Potable Water Quality Characteristics


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INTRODUCTION

All living organisms on this planet are dependent on water either as a place of habitat or for drinking. Humans are not excluded from this rule, where the body, depending on size is said to consist of between 55% to 68% water. To maintain proper hydration, the human body needs approximately one to two liters of water per day, which is more or less equivalent to six glasses [1]. To cater for this need in the modern era, facilities are built to treat raw water sources before it is distributed to the general population.

In Malaysia, the most tapped raw water source are rivers, which are technically under the jurisdiction of the respective state governments [2], supported by federal agencies as ascribed in the constitution. Most water treatment plants employ conventional treatment systems, that typically consist of filtration (such as sand filtration), coagulation and flocculation, disinfection (chlorination) and flouridisation. As development becomes more rampant, river water quality degradation also becomes more widepsread, consequentially broadening the spectrum of contaminants. Conventional treatment systems, at times, are not able to remove these contaminants and as a result they might enter the distribution and supply network. To manage this problem, the Environmental Quality Act, 1974, prescribes more stringent regulatory compliance for wastewater discharging premises located upstream of a water intake point [2]. That being so, not all contaminants are covered under the Act, therefore the risk of contamination cannot be totally eradicated. This fact is more so true in this era of climatological and morphological change, where rivers are more susceptible to contamination [2].

If the quality factor is taken into account, relative to the National Water Quality Standards (NWQS) for Malaysia (Tables 1 and 2), the expected water stress for potable supply would be even higher than what it is today, particularly in view of ammoniacal nitrogen (NH_3^{-N}) levels. Rivers in Malaysia are known to be affected by NH_3^{-N} pollution from sewage contribution [3]. The NWQS prescribes a Class IIA/IIB water source as being suitable for conventional treatment, whereas a Class III water source requires advanced treatment [4]. The Class II NH_3^{-N} levels stipulates the constituent to not be more than 0.3 mg/l, although in practice, some water service providers practice a cut-off point of 1.5 mg/l (Class IV).

Table 1 : Excerpt of the NWQS

Parameter	Unit	Classes					
		I	IIA	IIB	III	IV	V
Ammoniacal Nitrogen (NH_3-N)	mg/l	0.1	0.3	0.3	0.9	2.7	> 2.7
BOD_5	mg/l	1	3	3	6	12	> 12
COD	mg/l	10	25	25	50	100	> 100
DO	mg/l	7	5 - 7	5 - 7	3 - 5	< 3	< 1
pH		6.5 - 8.5	6.5 - 9.0	6.5 - 9.0	5 - 9	5 - 9	-
Color	TUC	15	150	150	-	-	
Electrical Conductivity	µS/cm	1000	1000	-	-	6000	-
Floatables		NV	NV	NV	-	-	-
Salinity	ppt	0.5	1	-	-	2	-
Taste		NOT	NOT	NOT	-	-	-
Total Suspended Solids	mg/l	25	50	50	150	300	300
Temperature	°C	-	Normal + 2°C	-	Normal + 2°C	-	-
Turbidity	NTU	5	50	50	-	-	-
Fecal Coliform	counts/100ml	10	100	400	5000 (20000)[a]	5000 (20000)[a]	-
Total Coliform	counts/100ml	100	5000	5000	50000	50000	>50000

Note : NV = No visible floatable materials or debris NOT = No objectionable taste

Table 2 : NWQS class definitions

Class	Definition
I	Conservation of natural environment. Water supply I - Practically no treatment necessary (except by disinfection or boiling only). Fishery I - Very sensitive aquatic species.
IIA	Water supply II - Conventional treatment required.
IIB	Fishery II - Sensitive aquatic species.
III	Recreational use with body contact.
IV	Water supply III - Extensive treatment required.
V	Fishery III - Common of economic value, and tolerant species; livestock drinking.

Fortunately, NH_3^{-N} itself is not considered to be a toxic substance, though it does emit a pungent odor, as in the case of the 2006 and 2010 contamination at two treatment plants in Selangor [5]. Despite this, NH_3^{-N} may still react with chlorine from the disinfection process to produce chloroamines [6].

TURBIDITY AND TOTAL SUSPENDED SOLIDS

Sediment load contribution on the other hand, has led to murky river conditions in various watersheds as illustrated in Figure 1. The contamination typically originates from agricultural runoff (e.g. palm oil), irrigation, logging and land-clearing activities [2]. Water quality parameters that are used to gauge the clarity of water include turbidity (expressed in terms of nephelometric turbidity units or NTU) and total suspended solids (TSS, expressed in mg/l). There is usually a correlation between these two parameters and water service providers are most concerned when turbidity in the raw water source exceeds 50 NTU, which of course corresponds to the threshold of the NWQS.

Providers typically target an NTU < 1 at post-treatment, though this varies from region to region and between providers. Low turbidity (hence TSS), does not only ensure a desirable clarity of the water for supply but also ensures maximum disinfection potency. Elevated turbidity may incur risk of transmitting gastrointestinal diseases, as viruses or bacteria can become attached to the suspended solid [7]. The suspended solids also interfere with the disinfection process as the particles can shield microbes from the chlorine compund and even from ultraviolet (UV) sterilisation [7].

That being so, taking turbidity and TSS as the only two constituents for consideration in potable water supply is inadequate, as there are a myriad to other parameters which also have a direct bearing towards public health.

PATHOGENS

Water-borne pathogens usually incur short-term health impacts towards consumers due to bacterial and sometimes, viral infection. Microorganisms like these are naturally present in the environment though usually at low levels, which is also why the NWQS recommends disinfection by boiling for a Class I water source [4]. Contamination may occur as a result of fecal input from animals or domestic sewage contamination. Relevant bacterial parameters water quality assessment include total coliform, fecal coliform, E. coli, Gardia lamblia and Enterocci. Coliforms are measured in units of either cfu (coliform forming units) or MPN (most-probable number) where the former entails direct counting of microbe colonies on a Petri dish whereas the latter utilises a statistical method of quantification based on the number of positives from test tube analyses [8]. E. coli bacterium is not necessarily pathogenic (depending on the strain) but can be considered to be an indicator of pathogenic contamination.

The O157 strain produces a potent toxin which can cause severe diarrhoea and in some cases renal failure and death [9]. Giardia lamblia is a parasite that colonises and reproduces in the small intestine, causing diarrhoea and fever [10]. The source of the parasite are primarily fecal such as untreated sewage sources or from animal grasing. Enteroccoci or more specifically, E. faecalis can cause endocarditis and bacteremia, urinary tract infections (UTI) and meningitis [10]. The state of Hawaii, in the USA, only tolerates 7 cfu/100ml of the constituent to be present in surrounding coastal waters (for recreational use), above which the state will post health warning for patrons to stay out of the water [11].

Figure 1: Streams with elevated turbidity and TSS (a) Sungai Tinggi (Sungai Selangor) (b) Sungai Belatop, Cameron Highlands (c) Sungai Dua Canal, Pulau Pinang

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In Malaysia, disinfection is usually done via chlorination, though there are also other methods, like membrane filtration, reverse osmosis and ozonation.

CHEMICAL CONSTITUENTS

Besides the above physical and bacteriological considerations, there are a wide variety of other chemical constituents which should also be considered in potable water usage; this includes nitrate (typically measured as NO_3 or NO_3^{-N}). Nitrate contamination in surface water bodies originate from fertilizers such as ammonium nitrate, similar processing facilities or waste dumps [12]. If the contaminated water is consumed (above 10 mg/l of NO_3^{-N}) by an infant, expecting or breastfeeding mother, a condition known as "blue baby syndrome" may arise as a consequence of decreased oxygen carrying capacity in the infant's blood. Although elevated levels of nitrate are more commonly anticipated in groundwater sources [13], there have been cases in Malaysia where severely high nitrate levels in rivers have been observed. One such river is Sg. Bongkok (Figure 2), in Gurun, Kedah where NO_3^{-N} levels were observed to be between 27 to 210 mg/l [14]; correspondingly, NO_3^{-N} levels were also elevated here, between 2.59 to 27.51 mg/l. Fortunately the water is not used for domestic supply though local potable consumption cannot be entirely ruled out.

