Environmental Affects on Drinking Water Quality and Drinking Water Quality Differences Depending on the Source

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ABSTRACT

The purpose of this report is to give the reader an understanding in how drinking water quality differs from different water sources and how water quality changes during different scenarios (exposure to environment and temperature differences). At first, water quality requirements (standards) and theory are explained for assessing which factors are relevant to test, both chemical and microbiological.
Several parameters were chosen to be tested in the empirical part, taking into consideration the possible effects on human health and the availability of testing. Four different scenarios were established (water exposed to different temperatures and the environment) and four different bottled water brands and tapped water from one source were selected for testing. These scenarios, or treatments, were chosen to reflect real life situations, such as opening a bottle, drinking a small amount and leaving it at a cold temperature (5 degrees) for a long duration (3 days).

Testing the chosen parameters four different techniques were used – Gran titration, ion chromatograph, nutrient kits and standard plate count (Kimtal in Danish).
The results show different outcomes for the different types of water and some of the results deviate for each scenario. The pH-value and hydrogen carbonate (gran titration) deviate between the brands (source), for example the pH values range from lowest at 6.8 to highest at 7.7, but experienced no significant changes in all water treatments. This is also the case for the chemical analysis (ion chromatograph and nutrient kits). For instance, the amount of sodium in the brand Evian is at 10 mg/l where the brand Kildevæld has an amount of 48 mg/l.
The result obtained from the plate count test shows a general picture of how bacteria grow faster when the water has been exposed and is kept at a warm temperature.
In some cases, the values of the different elements noted on the bottled water labels deviate from the values obtained in the experiments, such as pH and magnesium, which questions whether or not the information on the bottled labels is reliable.
From our test results we can conclude that the quality varies significantly for each source, where changes in quality throughout the different treatments only have a significant effect on microbiology.

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1 Introduction

Water is one of the most important resources worldwide. Factories use it for production, it is used for agriculture and it is consumed by billions of people all over the world daily. In this research we will focus on the quality of the water that people use as drinkable water – bottled or tapped water, how to compare them and which is better to use.

Water is the most commonly used chemical solvent in our everyday lives and is rightfully so, not only for its useful properties, but rather for being essential to humans and all other life forms for that matter. In fact, it is the most important need for us humans other than the very air we breathe. But, the water that we use or drink is in fact not just a composition of hydrogen and oxygen (H2O) but rather a large list of other elements that can be found in the water, such as Sodium and Magnesium. Every time you drink a glass of water you are not only consuming different chemicals but also very small living organisms, such as bacteria. No matter where the water comes from in nature, it will never be just H2O and, in fact, water that is considered “clean” contains many elements and microorganisms. Thereby, the water that we drink may seem clean, but it is not pure (not distilled, since it contains other compounds). Therefore, water can have many differences depending on the amount of each elements and microorganisms in it, which in the end will affect the taste and overall quality.

But how and when do you know if the water you are consuming is of high quality? The quantities of different types of compounds and bacteria in the water define its quality in a certain way.

There are two common accesses to fresh water: tapped and bottled. Many of the suppliers provide test results of different compounds which can be rather hard to understand and make conclusions from for regular consumers. What is more, the consumer is never sure when and how often the tests are performed. Are the test samples taken directly from the source, or before the water is distributed?

Moreover, one might also be unsure how the water quality might be affected by the environment when it is stored and consumed. For example, can a warm environment be potential in regard to bacteria growth in the bottled water? Can contact with local environment introduce new bacteria to the water?

Our aim of the report is to determine the best quality water, by exposing it to the various environments and observing the effects these environments have on our water samples. This is why we will try to compare the amounts of different chemical compounds and bacteria in the water, that are relevant relating to human health and preference.

