Drinking Water Quality in Malaysia: A Review on Its Current Status

Zurahanim Fasha Anual1*, Wan Nurul Farah Wan Azmi1, Nurul Izzah Ahmad1, Norashah Mohammad Sham1, Wan Rozita Wan Mahiyuddin1, Yuvaneswary Veloo1 and Nor Aini Abdullah2

1Environmental Health Research Centre, Institute for Medical Research, National Institutes of Health, Malaysia
2Infectious Disease Research Centre, Institute for Medical Research, National Institutes of Health, Malaysia

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*Corresponding author: Zurahanim Fasha Anual, Environmental Health Research Centre, Institute for Medical Research, National Institutes of Health, Malaysia

Abstract

Access to safe drinking water is fundamental to health. This review aims to assess the status of drinking water quality in Malaysia. Only peer-reviewed cross-sectional articles from January 2000 until May 2018 focusing on treated water and groundwater in Malaysia were included in this review. Based on the inclusion criteria, 30 articles were selected which measures water quality parameters in drinking water. Overall pooled mean for physical parameters (pH, turbidity, total suspended solids, total dissolved solids, temperature and conductivity) were within the reference levels established by the Malaysian National Drinking Water Quality Standard. In this review, the generally low number of available studies which fulfill the inclusion criteria means that interpretation of results must be exercised with caution. This review may provide policy makers with reliable scientific evidences for better management practice and it is hoped that the findings will support the planning of future researches in this field.

Keywords: Chemical contaminants; Microbiological contamination; Tap water; Water pollutants; Treated water

Introduction

According to the World Health Organization (WHO), access to safe water supply is basic human rights [1]. Since 1990, 2.6 billion people have gained access to improved drinking water of which 96% are urban population as opposed to 84% rural population (WHO and UNICEF 2015). Estimation by the [2] shows that 663 million people worldwide still use unimproved drinking water sources, including unprotected wells, springs and surface water. Almost half of them live in sub-Saharan Africa whereas one fifth live in Southern Asia.

Malaysia is a tropical country blessed with abundant rainfall throughout the year, yet the nation is still experiencing water shortage and issues with water quality. The Department of Environment in the 2017 Annual Report stated that almost 63.94% (144) out of 477 rivers in Malaysia are categorized as Class II whereas 30.19% (144) are in Class III. Major pollutants in the rivers are biochemical oxygen demand (BOD) from sewage, agro-based and manufacturing industries, ammoniacal nitrogen from animal farming and domestic sewage as well as suspended solids from earthworks and land-clearing activities [3]. In Malaysia, water supply for domestic use derives 99% from surface water such as rivers whereas the remaining 1% originates from groundwater [4]. The most common source of drinking water in Malaysia is tap water, bottled drinking water as well as bottled mineral water [5]. Surface water extracted from Sungai Langat, Sungai Selangor and Sungai Kinta in West Coast Peninsular Malaysia are amongst water supply most generally utilized for drinking water [6]. On the other hand, states like Kelantan, Terengganu, Pahang, Perlis, Kedah, Sabah and Sarawak use groundwater as drinking water source [7].

In Malaysia, extensive studies have been conducted on drinking water quality but to our knowledge, no extensive review on status of drinking water quality have been done thus far. While some studies focused on microbiological, chemical, elemental or physical parameters either in treated water, filtered water, ground water or mineral water; however, it is difficult to come to a conclusion with regards to the status of overall drinking water quality in this country.

Hence, this review is undertaken to systematically review on drinking water quality studies conducted in Malaysia and compile all available data on its status in this country, to compare with the National Drinking Water Quality Standards (NDWQS) and finally to provide the policy maker with scientific evidence for better management practice.
Materials and Methods

All peer reviewed cross-sectional studies which were assessing water quality in Malaysia based on the parameters in the National Drinking Water Quality Guidelines (NDWQS) were sought for. As our stakeholders were interested in the current status of Malaysian water quality, the search was limited to the more recent studies from year 2000 to May 2018. Studies were eligible for inclusion if the water samples included treated water (filtered, bottled, tap water) and groundwater (bottled mineral water, well water) that were used for drinking water. Only field-based studies of observational longitudinal or cross-sectional design that use primary or secondary data and risk assessment involving water quality parameters (whether or not included in the NDWQS) conducted in Malaysia were considered. At least one water quality parameter analysed in the studies should be included in NDWQS. The drinking water quality parameters consisted of various groups, which were physical parameters, microbiological, elementals and other chemicals.