Typical metal constituents that come under scrutiny in water quality assessment include arsenic (As), copper (Cu), cadmium (Cd), chromium (Cr), lead (Pb) and nickel (Ni). Exposure to these

Figure 2 : Sungai Bongkok (Gurun, Kedah)

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heavy metals (such as through consumption) over a long-period of time, will propogate tissue build-up and potentially incur long-term health effects including stomach pain, nausea, diarrhea, partial paralysis, numbness in hands and feet, blindness, thickening and discoloration of the skin, cancer, renal failure, liver cirrhosis and hair loss [10]. Landfills and metal industries are the usual suspects for heavy metal contribution, particularly those located upstream of a water intake.

An infamous heavy metal contamination case involved the small town of Hinkley, in the Mojave Desert of California, USA. Hexavalent chromium, otherwise known in chromium (VI), percolated into the aquifer layer of the area, apparently due to wastewater discharge from Pacific Gas and Electric (PG&E) [16]. The current average chromium (VI) levels in Hinkley average around 1.19 ppb with a peak of 3.09 ppb, compared to the California health goal of 0.06 ppb [16]. Interestingly, since then, further studies have shown that chromium (VI) contamination in US cities is quite widespread as 89% of tap water samples in 35 cities, showed the constituent to be above the targeted health goal [17].

Pesticide is a composite term used to describe a collection of chemical constituents used to kill pests, largely in an agricultural setting that can enter the water column, either through runoff or irrigation [12]. Herbicides and insecticides are two types of pesticides most widely used in agriculture. Chemical classes of pesticides include organochlorine, carbamate, organophosphorus and chlorophenoxy compounds [18]. Organochlorine pesticides such as aldrin or dieldrin, chlordane, DDT, heptachlor and hexachlorobenzene are persistent and have high potential for bioaccumulation that can incur carcinogenic effects, disturbance of the reproductive system, disruption of the immune system and even cause damage to DNA structure [10].

As Malaysia is the second largest palm oil producer in the world, the usage of these pesticides have long been assumed to be rampant, though not many comprehensive studies pertaining to their presence and transformation (metabolites) in the water column have been done. More worrying, encroachment of riparian zones (river reserves) in palm oil plantations removes vegetation which help natural phytoremediation [2]. Pesticide usage in vegetable farms in Cameron Highlands is also assumed to be widespread, though not much is known about their levels and distribution in the watercourses. This is quite critical as there are several potable water intake points located in that area, not to mention the water is also used by the local Orang Asli. The NWQS lists a wide array of tolerable pesticide levels that should not be exceeded for potable supply and consumption.

TRACE CONTAMINANTS

Recent research developments have revealed that other contaminants at trace levels also need to be given consideration in potable water usage. These contaminants extend beyond the conventional part per million (ppm) range and requires measurement at either the part per billion (ppb) or part per trillion scale. Examples of such contaminants include trihalomethanes (THMs) and perfluorooctane sulfonate (PFOS).

Trihalomethanes are a by-product of chlorination in the water treatment disinfection process where chlorine reacts with organic matter to produce THMs such as chloroform, bromoform, bromodichloromethane and dibromochloromethane [19]. Long term exposure to THMs, may result in adverse health effects towards the central nervous system, liver, kidneys and heart [10]. In fact, chloroform is regarded as a "probable human carcinogen" by the US Environmental Protection Agency (US EPA). In view of this, the agency recommends no more than 80 ppb of THMs to be present in treated water [20].

PFOS is a global pollutant commonly found in the metal plating, textile, paper and paint industries [21]. The contaminant is thought to incur a wide range of health effects, such as being an endocrine disruptor and induce hypertension in pregnant women. Some studies have also indicated that the constituent increases risk of attention deficit disorder (ADHD) [21]. The US EPA recommends no more than 0.2 µg/l of PFOS [21] to be present in water intended for consumption. PFOS is also commonly associated with perfluorooctanoic acid (PFOA), as they typically originate from the same source and incur similar health effects. In 2009, the US EPA set a provisional health advisory for limiting PFOA at 0.4 µg/l [22].

CONCLUSION

The above are only a select few of constituents and parameters that affect drinking water quality. There are a myriad of other contaminants which also need to be controlled and assessed before a water source can be deemed as safe and fit for human consumption. As we progress towards becoming a developed nation, the amount of pollution and spectrum of constituents will also increase, potentially compromising on the quality of our drinking water. The relevant authorities and service providers must be up to the mark in facing these challenges, to ensure that our raw water sources are of good quality for potable use. ■

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