Assessment of the quality of Moroccan bottled water by application of quality indices

E. Gharibi, M. Ghalit, J.-D. Taupin, N. Patris and D. Kouotou

ABSTRACT

Water quality indices (WQI) are essential tools for the overall assessment of the quality of water reserved for human consumption or for other uses. In the present study, two WQI were selected for the assessment of bottled waters: the Canadian Council of Ministers of the Environment (CCME-WQI) index and the bottled water quality index (BWQI). Both indices illustrate the composite influence of different water quality parameters and communicate water quality information to the public and legislative decision-makers. Another indicator of water quality (total hardness–total dissolved solids) is used to compare these results with the two quality indices. The results obtained showed that the mineral waters EM_2, EM_4, EM_7, spring water E_S and table water are of excellent quality. Waters EM_1, EM_3, EM_5, and EM_6 are good enough to drink. By contrast, the gaseous mineral waters (EM_G and EM_{GL}) are considered unacceptable for sustained or substantial consumption.

Key words | bottled waters, bottled WQI, CCME–WQI, Morocco, total hardness–total dissolved residues index, water quality indices

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INTRODUCTION

Access to clean and drinkable water that meets quality standards is still not possible for more than one billion people (Smedley & Kinniburgh 2002). The degradation of water quality due to different contamination sources makes oversight of its quality a necessary priority. Several water quality indices (WQIs) have been developed to evaluate its bio-physical-chemical characteristics. They are used to enable different environmental monitoring agencies to check quickly and make effective decisions. A water's quality is judged on the basis of various substances it contains, their quantity and their effects on the ecosystem and on human beings. It can be evaluated using physical, chemical, biological and microbiological parameters, to match up with the standard level for each substance which can be mandatory or recommended by the World Health Organization (WHO 2011). The use of each quality parameter taken individually does not give enough significance to describe water quality. Therefore, WQIs have been developed to provide numerical expressions linking a large number of quality parameters into a single cumulative factor and thus present a global status on the water quality. They are usually given as a simplified and logical expression, such as excellent, very good, marginal or poor, etc. (Nasirian 2007; Semiromi *et al.* 2011), allowing management decisions (Karbassi *et al.* 2011; Lumb *et al.* 2011).

Finally they reflect the ability of surface water and groundwater to be consumed by humans or not (Akoteyon *et al.* 2011; Gebrehiwot *et al.* 2011; Al-Omran *et al.* 2015; Sethy *et al.* 2017). Horton (1965) gave the first formulation of a water quality index, in which he took into account the reduction of variables, their reliability and the significance of the sampling sites.

Several WQI have been proposed (Brown *et al.* 1970; Hallock 2002; Abbasi & Abbasi 2012; Tsakiris 2016). Similarly, several countries have adopted the WQI approach to assess the overall status of their water reservoirs, e.g. Canada (CCME 2001) which adopted the CCME–WQI, the United States (Canter 1996), and the United Kingdom (House 1990).

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NSF–WQI (Brown *et al.* 1970) is the index most widely used. This index is based on the improvement of the Horton index (Horton 1965) after a more in-depth definition of the different parameters that characterize water quality.

The two indices, NSF–WQI and CCME–WQI have been adopted and are used by several countries (Alexakis *et al.* 2016). The CCME–WQI index is defined as a basis for communication on water quality issues between several countries.

A specific groundwater quality index for human consumption (GWQI) has been developed and is one of the most effective ways to describe the quality of groundwater (Krishan *et al.* 2016; Zaidi *et al.* 2016; Bouderbala 2017; Singh & Hussian 2017).

For bottled water, a new index known as BWQI has been presented in the works of Toma *et al.* (2013) and Tsakiris (2016), constituting the first attempt to classify well kept and conditioned waters.

However, limitations of the different WQIs usually require the use of several WQI. An index relies on subjective judgements to measure only a few of the numerous variables available. Likewise, an index is often limited in terms of time and space. In addition, these indices do not take into account the impact of other types of contaminants (hormones, pharmaceutical traces, radioactive elements, etc.) which have been reported in drinking water in different countries. To take these limitations into account, several methods have been proposed in the literature for estimating unequal influences of the parameters or the indicators in the development of an index. Two broad categories are mostly used: statistical-based methods (like PCA/PFA) and participatory-based methods (subjective evaluation by experts). However, those methods are not universally suitable (Sutadian *et al.* 2017). Hence, other tools have been tested and have shown to be more satisfactory to determine and prioritize the parameters. Among them the AHP (Analytic Hierarchy Process), which is a Multi Criteria Decision Analysis tool, was tested in different research areas with success (Sutadian *et al.* 2017). It allows users to calculate the magnitude of each parameter and prioritize them. Sutadian *et al.* (2017) have used this tool on 70 different water parameters (physical–chemical parameters, chemistry, trace metals, detergents, microbiology, etc.) in a West Java river and the results showed that only 13 parameters were predominant in WQI for this zone of study.

The objective of the present study is to determine the quality of several bottled waters used in Morocco based on the two main quality indices (BWQI and CCME–WQI) and to evaluate the strengths and weaknesses of the two WQI models, and hence to suggest the most appropriate index model.

MATERIALS AND METHODS

Sampling

The bottled waters studied (17 bottles of 0.5 and 1.5 L) were bought in a supermarket according to the recommendations of the International Bottled Water Association (IBWA 2008; Dege 2011).

All the bottles used were made of plastic, mainly polyethylene terephthalate (PET). The chemical analysis of bottled water for trace elements was performed by Inductively Coupled Plasma–Mass Spectrometry (ICP–MS) modeliCAP Q ThermoScientific. The analytical methods applied are described in detail in *Standard Methods for the Examination of Water and Wastewater* (APHA 2005) and water analysis (Rodier *et al.* 2009).

The bottled water sector in Morocco has seven main local operators, such as Oulmès Mineral Waters, which is the leading operator with over 72.6% of the total value of the market at 150M$ in turnover, Sotherma (17.5%, 30M$), CCI (3.4%, 5M$), Brasseries of Morocco (3.2%, 5M$), Al Karama (1.4%, 2M$) and other companies including Sodalmu and Mineral Water Chefchaouen. The average consumption of bottled waters was estimated to be 28.4 L per inhabitant in 2015.

The studied waters are either produced in areas far away from agglomerations (denominated natural mineral and spring waters), or table waters that are taken from public drinkable water supply networks of cities and which undergo ultrafiltration treatment or reverse osmosis purification. As per Moroccan Law No. 36–15 on water, the term natural mineral water identifies a water coming directly from a groundwater compartment by natural (spring water) or drilled emergences, which has a naturally constant chemical composition and which does not require any chemical treatment to make it drinkable.

This study includes seven natural mineral waters (EM_1–EM_7), one gaseous natural mineral water (EM_G), one carbonated natural mineral water (EM_F), one gaseous light natural mineral water (EM_{GL}), one spring water (E_S), five table waters (ET_1–ET_5) and one carbonated table water (ET_P) (Table 1) (Ghalit *et al.* 2015; METLE 2016).

Water quality indices

In the present study, two indices of water quality were determined: the BWQI developed by Tsakiris (2016) and adapted for the evaluation of bottled water, and the CCME–WQI defined by the Canadian Council of Ministers of the Environment (CCME 2001). The results were compared to the basic total hardness–total dissolved solids (TH–TDS) index (Li *et al.* 2014; Du *et al.* 2017).

BWQI index

The proposed BWQI is actually the first scientifically designed index for bottled water samples. It is based on seven parameters of water: pH, *Escherichia coli* bacteria, nitrates, nitrites, chlorides, sulphates and electrical conductivity. Each parameter is represented by a sub-index (SI) on a scale of 0 to 1. The model consists of two steps, the first step being an ON/OFF process testing the bottled water sample for two requirements: (a) absence of an *Escherichia coli* bacteria population; and (b) pH between 6.5 and 9.5. If these two requirements are met, the evaluation procedure continues to the second step, based on a multiplicative model using the other five parameters with their corresponding exponents. This multiplicative process is presented by the following relation:

$$\prod_{i=1}^{N} Si^{\lambda_i}$$

where S_i is a sub-index ranging from 0 to 1, representing the 7 parameters; the λ_i exponents refer to sensitivity coefficients and represent the weight of each sub-index in the final index; and N represents the total number of sub-indices that participate in this multiplicative procedure.

It should be mentioned that the absolute maximum values of the selected parameters are the limits of the values proposed by the European and WHO standards (Council Directive of the European Union 1998; WHO 2011), above which water is not appropriate for human

Table 1 | Sampled bottled water in Morocco

Samples		Source	Society	Subsidiary company
EM_1	Aïn Saïss	Aïn Saïss	SOTHERMA Danone	AL MADA
EM_2	Sidi ali	Sidi Ali Cheriff	OULMES s.a.	Holmarcom
EM_3	Sidi Harazem	Sidi Harazem	SOTHERMA	AL MADA
EM_4	Aïn Atlas	HAMOU AGAMGAM	OULMES s.a.	Holmarcom
EM_5	Aïn Ifrane	BENSMIM	EAE	Groupe Castel
EM_6	Aïn Soultane	Imouzzer Kandar	AL KARAMA	Ynna Holding Groupe Chaabi
EM_7	Chaouen	Sahel Kharouba	Water Mineral Chefchaouen s.a.r.l	–
EM_F	Aïn Saïss finement pétillante	Aïn Saïss	SOTHERMA Danone	AL MADA
EM_G	Oulmés	Lalla haya	OULMES s.a.	Holmarcom
EM_{GL}	Oulmés Légère	Lalla haya	OULMES s.a.	Holmarcom
ES	RIF	Sahel Kharouba	Water Mineral Chefchaouen s.a.r.l	–
ET_1	Bahia	Berrechid	OULMES s.a.	Holmarcom
ET_2	Ciel	Oujda	The Coca Cola Company	CCI
ET_3	Mazine	Berrechid	SODALMU	–
ET_4	Maraqua	Benslimane	Maraqua Waters s.a.r.l	–
ET_5	Amane Souss	Ait melloul	AL KARAMA	Ynna Holding Groupe Chaabi
ET_P	Bonaqua Pétillante	Marrakech	The Coca Cola Company	CCI

consumption. If the measured parameter is above the allowable value, the S_i value becomes null.

Usually, scores above 0.850 reflect excellent water, while marks ranging from 0.700 to 0.850 are given for adequate/good water quality For an index less than 0.700, the quality of the water is considered marginal. If the score is null, the bottled water is of unacceptable quality.

CCME–WQI index

CCME–WQI provides a consistent method which was formulated by Canadian jurisdictions to convey water quality information for both home management and public use. Moreover, the Canadian Council of Ministers of the Environment (CCME) has developed a WQI which can be applied by many water agencies in different countries by integrating slight modifications (CCME 2001; Lumb et al. 2006). This method was developed in order to evaluate surface water for the protection of aquatic life in accordance with specific guidelines. The parameters related with various measurements may vary from one station to another, and the sampling protocol requires at least four parameters, which should be sampled at least four times (Tyagi et al. 2013).

The CCME–WQI combines three reduced variables (scope (F_1), frequency (F_2) and amplitude (F_3)) ranging from 0 to 100, and yielding a final number ranging from 0 to 100 according to the equation below:

$$WQI = 100 - \frac{\sqrt{F_1^2 + F_2^2 + F_3^2}}{1.732}$$

Here 'scope' represents the degree of non-compliance with water quality guidelines during the study period; 'frequency' represents the percentage of 'non-compliant results'; and 'amplitude' represents the gap between the non-conforming analytical results and the objectives to which they relate. According to the CCME–WQI value, water is classified into five categories which are: excellent, good, fair, marginal and poor. The value 100 expresses excellent quality (CCME 2001).

TH vs TDS index

Another basic quality drinking water index (Li et al. 2014; Du et al. 2017) is the relationship between the total dissolved solids and the total hardness. The TDS represents the total weight of solids dissolved in a solution and expresses the degree of salinity of water. Water may be classified as freshwater (TDS < 1,000 mg/L), brackish water (1,000 < TDS < 10,000 mg/L) and saline water (TDS > 10,000 mg/L) (Wanda et al. 2011). The TH is a measure of the Ca^{2+} and Mg^{2+} content dissolved in water and is expressed as $CaCO_3$. Waters can be classified as fresh water (TH < 150 mg/L ($CaCO_3$), moderately hard water (150 < TH < 300 mg/L), hard water (300 < TH < 450 mg/L) and very hard water (TH > 450 mg L)) (Peiyue et al. 2011).

Although the TDS and TH are two important parameters for indicating that water may be drinkable, they do not fully reflect the overall quality of the water.

LOCALIZATION AND CHEMISTRY OF BOTTLED WATERS

Table waters produced from public drinkable water supply networks undergoes additional approved treatments (ultrafiltration, reverse osmosis, etc.) before being bottled. The origin of these waters is not taken into account, being blurred by a series of artificial physical–chemical processes which can deeply change their chemical quality. The Bonaqua water (ET_P) has been artificially gasified.

Natural mineral waters and spring water are obtained directly from groundwater by a natural emergence or by drilling, and these waters have a constant chemical composition over time and do not require any further chemical treatment to be made drinkable.

With the exception of the mineral water of Chaouen (EM_7) and the Rif spring water (E_S), which come from the Rif, all other natural waters have their origin in the plateau of Oulmès in Meseta located in the Middle Atlas region in the western part of Morocco (Figure 1).

The chemistry of mineral waters from springs or other natural waters depends on their geological context. E_S, EM_1, EM_4, EM_5, EM_6 and EM_7 are extracted or emerge from a Jurassic carbonate aquifer (limestone and dolomite) with bicarbonated calco-magnesian facies, with a possible interaction with other minerals during

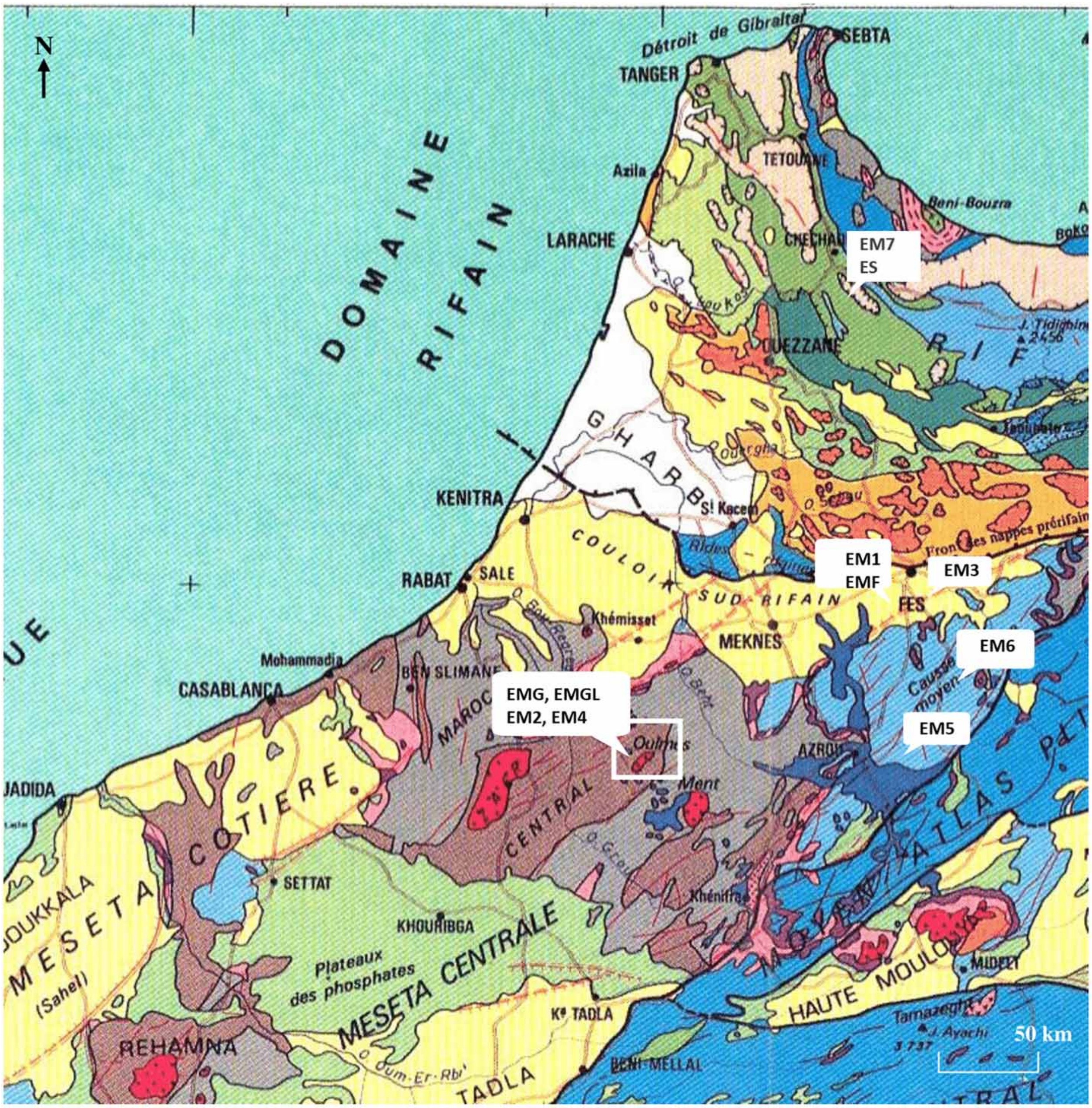

Figure 1 | Geological situation of the main sources of bottled waters in Morocco (Elbatloussi *et al.* 2005).

underground transfer when sodium predominates (Cidu & Bahaj 2000). EM_3 comes from Miocene detrital marls with the presence of evaporite layers which give a chlorinated calco-sodium facies (Charroud *et al.* 2007). EM_2, EM_G (EM_{GL}) arise in the granites of the Oulmès plateau, showing a sodium bicarbonate facies. Nevertheless, EM_G contains chlorides, and presents a natural gas phase which suggests that, in addition to the geological context, the chemical acquisition of water may include the contribution of CO_2 and a mineralized fluid of deep origin (Wildemeersch *et al.* 2010).

To proceed with quality water classification, 29 parameters have been determined according to Rodier *et al.* (2009) and are compiled in Table 2.

Table 2 | Analytical results

Parameter	Water Unit	EM_1	EM_2	EM_3	EM_4	EM_5	EM_6	EM_7	EM_F	EM_G	EM_{GL}	E_S	ET_1	ET_2	ET_3	ET_4	ET_5	ET_P
E.C.	μS/cm	663	291	1,299	335	582	695	518	653	2,160	2,160	175	334	166	355	192	234	1,226
pH	–	7.5	7.55	7.44	7.73	7.55	7.58	7.32	5.45	6.02	5.71	7.1	7.05	7.03	6.94	7.05	6.77	5.38
Alc	mg/L	366	73.2	341.6	170.8	402.6	442.3	311.1	372.1	823.5	854	109.8	42.7	64.1	54.9	30.5	51.9	268.4
TDS	mg/L	545.5	182.3	877.1	273.6	559.9	615.6	464.3	341	1,206	1,358	167	273	160	187	186	122	742
DOC	mg/L	2.45	1.55	7.77	5.22	7.38	8.8	8.05	6.19	11.78	9	4.69	1.2	4.28	2.74	1.4	1.26	7.78
Color	TCU	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Ca^{2+}	mg/L	56.1	16	69.7	19.2	89.7	76.1	79.3	63.3	105.2	102.5	28	7.2	11.2	16	14.5	16	50.5
Mg^{2+}	mg/L	43.6	7.7	37.9	12.2	35.1	46.5	14.8	45.1	66.6	58.2	6	5.3	4.3	9.6	7.7	7.2	15.8
TH	mg/L	329	69	190	319	71	368	536	98	46	79	68	2,589	495.4	39.7	94.5	381.2	343.3
P	mg/L	0	0.11	0.02	0.18	0.06	0	0	0.03	0.49	0.45	0.01	0	0	0	0	0	0
Cl^-	mg/L	46.15	21.3	246.7	14.2	14.2	10.6	17.7	55	301.7	291.1	12.2	81.6	32	82.5	33.7	42.6	49.7
$NO_{3\text{-}(NO2\text{-})}$	mg/L	8.32	1.49	3.98	5.19	6.62	23.08	1.67	8.64	2.18	2.89	0.78	0.93	1.14	10.07	1.7	2.52	6.69
SO_4^{2-}	mg/L	8.1	37.6	26.8	12.1	8.5	12.9	25.2	9	13.8	14.6	15.9	22.7	16.9	16.9	15.8	21.6	105.3
NH_4^+	mg/L	0.12	0.1	0.09	0.08	0.08	0.09	0.08	0.08	0.13	0.09	0.08	0.08	0	0	0	0	0
Na^+	mg/L	16.6	22.6	148	34.2	2.4	3.4	13.8	15.1	267.2	267.2	10.1	61.4	29.2	45.8	9.6	24	105.6
K^+	mg/L	0.5	2.3	2.4	5.6	0.7	0.7	0.6	0.5	21.5	21.4	0.5	1.1	0.8	0.8	0.5	1	1.1
Ba	mg/L	11.62	31.69	16.15	40.14	6.01	7.9	24.62	11.98	248.33	272.1	11.34	12.01	0.25	15.77	0.5	0	75.93
As	mg/L	0.14	1.1	0.39	3.33	0.06	0.14	0.05	0.6	15.58	13.72	0.03	0.1	0.05	0.17	0.01	0	0.9
Zn	mg/L	0.35	6.09	0.38	0.21	0.97	0.77	3.01	0.42	16.67	5.42	1.96	0.31	0.43	0.93	4.73	0	2.3
Pb	mg/L	0	0	0	0	0	0.01	0	0.52	0.05	0	0	0	0	0	0.04	0	0
Fe	mg/L	0.4	0.2	0.5	0.2	0.13	0.94	0.44	0.78	5.22	2.14	0.25	0.58	0.27	8.21	0.08	0	1.2
Cr	mg/L	0.32	0.03	0.34	0.12	0.69	0.16	0.05	0.4	0.02	0.04	0.04	0.09	0.41	0.04	0.66	0	0.08
Cd	mg/L	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cu	mg/L	0.08	0.56	0.1	0.03	0.12	0.28	0.05	0.36	11.76	2.02	0.03	0.02	0.19	0.34	0.27	0	1.32
Ni	mg/L	0	0.65	0.02	0	0.1	0.18	0	0.01	8.71	1.74	0.05	0.06	0.12	0.07	0.43	0	0.23
Mn	mg/L	0.07	0.05	0.04	0.01	0	0.03	1.14	0.1	470.66	501.86	21.61	0.03	0.03	0.16	0.07	0	0.25
Al	mg/L	0.69	0.86	1.42	3.3	0.04	1.87	1.22	2.14	6.33	3.97	0.67	12.11	0.5	16.92	1.82	0	24.7
Br	mg/L	0.12	0.1	0.13	0.1	0.21	0.1	0.1	0.12	0.14	0.14	0.1	0.15	0.22	0.1	0.1	0	0.1
F	mg/L	1.63	1.1	1.03	1.23	0.12	0.25	0.39	1.63	0.31	0.31	1.32	0.95	1.06	1.14	1.25	0	1.23

RESULTS AND DISCUSSION

The calculations of the BWQI, CCME–WQI model and TDS–TH are summarized in Table 3.

The classification of waters in relation to the TDS–TH graph (Figure 2) shows waters distributed between plot zones Z_1, Z_2, Z_3 and Z_8: Z_1 includes table waters with low mineralization and fresh waters EM_2 and EM_4 from the Oulmes plateau; Z_2 corresponds to carbonated table water and mineral waters from the Chaouen area; and Z_3 comprises the Middle Atlas waters, except for the deep thermal waters of Oulmès, which are classified in Z_8 as very hard waters.

Considering Table 3, the classifications of the three quality indices generally present the same range in the excellent–good level for the whole sample set. However the TDS–TH methodology is more restrictive with intermediate range quality.

The majority of the waters studied, still or gasified, are in the excellent to good categories. The mineral waters EM_3, EM_5 and EM_6 show lower quality indices than those of the other waters. Gaseous mineral waters (EM_G and EM_{GL}) have been found to be fair or unacceptable for human consumption.

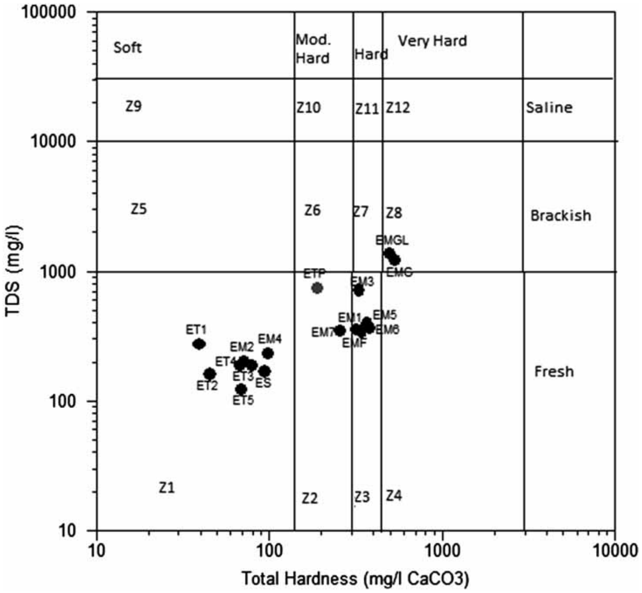

Figure 2 | Water distribution according to the TDS–TH classification.

Table 3 | Quality indices of bottled water in Morocco

		BWQI[a]		CCME–WQI[b]		TDS–TH[c]	
Sample	**Code**	**Score**	**Quality**	**Score**	**Quality**	**Zone**	**Quality**
Aïn Saïss	EM_1	0.76	Adequate/Good	90	Good	Z3	Hard–Fresh
Sidi Ali	EM_2	0.92	Excellent	100	Excellent	Z1	Soft–Fresh
Sidi Harazem	EM_3	0.52	Marginal	95	Excellent	Z3	Hard–Fresh
Aïn Atlas	EM_4	0.87	Excellent	100	Excellent	Z1	Soft–Fresh
Aïn Ifrane	EM_5	0.82	Adequate/Good	95	Excellent	Z3	Hard–Fresh
Aïn Soultane	EM_6	0.51	Marginal	95	Excellent	Z3	Hard–Fresh
Chaouen	EM_7	0.92	Excellent	100	Excellent	Z2	Moderately Hard–Fresh
Aïn Saïss FP	EM_F	0.76	Adequate/Good	90	Good	Z3	Hard–Fresh
Oulmés	EM_G	0	Unacceptable	67	Fair	Z8	Very Hard–Brackish
Oulmés L	EM_{GL}	0	Unacceptable	67	Fair	Z8	Very Hard–Brackish
RIF	E_S	0.95	Excellent	100	Excellent	Z1	Soft–Fresh
Bahia	ET_1	0.88	Excellent	100	Excellent	Z1	Soft–Fresh
Ciel	ET_2	0.90	Excellent	100	Excellent	Z1	Soft–Fresh
Mazine	ET_3	0.79	Adequate/Good	100	Excellent	Z1	Soft–Fresh
Maraqua	ET_4	0.90	Excellent	100	Excellent	Z1	Soft–Fresh
Aman Souss	ET_5	0.87	Excellent	100	Excellent	Z1	Soft–Fresh
Bonaqua P	ET_P	0.87	Excellent	90	Good	Z2	Moderately Hard–Fresh

[a]Tsakiris (2016).
[b]CCME (2001).
[c]Li *et al*. (2014); Du *et al*. (2017).

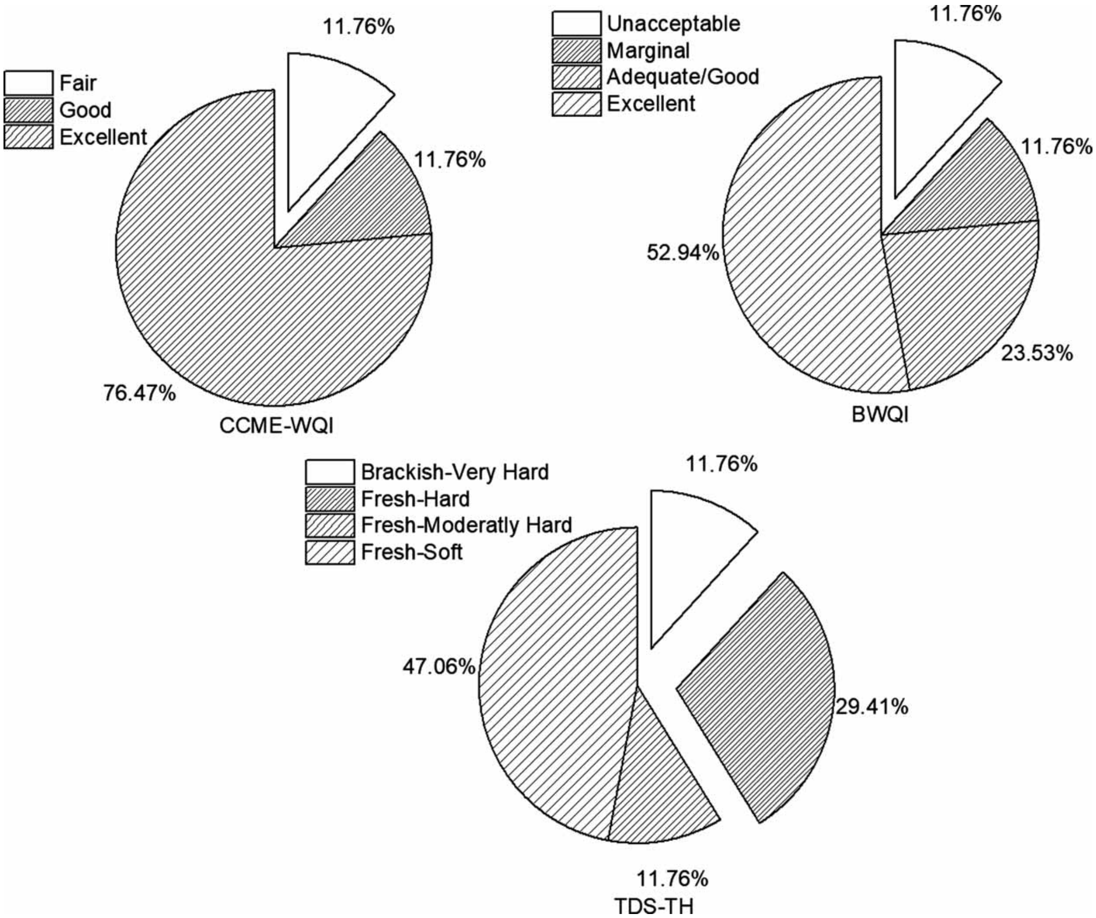

Figure 3 | BWQI, CCME–WQI and TDS-TH distribution of the bottled water.

Regarding the origin of waters, the water extracted from the Rif (EM_7 and ES) and the superficial springs (EM_2 and EM_4) are of excellent quality. Springs from Middle Atlas show good quality indices, whereas the deep thermal waters taken from the plateau of Oulmès are of a mediocre quality. Overall (Figure 3), the 'excellent' qualification represents 82.35% of the waters tested for CCME–WQI, 52.94% for BWQI and 47.06% for TDS–TH. The three approaches agree in classifying the gaseous mineral waters as not recommended for long-duration consumption.

CONCLUSION

In order to assess the impact of physico-chemical parameters on the quality of water (drinking water in particular), different WQI have been developed, based on numerical modelling, presenting a global status for water quality. Even if these assessments are often subjective and incomplete (e.g. non-inclusion of new contaminants) they are used by numerous countries to define the conditions of use.

Two global WQI used internationally (CCME–WQI and BWQI) have been tested on Moroccan bottled natural and table waters in comparison with a more basic quality classification, TDS–TH, to show their respective levels of adequacy. The main classifications (optimal, average, poor) are well discriminated by the two WQI indices and the TDS–TH methodology, but the latter is more restrictive to the intermediate range quality.

The majority of the waters studied, still or gasified, are classified in the excellent to good categories. The mineral waters EM_3, EM_5 and EM_6 show lower quality indices and the gaseous mineral waters (EM_G and EM_{GL}) are considered fair to unacceptable for regular human consumption. The qualifications are attributed in relation to one or more parameters in combination (high mineralization, high alkalinity, high NaCl content, CO_2 content) which are determined by the water's circulation in the local or regional geological context, in particular in the case of EM_3 with dissolution of evaporites in Miocene formation, and for EM_G and EM_{GL} deep and gaseous thermal water origins. Table waters show good quality, except for ET_p where the addition of CO_2 causes a decrease of its quality.

Future work will focus on the analysis of ^{18}O and ^{2}H isotopes of Moroccan natural waters to highlight the effect of geo-climatic origin on water quality and the potential effect of chemical interaction beween water and plastic bottles in relation to the storage duration and temperature.

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