The exclusion criteria were narrative or systematic reviews, conference abstracts, proceedings, reports, theses and keynote texts. Surface water and ground water (not used for drinking purposes) were excluded for this review. Apart from literature which were published in English and Malay language, the literature which were published in other languages such as Chinese and Indian languages were also included. We sought help from Chinese and Indian colleagues to interpret the abstract and the content of the potential eligible report.

Search strategy and quality assessment

**Table 1:** Search strategy for identification of studies.

| Keywords |
|----------|
| 1. 'tap water' OR 'raw water' OR 'drinking water' OR 'ground water' OR 'treated water' |
| 2. 'heavy metals' OR 'pesticides' OR 'microbial' |
| 3. 'pollutants' OR 'contaminants' |
| 4. 'Malaysia' |
| 5. 'quality' |
| 6. Combination of 1 AND 2 AND 3 AND 4 AND 5 |

The search for potentially included articles was mainly through on-line bibliographic databases. Systematic searches were conducted using major relevant databases i.e. Science Direct, PubMed and Scopus using the keywords and search strategy (Table 1). In addition, Google Scholars were also used in order to capture articles which were unindexed. We also checked the references list of identified studies for potential included articles. The citation of potential eligible studies retrieved was exported into the citation manager (EndNote) and duplicates were eliminated. Two reviewers independently examined the abstracts for the inclusion criteria using the pre-designed data extraction form for eligibility (Appendix 1). If there were uncertainty or disagreement, the opinion of the third person was sought to resolve and decisions were made upon reading the full text article.

The quality of each included studies was assessed based on the following domains:

1. **Optimal number of samples to determine the power of study**
2. **Sample replication to ensure precision and accuracy of the results**
3. **Water sampling method must follow the established methods**
4. **Laboratory analysis replication to ensure consistency of the measurement**
5. **Quality control parameters which emphasize on Certified Reference Materials (CRM) for elementals and chemicals.**

Assessment risk of bias was evaluated using a form (Appendix 2).

If the elements of quality assessment were not mentioned anywhere in the articles, the risk of bias was considered high while scanty description on the elements were considered unclear. The risk of bias was considered low if the elements of quality assessment were described in detail.

Statistical analysis

The mean, standard deviation and number of samples for each parameters from the included studies were extracted from the articles. The mean values are then converted to weighted arithmetic mean. Articles with high weight contribute more to the weighted mean than articles with low weight. This is to differentiate the contribution of each article based on the number of samples collected. The overall weighted mean and 95% confidence interval of all the parameters was then calculated to present the status of drinking water in Malaysia.

Results

Search strategy results

A total of 620 articles were discovered and 99 articles were identified through hand search and back searching from reference list. After screening for duplicates and relevant articles, 655 articles were excluded. The remaining 64 articles were assessed for eligibility criteria and (34) were excluded due to no relevant data available (n=30) and review articles (n=4). Thus, (30) articles were included in this review (Figure 1). No articles other than Malay and English language were found when the search strategy was conducted.

As mentioned in Figure 1, 29 articles were excluded in this review. Even though these articles were published after the year 2000, majority (86.2%) were excluded since they were intervention studies. The remaining 4 articles were not included as they were proceedings and review article (Table 2).
### Table 2: Characteristics of studies included in the review.

| Study No. as Cited in Reference | Study Abbreviation | Study Locations | Water Sample | Sampling Date | *Study Design | Water Quality Parameters Analyzed (Physical Parameters, Microbiology, Chemicals & Elements) |
|---------------------------------|--------------------|----------------|--------------|---------------|--------------|----------------------------------------------------------------------------------|
| [8] Ab Razak et al. 2016        | Pasir Mas, Kelantan | 214 drinking water samples from residential | Not stated | CS | Al, Pb, Fe, Cu, Cd, Cr, Ni, Zn |
| [9] Abdulkahar & Soh 2011       | Peninsular Malaysia (PM) | Water treatment plant - TPO, SRO, AOP | June 2003-May 2004 | CS | Alkenes (cis & trans 1,2-DCE, TCE) Alkanes (CHCl₃, CHCl₂Br, CHClBr₂, 1,2-DBA) Aromatics (benzene, toluene, ethyl benzene, chlorobenzene, 1,4 -DCB, 1,2-DCB) |
| [10] Abdulkahar et al. 2003     | Tampin, Negeri Sembilan & Sabak Bernam Selangor district | Water treatment plant - TPO, SRO, AOP | The whole year 2001 | CS | Trichloromethanes (THM) |
| [11] Abu Hassan et al. 2011     | Labu & Langat rivers | Water treatment plant - TPO | January 2005-December 2009 | CS | Ammonia, manganese |
| [12] Ahmad et al. 2015          | Sungai Petani, Kedah | 9 TW samples and 3 well water samples collected from different locations around Sungai Petani, Kedah | Not stated | CS | As, Cr, Ni, Cd, Pb |
| [13] Anita Devi et al. 2015     | Petaling Jaya, Selangor | 100 drinking water samples from residential and restaurants | Not stated | CS | pH, dissolved oxygen, biochemical oxygen demand, temperature, turbidity, nitrate, phosphate, total coliform |
| [4] Azrina et al. 2011          | PM | TW collected from 2 locations from 12 states in PM | Not stated | CS | Flouride, chloride, nitrate, sulphate, Na, Mg, K, Ca, Fe, Cu, Zn, Cr, Mn, Ni, As, Cd, Pb |
| [14] Azrina et al. 2012         | PM | 24 bottles of DW and MW samples from 22 brands collected from supermarkets & hypermarkets in Klang Valley. The TW samples were collected from different locations in the 12 selected states of PM | Not stated | CS | NO₃⁻, SO₄²⁻, Na, Mg, K, Ca, Fe, Cu, Zn, Cr, Mn, Ni, As, Cd, Pb, F, Cl |
| [15] Chan et al. 2007           | Klang Valley | Filtered and unfiltered water at point of use in houses around Kajang, Serdang, Cyberjaya, Puchong and Bangi | Jul-04 | CS | Turbidity, pH, Total suspended solid, Total coliform, E. coli, S. faecalis, P. aeruginosa |
| [16] Drullok et al. 2011        | Sg Lembing & Bukit Ubi in Kuantan District | Collected from 100 respondent kitchens’ tap | Feb - April 2011 | CS | Turbidity, pH, Total suspended solid, Total coliform, E. coli, S. faecalis, P. aeruginosa |
| [17] Idrus et al. 2014          | Rural area, Kelantan | A total of 454 groundwater samples were collected as part of monitoring quality of Water Supply and Environmental Sanitation Program (BAKAS) | Mac – Dec 2013 | CS | Ca, Mg, Na, K, HCO₃⁻, Cl, SO₄²⁻, Mn, Cr, Zn, As, Pb, Cu |
| [18] Isa et al. 2014            | Kapas Island, Terengganu | 126 groundwater samples collected from 7 boreholes that were constructed perpendicular to the coastal area with a maximum distance of approximately 150 m from the coastline. Borehole installations were done with different depths | Feb - April 2011 | CS | Ca, Mg, Na, K, HCO₃⁻, Cl, SO₄²⁻, Mn, Cr, Zn, As, Pb, Cu |
| Reference | Year | Location | Sample Size | Sampling Time | Parameters | Results |
|-----------|------|----------|-------------|---------------|------------|---------|
| [19] Khoo et al. 2011 | | Petaling Jaya & Puchong | 28 environmental water and 5 DW samples were collected in Malaysia; 26 environmental water, 3 DW and 2 effluent water were collected in Thailand | Oct-Dec 2011 | Temperature, turbidity, salinity, pH, DO, total dissolved solid | Giardia, Cryptosporidium, Hookworm, Ascaris, Schistosoma, Blastocystis, Entamoeba cysts, Enterobius ova, Hymenolepis ova, tapeworm ova, Toxocara ova, Toxoplasma oocysts, ectoparasites of the orders Anastroca & Cladocera, copepods, lice, & Brachinecta organisms |
| [20] Kumar et al. 2014 | | Songkla, the Southeastern coast of Thailand | | | | |
| [21] Lim et al. 2013 | Seri Kembangan, Selangor | 100 water samples were collected from Taman Serdang Raya, Taman Serdang Jaya, Taman Sri Serdang, Taman Universiti Indah, Taman Sungai Besi Indah, Taman Belimbang Indah, Taman Muhibbah, Kampung Baru Seri Kembangan & Taman Bukit Serdang | 21 Dec 2010 - 9 Feb 2011 | Temperature, pH, conductivity, total dissolved solid, Pb | | |
| [22] Mohd Hassni et al. 2017 | Klang Valley | 13 samples from eight natural spring water and five flavoured bottled drinking water | 2014 | Pb, Cd | | |
| [23] Mohd Sham et al. 2009 | Selangor, Perak, Melaka, Kelantan, Terengganu, Kuala Lumpur & Kota Kinabalu | 3 sites in Selangor & 1 site each in Perak, Melaka, Kelantan, Terengganu, Kuala Lumpur & Kota Kinabalu. 2067 water samples were collected from 689 selected households | Not stated | Fluoride | | |
| [24] Nalatambi 2009 | Bandar Sunway Residential area, Petaling Jaya Selangor | Collected from four different areas: Sunway University College, Sunway Villa Apartment, Sunway Condominium and PJ 7/11 Bandar Sunway. | Not stated | Cu, Cr, Cd, Zn, Pb, Ca, Mg | | |
| [25] Ong et al. 2007 | Klang Valley | TW around S1-4, Sunway, Subang Jaya, USJ, Puchong, Sri Damansara, Damansara Jaya, Tropicana, Bandar Utama, Taman Tun, Bandar Seri, Section 10, 12, 14, 17, 19 and PJ Old Town | Not stated | Colour, pH, turbidity, hardness, residual chlorine, sulphate, Zn, Ba, Cd, Cr, Pb, Cu, Fe, Mn, Mg, Ni | | |
| [26] Praveena et al. 2018 | Seri Kembangan, Selangor | Ninety water samples from water vending machines in six areas (Balakong, Serdang Jaya, Seri Serdang, Taman Pinggiran Putra, Taman Equine, Lestari Perdana) | Not stated | E. coli | | |
| [27] Qaiyum et al. 2011 | Mukim Parit Lubok & Parit Raja, Batu Pahat Johor Perak | Drinking water samples were collected at the 100 respondent’s kitchen tap. | Not stated | Al | |
### Cross sectional descriptive (CS), CS*-Cross sectional with emphasis on risk assessment; TPO-treatment plant outlet, SRO-service reservoir outlet, AOP-auxiliary outlet point; DW-drinking water, MW-mineral water, TW-tap water, ROW-reverse osmosis water.

### Study locations

Of the thirty papers included in the review, nine studies were conducted in Peninsular Malaysia consisting of several states \[4,9,14,19,23,30,31,33,35\]. A total of sixteen studies focused their study locations in a single state namely Selangor \[7,13,15,21,22,24,25,29\], Pahang \[12\], Kelantan \[8,17,34\], Terengganu \[18\], Johor \[26,32\], Perak \[27\] and Sarawak \[28\]. Two studies were conducted in selected areas in both Selangor & Negeri Sembilan \[10,11\], two studies were conducted in more than five states namely Selangor, Perak, Melaka, Kelantan, Terengganu, Kuala Lumpur and Sabah \[23\] and one study was conducted in three states which were Kelantan, Terengganu and

| Study Location | Authors & Year | Collection Method | Subsamples | Sampling Dates | Data Considered | Results |
|----------------|----------------|-------------------|------------|----------------|----------------|---------|
| Perak          | Rahmanian et al. 2015 | Collected from ex-minerals and mining activities in Bandar Universiti, Bandar Seri Iskandar, Siputut, Tronoh, Taman Maju, Batu Gajah, Universiti Teknologi Petronas & Ipoh. Drinking water samples were collected from TW of residential and commercial areas while mineral and ROW samples were purchased from local supermarkets | Not stated | CS* | pH, conductivity, turbidity, Cu, Zn, Mg, Fe, Cd, Pb, Cr, As, Hg, Sn |
| Sarawak        | Richard et al. 2016 | Two drinking water treatment plants and seven distribution system sites | July 2012-October 2013 | CS | pH, temperature, conductivity, total dissolved solids, salinity, dissolved oxygen, turbidity, ammonia, chlorine, nitrite, nitrate, fluoride, parasites (Giardia, Cryptosporidium, Spirometra, Blastocystis, nematode larvae-like, Taenia ova-like, Acanthamoeba, Naegleria) |
| Langat River basin | Santhi et al. 2012 | River waters samples were collected from Semenyih & Labu River. 30 TW samples were collected from houses in Kuala Lumpur & 9 brands of MW bottled in PET containers were purchased from shops around Kuala Lumpur | Sept 2008 - March 2009 | CS | Turbidity, pH, temperature, Dissolved oxygen, Bisphenol A |
| Pasir Mas Kelantan, Kuala Terengganu & Kota Kinabalu, Sabah | Shahrudin et al. 2010a | Three replicated water samples were collected from each sampling site. A total of 247 of parallel number of respondents from each study site involved in this study | Not stated | CS* | Fluoride |
| Selangor, Melaka, Perak, Kelantan, Kuala Lumpur, Terengganu, Sabah | Shahrudin et al. 2010b | 2067 water samples were analysed for fluoride | Not stated | CS | Fluoride |
| Kota Tinggi, Johor | Siti Fariawana et al. 2010 | 6 palm oil estates with private water supply and 4 estates with public water supply. | Jan 2009 - Jan 2010 | CS* | pH, total dissolved solid, turbidity, residual chlorine, Al |
| PM | Soh & Abdul-lah 2007 | Water treatment plant - TPO, SRO, AOP | June 2003-May 2004 | CS | Trichloroethylene, CHCl3, CHCl2Br, CHClBr2, total trihalomethane, benzene, toluene, ethyl benzene, chlorobenzene, 1,4-DCB, 1,2-DCB |
| Kelantan | Tan et al. 2016 | Seventeen water samples from water vending machines in three localities in Kelantan | Not stated | CS | pH, temperature, turbidity, E. coli |
| Johor | Yusof et al. 2001 | Disused mining pool throughout PM and 27 WTP in Johor state | Not stated | CS | pH, temperature, radionuclides (radium, thorium, uranium) |
Sabah [30]. In addition, one study was conducted in collaboration with the neighbouring country, Thailand as well as Selangor [20]; (it is worthy to note that this review only considers data for Malaysia and do not include those from Thailand).

### Water samples

Majority of the studies collected water samples from domestic kitchen tap [4,7,8,12-16,19,21,23,24,26,27,29-32] while only few studies focused on drinking water treatment plant (DWTP) samples [9,10,28,33,35]. At least three studies [11,14,22,27,29] bought some of their samples from selected supermarket or hypermarket situated around their study areas. Water samples also comprised well water [12] as well as ground water samples [17,18]. In addition, two studies collected samples from water vending machines in Selangor and Kelantan [25,34].

**Figure 1:** Flowchart for search strategy results.

### Sampling date

The earliest drinking water samples were collected in 2001 and the latest were in 2014. However, half of the selected studies (thirteen studies) did not mention sampling date. Five studies were conducted within one-year period [9,10,29,32-33]. Six studies completed their sample collection within 1-3 months’ time [15, 18-21,28]. Only one study analysed water samples in a long run, however these researchers used secondary data [11].

### Study design

Cross sectional descriptive (CS) dominated studies conducted on drinking water quality in Malaysia followed by six studies with emphasis on risk assessment to human health.
Water quality parameters

The search resulted in 64 studies retained for full text review. In total, 30 studies met the inclusion criteria. Ten studies reported on physical parameters including pH, temperature, turbidity, conductivity, total suspended solid (TSS), total dissolved solid (TDS), dissolved oxygen (DO), colour and water hardness in water samples originating from water treatment plants (WTP), tap water, mineral water, bottled drinking water as well as water from vending machines. Nineteen studies reported on elements in water samples such as arsenic (As), cadmium (Cd), lead (Pb), manganese (Mn), copper (Cu), chromium (Cr), iron (Fe), sodium (Na), potassium (K), zinc (Zn), nickel (Ni), magnesium (Mg), calcium (Ca), aluminium (Al), mercury (Hg), stanum (Sn), barium (Ba), fluoride (F), nitrate (NO₃⁻) and sulphate (SO₄²⁻). One study reported on radionuclides (radium, uranium and thorium) in disused mining pool. Six studies measured chemical parameters such as trihalomethane (THM), bisphenol A (BPA), residual chlorine and ammonia. Two studies focused on volatile organic compounds (VOCs) in WTP such as Trichloroethylene, CHCl₃, CH₂ClBr, CHBr₂Cl, total trihalomethene, benzene, toluene, ethyl benzene, chlorobenzene, 1,4-DCB, 1,2-DCB, alkenes (cis & trans 1,2-DCE, TCE), alkanes (CHCl₃, CH₂ClBr, CHBr₂Cl, 1,2-DBA) and aromatics (benzene, toluene, ethyl benzene, chlorobenzene, 1,4-DCB, 1,2-DCB). Four studies described on microbiological aspects which include total coliform, faecal coliform, E.coli, S. faecalis, P. aeruginosa in drinking water, WTP and water from vending machines. One study reported on Giardia, Cryptosporidium, Hookworm Ascaris, Schistosoma, Blastocystis cysts, Entamoeba cysts, Enterobius ova, Hymenolepis ova, tapeworm ova, Toxocara ova, Toxoplasma oocysts, ectoparasites of the orders Anastroca and Cladocera, copepods, lice and Brachinecta organisms in environmental, drinking and effluent water samples.

Study quality

More than three quarter of included articles were published in peer-reviewed journal.

Quality assessment

Table 3 reports on the overall quality assessment of parameters analysed for drinking water quality for the included articles in this review while Table 4 shows its summary. Out of 35 articles included in this review, two articles [8,28] fulfilled requirement for four quality assessment parameters (Table 3). Meanwhile, two articles [4,17,25] fulfilled requirement for three quality assessment parameters. Nine articles met only two criteria of quality assessment parameters. About four articles did not fulfil the requirement of quality assessment, where two articles did not properly described their sampling methods [11,23] while another two articles did not include any quality assessment parameters in the methodology of the article [10,13]. More than 50% of the articles were at high risk of bias (56.0%), while only 30.7% of the quality assessment parameters showed low risk of bias (Table 3). The remaining 22.2% of the quality assessment of included articles did not describe the quality assessment clearly. When individually analyzing each item of the quality assessment parameter, it can be noted that nearly three quarter (73.3%) of the articles reported a clear and well defined sampling methods while about 33.3% of articles reported on sample replication and another 23.3% of articles reported proper quality control parameters. A total of 16.7% of articles reported on analysis replication while only two studies [8,17] calculated their sample sizes (Table 4).

Table 3: Study quality and risk of bias.

| No | References          | Sample Size Calculation | Sample Replication | Sampling Method | Analysis Replication | Quality Control | Total Low Risk of Bias |
|----|---------------------|-------------------------|---------------------|----------------|----------------------|-----------------|------------------------|
| 1. | Ab Razak et al. [8] | 0                       | 0                   | 0              | 0                    | 0               | 4                      |
| 2. | Richard et al. [28] | 0                       | 0                   | 0              | 0                    | 0               | 4                      |
| 3. | Azrina et al. [14]  | 0                       | 0                   | 0              | 0                    | 0               | 3                      |
| 4. | Idrus et al. [17]   | 0                       | 0                   | 0              | 0                    | 0               | 3                      |
| 5. | Praveena et al. [25]| 0                       | 0                   | 0              | 0                    | 0               | 3                      |
|   | Authors                                      | Year | Source | Current Status |
|---|---------------------------------------------|------|--------|----------------|
| 6 | Abdullah & Soh [9]                          | 2015 | ISO 8575 | 2              |
| 7 | Azrina et al. [4]                           | 2015 | ISO 8575 | 2              |
| 8 | Chan et al. [15]                            | 2015 | ISO 8575 | 2              |
| 9 | Dzulfikar et al. [16]                       | 2015 | ISO 8575 | 2              |
| 10| Isa et al. [18]                             | 2015 | ISO 8575 | 2              |
| 11| Khoo et al. [19]                            | 2015 | ISO 8575 | 3              |
| 12| Qayyum et al. [26]                          | 2015 | ISO 8575 | 2              |
| 13| Soh & Abdullah [33]                         | 2015 | ISO 8575 | 2              |
| 14| Yusof et al. [35]                           | 2015 | ISO 8575 | 2              |
| 15| Ahmad et al. [12]                           | 2015 | ISO 8575 | 1              |
| 16| Kumar et al. [20]                           | 2015 | ISO 8575 | 1              |
| 17| Lim et al. [21]                             | 2015 | ISO 8575 | 1              |
| 18| Mohd Hasni et al. [22]                      | 2015 | ISO 8575 | 1              |
| 19| Nalatambi [24]                              | 2015 | ISO 8575 | 1              |
| 20| Ong et al. [7]                              | 2015 | ISO 8575 | 1              |
| 21| Rahmanian et al. [27]                       | 2015 | ISO 8575 | 1              |
| 22| Santhi et al. [29]                          | 2015 | ISO 8575 | 1              |
| 23| Shaharuddin et al. [30]                     | 2015 | ISO 8575 | 1              |
| 24| Siti Farizwana et al. [32]                  | 2015 | ISO 8575 | 1              |
| 25| Tan et al. [34]                             | 2015 | ISO 8575 | 1              |
| 26| Abdullah et al. [10]                        | 2015 | ISO 8575 | 0              |
| 27| Abu Hasan et al. [11]                       | 2015 | ISO 8575 | 0              |

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Results for physical parameter

Figure 2 shows the pooled mean of physical parameters in reviewed articles which include pH, turbidity, total suspended solid (TSS), total dissolved solid (TDS), and temperature. There were twelve articles reporting on pH, ten on turbidity, two on TSS, four on TDS, and seven on temperature. Reported pH levels from most of the studies complied with Malaysian National Drinking Water Quality Standard (NDWQS) except for studies by [15,32]. Study by [32] also demonstrated turbidity levels almost two times exceeding the 5 NTU limit in the NDWQS. The range of fluoride reported by both articles by [30,31] were below than the range stipulated in NDWQS. To date, no reference levels exist for TSS, temperature, sulphate, and fluorine.

Results for total element concentrations

Pooled average and range of total elements concentrations (mg/L) in drinking water in Malaysia as reported by included articles are presented in Figure 3-6. Figure 4 showed the pooled average and range of total element concentrations (mg/L) that exceeded the NDWQS; they were arsenic (As), cadmium (Cd), lead (Pb), manganese (Mn), nickel (Ni), aluminium (Al), chromium (Cr) and, copper (Cu). Elements concentrations varied widely for different studies. The highest concentrations and the only exceeding average value for Mg were reported by [7] while for other studies all values were below the range stipulated in NDWQS. To date, no reference levels exist for TSS, temperature, sulphate, and fluorine.

Chemical parameters

In this review, chemical parameters include ammonia, trihalomethane (THM), chloroform, bisphenol A (BPA), trichloroethylene (TCE), benzene, toluene, ethylbenzene, chlorobenzene, dichlorobromomethane, and other volatile organic compounds (VOCs) such as 1,2 DBA, 1,4 DCB and 1,2 DCB which originated from four studies [9,10,29,33].
Measurements of VOCs were reported by [9,33]. The highest eleven organic compounds at different sampling points in Negeri Sembilan including chlorobenzene, dibromochloromethane, toluene and 1,1,1,2-Tetrachloroethane were described by [33]. Similar VOCs were measured by [9] in a study conducted in Peninsular Malaysia. None of the VOC concentrations from these two studies exceeded the NDWQS.
Figure 3: Pooled average and range of inorganic ion levels in drinking water as reported by included articles
Figure 4: Pooled average and range of total elements concentrations (mg/L) in drinking water that exceeded NDWQS in Malaysia as reported by included articles.
THM concentrations reported by [10] ranged from 2.4 to 136.5µg/L (average: 61.0 ± 18.0µg/L) from distribution system for districts of Tampin and Sabak Bernam. None of the samples exceeded the stipulated THM guidelines of 1000µg/L in the NDWQS.

A study by [29] reported BPA concentrations in tap water and bottled polyethylene (PET) containers. BPA concentrations in 30 tap water samples ranged from 3.5 to 59.8ng/L (average: 14.1 ± 14.4ng/L) with highest BPA concentrations detected in samples connected to PVC pipes and water filter devices. Mean
BPA concentrations in mineral bottled water at room temperature (25°C) were significantly lower (3.3 ± 2.6ng/L) compared to those stored at 50°C (11.3 ± 5.3ng/L). BPA is not listed under the NDWQS.

Discussions

This review aims to shed light on the status of drinking water quality in Malaysia. Thus far, numerous studies have been conducted pertaining to physical, elemental, chemical and microbiological properties in drinking water. After screening articles for inclusion criteria, only thirty articles were included in this review.

All the included articles were of cross-sectional study design. We constructed domains for quality assessment of such studies which consist of sample size calculation, sample replication, sampling method, analysis replication and quality control for the lab techniques. Those quality assessment parameters are crucial to ensure more reliable and valid results. With an exception of one article [17], majority of the included articles did not perform the calculation of optimum sample size needed. Sample size calculation and stratification of sampling point is necessary to enable the inference of the result [36]. Other than that, quality assessment criteria which was lacking by the researchers were replication of the analysis. Thus, it is possible that these studies may be subjected to systematic errors resulted from observer bias and information bias.

In the NDWQS, recommended level for pH is between 6.5 to 9. Most of the included articles were within the range except for study by [15,32]. Study by [32] reported pH levels in drinking water between 5.81 to 7.41 which were slightly acidic for some of the samples. As for turbidity, the level of 5 NTU stipulated in the NDWQS was also exceeded by [32]. Study by [32] was conducted in palm oil estates in Kota Tinggi, Johor which used water samples from private water supply. Inefficiency of water treatment system as well as lack of training by personnel who handled the water treatment process were the main reasons for violation of water samples for pH and turbidity. Study by [15] reported slightly acidic drinking water samples from Kajang, Cyberjaya and Bangi. However, reasons for violation were not mentioned in the study.

Physical parameters such as pH is an important parameter as low pH may cause corrosion of pipes resulting in the presence of certain heavy metals such as cadmium, copper, lead and zinc although there is no health-based guideline value [37]. The WHO Guidelines for Drinking Water Quality 2007 suggests pH level between 6.5 to 9.5 in comparison with NDWQS for pH between 6.5 to 9.0. Although the upper limit for pH in the NDWQS is slightly lower than the WHO guidelines, pH levels in these studies [15,32] are not a matter of concern as chlorine disinfection is effective at pH less than 8 [37]. Turbidity affects the aesthetical values of drinking water as a result of visible cloudiness. To ensure effectiveness of disinfection, turbidity should be less than 1 NTU as recommended by the WHO [38]. Furthermore, water with high turbidity leads to health risk where it is ineffective against disinfectants as well as encourage bacterial growth during storage [39].

As for fluoride, studies by [23,30,31] showed mean fluoride levels which were lower than the NDWQS. As for [23], some of the samples slightly exceeded the upper limit of 0.6mg/litre of the fluoride levels in the NDWQS. Fluoride is widely used in dental preparations to combat dental caries, particularly in areas on high sugar intake by which it can be in the form of tablets, mouth washers, toothpaste, varnishes or gels for local applications. It is also added in drinking water in order to provide protection against dental cavities [40]. The WHO recommends fluoride levels in drinking water to be between 0.9 to 1.2mg/L. In Malaysia, the Oral Health Division of the Ministry of Health has initiated the programme to add fluoride in drinking water since 1972. Initially, the recommended fluoride levels in Malaysian drinking water were 0.7 to 1.0mg/L. Considering the availability of alternative sources of fluoride and the higher average volume of water intake in a tropical climate, the levels have been reviewed to between 0.5 to 0.7mg/L [41]. The NDWQS was revised recently and the fluoride levels permitted in drinking water are between 0.4 to 0.6mg/L.

In this review, studies reporting on chemical elements were very scarce. Only 14% out of the total number of studies included reported on chemical elements. For chemical parameters, pooled estimates were not able to be calculated as data was insufficient for each chemical parameters. Although some of the VOC compounds were reported by more than one studies, however results from [33] cannot be utilized for the computation of summary mean estimates because the study did not mention the number of water samples collected.

In general, measurements of VOC, THM and BPA reported by the researchers were within the stipulated guidelines of the NDWQS. VOC and THM levels were considered low since the levels were only about up to 20% of the recommended guideline values.

As for BPA, the parameter is not listed in the NDWQS hence no comparison against the guidelines can be made. Bisphenol A is a monomer used extensively in the production of polycarbonate, epoxy resins and as a non-polymer additive in plastics such as polystyrene. BPA is also added in drinking water in order to provide protection against dental cavities [40]. The WHO recommends fluoride levels in the NDWQS. Fluoride is widely used in dental preparations to combat dental caries, particularly in areas on high sugar intake by which it can be in the form of tablets, mouth washers, toothpaste, varnishes or gels for local applications. It is also added in drinking water in order to provide protection against dental cavities [40].

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with [29] were lower ranging from not detected to 2ng/L [46,47] whereas [48-50] reported higher BPA levels in water samples from Brazil and China at 160ng/L and 99ng/L. Inclusion of this endocrine disrupting chemicals (EDC) as one of the parameters in the guidelines is deemed essential. Many EDC-related diseases are currently on the rise and EDC are found in many products such as plastic bottles, detergents, flame retardant, food, toys and even cosmetics.

In terms of microorganisms, the number of studies conducted were very limited. However, based on those studies, it was found that the unfiltered water and underground water were highly contaminated. One of the study has revealed that all the unfiltered drinking water that were sampled were positive for coliforms, fecal coliforms and E. coli which concluded that the drinking water is not safe to be consumed and may be harmful to human health. The total viable count for the samples were high and did not comply with the safety regulation from European Council (EC) for drinking water. It was compared with EC as Food Act and most countries do not state the limit of total count for drinking water. Another study that was conducted on groundwater which is used as drinking water, similar results were found. 49% of the samples were positive for Total coliform, 14% positive for E. coli and 3% positive for Salmonella even though according to the National standard for Drinking water, Total Coliform and E. coli must be absent in drinking water. As for the presence of parasite in the water, only one study was conducted, and it was found that drinking or household water is free of parasites. However, it was shown that the untreated environmental water was contaminated with waterborne parasites.

The generally low number of available studies in this review which fulfill the inclusion criteria means that interpretation of results must be exercised with caution. Nevertheless, extensive effort in searching databases safeguards against missing relevant studies. The limitation of this review is that the search strategy was conducted only until May 2018 and does not consider any results must be exercised with caution. Hence, relevant studies pertaining to drinking water quality in Malaysia might have been missing out and not included in this review.

Conclusion

Population growth and rapid industrialization advancement are some of the factors that increase pollutants in drinking water. In general, while some studies portray low level of contaminants and do not exceed the national drinking water guidelines, some studies slightly exceeded the stipulated guidelines. Although the overall water quality in Malaysia is fairly acceptable, we have to bear in mind that water pollution is rampant nowadays and measures have to be undertaken to safeguard the quality of drinking water through water treatment technology by water providers.

Author Contributions

All authors had complete access to the data in the study. NA contributed to the study concept and design. ZF and WNF acquired the data for the study. NA and WNF developed the search strategy. WR and NMS developed the pooled mean analysis. NIA and YV assisted with the analysis and interpretation of data. All authors were involved in the development of the manuscript. All authors critically revised the manuscript and approved the final version.

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