2 Problem analysis and formulation

2.1 Problem analysis

There are three things we would like to test throughout our experiment:

Firstly, the quality difference for different sources of water. Bottled and tapped water comes from different water sources. Tapped water in Denmark comes typically from the underground, while the bottled water is imported from different countries and it is collected from springs, underground water, mountains, surface waters, etc. The composition of water compounds can vary greatly depending on the source where the water is collected from, which in turn can have a significant impact on the overall water quality. The amount of nutrients, for example, may determine the growth of bacteria in the water.

Secondly, we will test the environmental effect on the water quality when it is exposed to different conditions. Exposure to different environments, for example, contact with the air and/or changes in the temperature, can have a significant impact on the characteristics of the water. We will test how water coming from different sources undergoes these changes and how significant they are.

Lastly, we will check the reliability of water composition that is stated on the label of the bottled water and information leaflet provided by the waterworks. Typically, the bottled water labels contain information about the water's chemical composition and waterworks companies make that information publicly available in form of leaflets. How reliable is that information? Consumer can never be sure whether the test samples are taken at the time of bottling or when the water is extracted from the source. Are the tests made for every batch of water?

2.2 Problem formulation

Based on the above analysis we form our main problem as following:

How does the quality of drinking water differ from each water source and what are the impacts on water quality when the water is subjected to different treatments (scenarios)?

2.3 Strategy

In order to answer the raised problem, we will select a few brands of water for testing. We will select water which is safe to be consumed according to the Danish tapped and bottled water requirements[1], so we don't have to perform a lot of tests that are safety related. In addition, the water samples will be selected based on the popularity and price. We would like to test cheap and expensive, as well as generally popular water brands.

Further on, we will expose our water samples to different environmental conditions, as we expect the environment and different storage conditions to have an impact on

1 Tapped water requirements from the Danish Requirements BEK law # 190, 1273, 466 and 5 & Danish Requirements for Bottled Water BEK # 1015 & 1020 28/10-2005

the microorganisms and compounds found in water. We will aim test scenarios to reflect real life scenarios as closely as possible. When we compare the test results between the samples, we should be able to answer the above mentioned questions.

3 Theory

3.1 What is in the water?

Water is a chemical compound which molecules contain two hydrogen atoms and one oxygen atom. In natural waters there are many other components that make up the complete composition of water. The cations with biggest concentration are calcium, magnesium, sodium and potassium, and the more important anions are hydrogen carbonate, sulphate, chloride and nitrate. These components create the chemical composition of fresh waters and must be considered assessing water quality.[2]

Drinking water is the most important type of natural waters; therefore its quality has to be good enough to fulfil all the requirements. Drinking water must be safe for humans and also it should contain various components. The most suitable properties and composition of elements is in real groundwaters and many undesirable substances, such as copper, lead and zinc, are absorbed when the surface water penetrates the soil.[3]

From groundwater sources it is usually possible to get water with favourable physical and bacteriological properties. If the water is not treated chemically, it does not loose its preferable properties. If water is treated using any kind of chemical treatment, it usually worsens the quality of water in a way that its value is considerably lower and it does not contain many of the important biological components. Also, it gets less pleasant to drink because of changes in sensory properties, like taste and odour.[4]

3.2 What is good drinking water?

According to textbook "Chemistry and Biology of Water, Air and Soil", Qualitative drinking water should be tasteless, odourless and colourless, and its optimum temperature should range from 8° to 12°C. If temperature is above 15°C, the water is no longer considered as refreshing.[5]

As water does not consist only of hydrogen and oxygen, there are various chemical compounds that influence water taste, as iron, manganese, magnesium, calcium, zinc, chlorides, sulphates, etc. The best pH of drinking water is 6-7,[6] and its value varies depending on temperature, respiratory processes, and salinity of the water.[7]

The chemical characteristics and properties of water rather depend on the different types of elements present, not so much on the total concentration of dissolved substances.

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2 Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia , Chapter 3.4.1.

3 Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia, Chapter 3.5.3.2.

4 Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia, Chapter 3.6.

5 Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia, Chapter 3.2.8.1

6 Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia, Chapter 3.2.8.2

7 Water Quality Criteria 1972, A Report of the Committee on Water Quality Criteria, