are set in determining the water quality of the water which include turbidity, total suspended solids (TSS), total dissolved solids (TDS), biochemical oxygen demand (BOD) and chemical oxygen demand (COD).

1.5 RESEARCH SIGNIFICANCE

The main purpose of this research is to determine the effectiveness of natural soil and mixture of natural soil and activated carbon in treating water as well as studying the compressibility behavior of the soils. Furthermore, this research will help to improve the application of RBF system by substituting natural soil with artificial soil that can effectively extract freshwater from underground sources and improve the water quality obtained.

CHAPTER 2

LITERATURE REVIEW

2.1 FRESH WATER

Fresh water is natural occurring water on the Earth's surface located in ice sheets, glaciers, icebergs, ponds, lakes, rivers, and streams, as well as underground as groundwater in aquifers and underground streams. Fresh water is commonly characterized by having low concentrations of dissolved salts and other dissolved solids. Freshwater occupies about less than one percent of the earth's surface, contains one third of all vertebrates and contribute disproportionately to global diversity. However, the increasing growth of human population and a vast increase in socio-economy development has led to severe pressures on the lack of freshwater that has upset the freshwater systems globally (Holland et al., 2012). In spite of that, fresh water is not suitable for drinking as it contains pollutants and pathogens that can harm our body besides lacking certain mineral salts needed by our body such as fluoride, chlorine, and calcium carbonate. Hence, drinking water that is free from pathogens and pollutants as well as containing the minerals needed by the human body is scarce in the world and a proper and efficient water treatment method is fundamental to ensure human survival.

2.1.1 DEMAND AND SUPPLY FOR DRINKING WATER

According to UN Water 2014 report in accordance with World Water Day 2014, 783 million people lack access to safe drinking water while the total freshwater withdrawals are believed to have increased by about 1 percent per year since the late 1980s. The water demand is projected to increase by some 44 percent by the year 2050 due to growing demands from manufacturing, thermal power generation, agricultural and domestic use. It has been estimated that by 2025, 1800 million people will be living in countries or regions with water scarcity and two thirds of the world population could be living under water stress condition. More than 80% of used water worldwide and up to 90% in developing countries is neither collected nor treated, thus threatening human and environmental health worldwide. This clearly depicts the scarcity of clean drinking water while the need for clean and safe drinking water is on the rise.

2.1.2 SOURCES OF WATER SUPPLY

Of all water on earth, 97% is salt water and only the remaining 3% is fresh water. Of that 3% of fresh water, 70% is inaccessible to humans as it is frozen in the polar icecaps. The other 30% of water supply sources are mostly present as moist soil or lies in underground aquifers. Only less than 1% of the world's various sources of water is in the form of fresh water which is accessible for direct human uses (U.S. Geological Survey, 2009). Around 20% of the total water used globally is from groundwater sources (renewable or not) and this share is on a rapid rise scale, particularly in dry areas (Comprehensive Assessment of Water Management in Agriculture, 2007). Fresh water sources include surface water such as in a river, lake, or fresh water wetland, under river flow, ground water as well as frozen water found in icebergs.

2.1.3 STANDARD FOR DRINKING WATER

Access to safe drinking-water is essential to health, a basic human right and a component of effective policy for health protection. The issue of access to clean and safe drinking water as part of health issue has been presented at international, national, regional and local level. In the year 1983–1984 and in 1993–1997, the World Health Organization (WHO) published the first and second editions of the Guidelines for Drinking-water Quality in three volumes as successors to previous WHO International Standards. Further developments of the guidelines were later published in 1995 through a process of rolling revision. There are many guidelines in determining the standard for clean and safe drinking water. However in this study, only two standards for drinking water will be considered; World Health Organization (WHO) water drinking standards as well as Malaysian National Standard for drinking water quality. According to World Health Organization (WHO), Geneva 2008, the examples of operational monitoring parameters for safe drinking water are provided in table 2.1 below.

OPERATIONAL PARAMETER	RAW WATER	COAGULATION	SEDIMENTATION	FILTRATION	DISINFECTION	DISTRIBUTION SYSTEM
pH						
Turbidity (or particle count)						
Dissolved Oxygen						
Stream/river flow						
Rainfall						
Colour						
Conductivity (total dissolved solids, or TDS)						
Organic carbon						
Algae, algal toxins and metabolites						
Chemical dosage						
Flowrate						
Net charge						
Streaming current value						
Headloss						
Ct^{a}						
Disinfectant residual						
Oxidation-reduction potential (ORP)						
DBPs						
Hydraulic pressure						

* Ct = Disinfectant concentration x contact time

Table 2.1: Examples of Operational Monitoring Parameters that can be used to Monitor Control Measures.

The reference guidelines outlined according to the Engineering Services Division Ministry of Health, December 2000 for safe drinking water criteria are shown in Table 2.2.

NO	PARAMETERS	COLUMN 1	COLUMN 2			COLUMN 3
		Acceptable Value	Frequency to be Monitored			Source of Reference
		Mg (unless otherwise stated)	Surface	Ground	Direct Impounding	
	Group 1					
1	Total Coliform	5000MPN/100ml or cfu/100ml	W	M	M	WHO1
2	Turbidity	1000 NTU	W	M	M	WHO2
3	Colour	300 TCU	W	M	M	WHO1
4	pH	5.5-9.0	W	M	M	MAL
	Group 2					
1	Total dissolved solids	1500	M	Y/4	Y/4	WHO1
2	Biochemical oxygen demand	6	M	Y/4	Y/4	WHO1
3	Chemical oxygen demand	10	M	Y/4	Y/4	WHO1
4	Chloride	250	M	Y/4	Y/4	MAL
5	Anionic detergent mbas	1.0	M	Y/4	Y/4	WHO1
6	Ammonia	1.5	M	Y/4	Y/4	WHO1
7	Nitrate	10	M	Y/4	Y/4	MAL
8	Iron	1.0	M	Y/4	Y/4	MAL
9	Fluoride	1.5	M	Y/4	Y/4	WHO1
10	Hardness	500	M	Y/4	Y/4	MAL
11	Manganese	0.2	M	Y/4	Y/4	WHO1
	Group 3					
1	Mercury	0.001	Y/4	Y/4	Y/4	MAL
2	Cadmium	0.003	Y/4	Y/4	Y/4	MAL
3	Selenium	0.01	Y/4	Y/4	Y/4	WHO1
4	Arsenic	0.01	Y/4	Y/4	Y/4	MAL
5	Cyanide	0.07	Y/4	Y/4	Y/4	MAL
6	Lead	0.05	Y/4	Y/4	Y/4	MAL
7	Chromium	0.05	Y/4	Y/4	Y/4	WHO1
8	Silver	0.05	Y/4	Y/4	Y/4	MAL
9	Copper	1.0	Y/4	Y/4	Y/4	MAL
10	Magnesium	150	Y/4	Y/4	Y/4	MAL
11	Sodium	200	Y/4	Y/4	Y/4	MAL
12	Zinc	3	Y/4	Y/4	Y/4	MAL
13	Sulphate	250	Y/4	Y/4	Y/4	MAL
14	Mineral oil	0.3	Y/4	Y/4	Y/4	MAL
15	Phenol	0.002	Y/4	Y/4	Y/4	WHO1

Table 2.2: Recommended Raw Water Quality Criteria and Frequency of Monitoring

NO	PARAMETERS	COLUMN 1	COLUMN 2			COLUMN 3
		Acceptable Value	Frequency to be Monitored			Source of Reference
		Mg (unless otherwise stated)	Surface	Ground	Direct Impounding	
	Group 4 ORGANOCHLORINE PESTICIDES					
1	Aldrin/dieldrin	0.00003	Y/4	Y/4	Y/4	MAL
2	Ddt	0.002	Y/4	Y/4	Y/4	MAL
3	Heptachlor & Heptachlor Expoxide	0.00003	Y/4	Y/4	Y/4	MAL
4	Methoxychlor	0.02	Y/4	Y/4	Y/4	MAL
	Non-Organochlorine pesticides					
5	Hexachlorobenzine	0.001	W/N	Y/4	Y/4	MAL
6	Lindane	0.002	Y/4	Y/4	Y/4	MAL
7	Chlordane	0.0002	Y/4	Y/4	Y/4	MAL
	Herbicides					
8	Dichlorophenoxyacetic acid	0.03	W/N	Y/4	Y/4	MAL
	Group 5 Radioactivity					
1	Gross α	0.1	W/N	W/N	W/N	MAL
2	Gross β	1.0	W/N	W/N	W/N	MAL
TOTAL	40 PARAMETERS					

W: Indicates parameters to be monitored at least once a week

M: Indicates parameters to be monitored at least once a month

Y/4: Indicates parameters to be monitored at least once every 3 months

Y: Indicates parameters to be monitored at least once a year

WHO1: Refers to WHO International Standards for Drinking Water 1963

WHO2: Refers to WHO Guidelines for Drinking Water Quality Vol 1 & 2 1964

MAL: Refers to values adapted for Malaysian conditions

Table 2.3 (continued): Recommended Raw Water Quality Criteria and Frequency of Monitoring

NO	PARAMETERS	COLUMN 1	COLUMN 2				COLUMN 3
		Maximum Acceptable Value	Frequency to be Monitored				Source of Reference
		Mg (unless otherwise stated)	Water Treatment Plant Outlet	Service Reservoir Outlet	Distribution System	Well/Spring	
1	*Group 4 Microbiological* Total Coliform	MPN filtration method must not be detected in 100ml sample	W	W	M	2Y	MAL
2	E-coli	Absent in 100ml Sample	W	W	M	2Y	WHO2
3	Coliform bacteria	Absent in 100ml Sample	W	W	M	2Y	WHO2
4	Faecal coliform	Membrane filter method absent in 100ml sample	W/N	W/N	W/N	W/N	EEC
5	Viruses	Absent in 100ml sample	W/N	W/N	W/N	W/N	NZ
6	Protozoa	Absent in 100ml sample	W/N	W/N	W/N	W/N	NZ
7	**Physical** Turbidity	5NTU	W	W	M	2Y	WHO2
8	Colour	15NTU	W	W	M	2Y	WHO2
9	pH	0.5-9.0	W	W	M	2Y	MAL
10	Free residual chlorine	0.2-5.0	W	W	M	2Y	WHO1
11	Monochloramine	3	WN	WN	WN	WN	WHO2
1	***Group 2*** Inorganic Total Dissolved Solids	1000	M	M	Y/2	2Y	WHO2
2	Chloride	250	M	M	Y/2	2Y	WHO2
3	Ammonia	1.5	M	M	Y/2	2Y	WHO2
4	Nitrate	10	M	M	Y/2	2Y	WHO1
5	Iron	0.3	M	M	Y/2	2Y	WHO2
6	Fluoride	0.4-0.5	M	M	Y/2	2Y	MAL
7	Hardness	500	M	M	Y/2	2Y	WHO1
8	Aluminium	0.2	M	M	Y/2	2Y	WHO2
9	Manganese	0.1	M	M	Y/2	2Y	WHO2
1	***Group 3*** ***Mercury***	0.001	Y/4	M	Y/2	2Y	WHO2
2	Cadmium	0.003	Y/4	Y/2	Y	2Y	WHO2
3	Arsenic	0.01	Y/4	Y/2	Y	2Y	WHO2
4	Cyanide	0.03	Y/4	Y/2	Y	2Y	WHO2
5	Lead	0.01	Y/4	Y/2	Y	2Y	WHO2
6	Chromium	0.05	Y/4	Y/2	Y	2Y	WHO2
7	Copper	1	Y/4	Y/2	Y	2Y	WHO1
8	Zinc	3	Y/4	Y/2	Y	2Y	WHO2
9	Sodium	200	Y/4	Y/2	Y	2Y	WHO2
10	Sulphate	250	Y/4	Y/2	Y	2Y	WHO2

Table 2.4: Drinking Water Quality Standards and Frequency of Monitoring

NO	PARAMETERS	COLUMN 1	COLUMN 2				COLUMN 3
		Maximum Acceptable Value	Frequency to be Monitored				Source of Reference
		Mg (unless otherwise stated)	Water Treatment Plant Outlet	Service Reservoir Outlet	Distribution System	Well/Spring	
11	*GROUP 3* *Trihalomethane* The sum of the ratio of the concentration to each of the guideline value should not exceed 1 Chloroform	0.2	Y/4	Y/2	Y	2Y	WHO3
12	Bromoform	0.1	Y/4	Y/2	Y	2Y	WHO2
13	Dibromochloromethane	0.1	Y/4	Y/2	Y	2Y	WHO2
14	Bromodichloromethane	0.06	Y/4	Y/2	Y	2Y	WHO2
15	Selenium	0.01	Y/4	W/N	W/N	W/N	WHO2
16	Silver	0.05	Y/4	W/N	W/N	W/N	MAL 1990
17	Magnesium	150	Y/4	W/N	W/N	W/N	MAL 1990
18	Antimony	0.005	W/N	W/N	W/N	W/N	WHO2
19	Barium	0.7	W/N	W/N	W/N	W/N	WHO2
20	Boron	0.5	W/N	W/N	W/N	W/N	WHO3
21	Molybdenium	0.007	W/N	W/N	W/N	W/N	WHO2
22	Nickel	0.02	W/N	W/N	W/N	W/N	WHO2
23	Uranium	0.002	W/N	W/N	W/N	W/N	WHO3
24	Hydrogen Sulphide	0.05	W/N	W/N	W/N	W/N	WHO2
25	Mineral oil	0.3	W/N	W/N	W/N	W/N	MAL 1990
26	Phenol	0.002	W/N	W/N	W/N	W/N	WHO1
27	Bromate	0.025	W/N	W/N	W/N	W/N	WHO2
28	Chlorite	0.2	W/N	W/N	W/N	W/N	WHO2
29	2-Chlorophenol	0.0001	W/N	W/N	W/N	W/N	WHO2
30	2,4-Dichlorophenol	0.0003	W/N	W/N	W/N	W/N	WHO2
31	2,4,6-Trichlorophenol	0.2	W/N	W/N	W/N	W/N	WHO2
32	Formaldehyde	0.9	W/N	W/N	W/N	W/N	WHO2
33	Dichloroacetic acid	0.05	W/N	W/N	W/N	W/N	WHO2
34	Trichloroacetic acid	0.1	W/N	W/N	W/N	W/N	WHO2
35	Trichloroacetaldehyde	0.01	W/N	W/N	W/N	W/N	WHO2
36	Dichloroaceto-Nitrile	0.09	W/N	W/N	W/N	W/N	WHO2
37	Dibromoaceto-Nitrile	0.1	W/N	W/N	W/N	W/N	WHO2
38	Trichloroaceto-Nitrile	0.001	W/N	W/N	W/N	W/N	WHO2
39	Cynogen Cloride	0.07	W/N	W/N	W/N	W/N	WHO2

Table 2.5 (continued): Drinking Water Quality Standards and Frequency of Monitoring

NO	PARAMETERS	COLUMN 1	COLUMN 2				COLUMN 3
		Maximum Acceptable Value	Frequency to be Monitored				Source of Reference
	Group 4	Mg (unless otherwise stated)	Water Treatment Plant Outlet	Service Reservoir Outlet	Distribution System	Well/Spring	
1	Aldrindelorine	0.00003	Y/4	W/N	W/N	W/N	WHO2
2	Dot	0.002	Y/4	W/N	W/N	W/N	WHO2
3	Heptache & Heptachlorexposide	0.00003	Y/4	W/N	W/N	W/N	WHO2
4	Methoxychlor	0.02	Y/4	W/N	W/N	W/N	WHO2
5	Lindane	0.002	Y/4	W/N	W/N	W/N	WHO2
6	Endosulfan	0.03	Y/4	W/N	W/N	W/N	AUS
7	Chlordane	0.0002	W/N	W/N	W/N	W/N	WHO2
8	1,2-Dichloropropane	0.04	W/N	W/N	W/N	W/N	WHO2
9	1,3-Dichloropropene	0.02	W/N	W/N	W/N	W/N	WHO2
10	Hexachlorobenzene	0.001	W/N	W/N	W/N	W/N	WHO2
11	Pentachlorophenol	0.009	W/N	W/N	W/N	W/N	WHO3
12	Alachlor	0.02	W/N	W/N	W/N	W/N	WHO2
13	Aldicard	0.01	W/N	W/N	W/N	W/N	WHO2
14	Ametyryn	0.05	W/N	W/N	W/N	W/N	AUS
15	Atrazine	0.002	W/N	W/N	W/N	W/N	WHO2
16	Bentazone	0.3	W/N	W/N	W/N	W/N	WHO3
17	Carbofuran	0.007	W/N	W/N	W/N	W/N	WHO3
18	Chlorotoluron	0.03	W/N	W/N	W/N	W/N	WHO2
19	Cynazine	0.0006	W/N	W/N	W/N	W/N	WHO3
20	2,4-Dichlorophenoxy acetic acid	0.03	W/N	W/N	W/N	W/N	WHO3
21	Dequat	0.01	W/N	W/N	W/N	W/N	WHO3
22	1,2-Dibromo-3-Chloropropane	0.001	W/N	W/N	W/N	W/N	WHO3
23	1,2-Dibromoethane	0.0004	W/N	W/N	W/N	W/N	WHO2
24	Isoproturone	0.009	W/N	W/N	W/N	W/N	WHO2
25	Mcpa	0.002	W/N	W/N	W/N	W/N	WHO2
26	Metolachlor	0.01	W/N	W/N	W/N	W/N	WHO2
27	Molinate	0.006	W/N	W/N	W/N	W/N	WHO2
28	Pendimethalin	0.02	W/N	W/N	W/N	W/N	WHO2
29	Permethrin	0.02	W/N	W/N	W/N	W/N	WHO2
30	Propanyl	0.02	W/N	W/N	W/N	W/N	WHO2
31	Pyridate	0.1	W/N	W/N	W/N	W/N	WHO2
32	Smazine	0.002	W/N	W/N	W/N	W/N	WHO2
33	Trifularin	0.02	W/N	W/N	W/N	W/N	WHO2
34	2,4-DB	0.09	W/N	W/N	W/N	W/N	WHO2
35	Dichlorprop	0.1	W/N	W/N	W/N	W/N	WHO2
36	Fenoprop	0.009	W/N	W/N	W/N	W/N	WHO2
37	Mecoprop	0.01	W/N	W/N	W/N	W/N	WHO2
38	2,4,5-T	0.009	W/N	W/N	W/N	W/N	WHO2
39	Terbuthylazine	0.007	W/N	W/N	W/N	W/N	WHO3

Table 2.6 (continued): Drinking Water Quality Standards and Frequency of Monitoring

NO	PARAMETERS	COLUMN 1	COLUMN 2				COLUMN 3
		Maximum Acceptable Value	Frequency to be Monitored				Source of Reference
	Organic Substances	Mg (unless otherwise stated)	Water Treatment Plant Outlet	Service Reservoir Outlet	Distribution System	Well/Spring	
40	Carbon Tetrachloride	0.002	W/N	W/N	W/N	W/N	WHO2
41	Dichloromethane	0.02	W/N	W/N	W/N	W/N	WHO2
42	1,2-Dichloromethane	0.03	W/N	W/N	W/N	W/N	WHO2
43	1,1,1-Trichloromethane	2	W/N	W/N	W/N	W/N	WHO2
44	Vinyl Chloride	0.005	W/N	W/N	W/N	W/N	WHO2
45	1,1-Dichloroethene	0.03	W/N	W/N	W/N	W/N	WHO2
46	1,2-Dichloroethene	0.05	W/N	W/N	W/N	W/N	WHO2
47	Trichloroethene	0.07	W/N	W/N	W/N	W/N	WHO2
48	Tetrachloroethene	0.04	W/N	W/N	W/N	W/N	WHO2
49	Benzene	0.01	W/N	W/N	W/N	W/N	WHO2
50	Toulene	0.7	W/N	W/N	W/N	W/N	WHO3
51	Xylene	0.5	W/N	W/N	W/N	W/N	WHO2
52	Etylbenzene	0.3	W/N	W/N	W/N	W/N	WHO2
53	Styrene	0.02	W/N	W/N	W/N	W/N	WHO2
54	Benzo (A) Pyrene	0.0007	W/N	W/N	W/N	W/N	WHO2
55	Monochlorobenzene	0.3	W/N	W/N	W/N	W/N	WHO2
56	1,2-Dichlorobenzene	1	W/N	W/N	W/N	W/N	WHO2
57	1,4-Dichlorobenzene	0.3	W/N	W/N	W/N	W/N	WHO2
58	Trichlorobenzene	0.02	W/N	W/N	W/N	W/N	WHO2
59	Di (2-Ethylhexyl) Adipate	0.08	W/N	W/N	W/N	W/N	WHO2
60	Di (2-Ethylhexyl) Phthalate	0.008	W/N	W/N	W/N	W/N	WHO2
61	Edetic Acid (EDTA)	0.6	W/N	W/N	W/N	W/N	WHO3
62	Acrylamide	0.0005	W/N	W/N	W/N	W/N	WHO2
63	Epichlorhydrin	0.0004	W/N	W/N	W/N	W/N	WHO2
64	Hexachlorobutadiene	0.0006	W/N	W/N	W/N	W/N	WHO2
65	Microcystin-LR	0.001	W/N	W/N	W/N	W/N	WHO3
66	Nitrilotriacetic acid (NTA)	0.2	W/N	W/N	W/N	W/N	WHO2
67	Tributylin Oxide	0.002	W/N	W/N	W/N	W/N	WHO2
	Group 5 ***Radioactivity***						
1	Gross α	0.1 Bg/l	W/N	W/N	W/N	W/N	WHO2
2	Gross β	1.0 Bg/l	W/N	W/N	W/N	W/N	WHO2
TOTAL	131 PARAMETERS						

W: Indicates parameters to be monitored at least once a week

M: Indicates parameters to be monitored at least once a month

Y/2: Indicates parameters to be monitored at least once in six months

Y: Indicates parameters to be monitored at least once a year

2Y: Indicates parameters to be monitored at least once in 2 years

WN: Indicates parameters to be monitored when necessary

WHO1: Indicates WHO Guidelines for Drinking Water Quality 1964

WHO2: Indicates WHO Guidelines for Drinking Water Quality 1993/96

WHO3: Indicates WHO Guidelines for Drinking Water Quality Addendum to Vol 1 1998

MAL: Indicates values adapted for Malaysian conditions

AUS: Indicates Australian Drinking Water Quality Guidelines, 1996

EEC: Indicates EEC Standard Council Directive (80/778/EEC)

NZ: Indicates Drinking Water Standards for New Zealand 1995

Table 2.7 (continued): Drinking Water Quality Standards and Frequency of Monitoring

2.2 TYPES OF TREATMENT FOR WATER

Raw water must be treated before they can be consumed. The purpose of treating raw water is to provide clean water that are free from pathogen microorganisms, dangerous organic or inorganic as well as less mineral substances in water. Most water resources in this world has been contaminated with various physical, chemical and biological parameter and these pollutants cannot be removed by boiling the water alone and as such, proper methods of water treatment is essential prior to human consumption. There are 21 mineral elements known or suspected to be essential for humans whereby fourteen elements are established as being essential to good health (Verma and Kushwaha, 2014). These elements in combined form affect bone and membrane structures (Ca, P, Mg, F), water and electrolyte balance (Na, K, Cl), metabolic catalysis (Zn, Cu, Se, Mg, Mn, Mo), oxygen binding (Fe), and hormone functions (I, Cr). Health consequences of micronutrient deficiencies include increased morbidity, mortality due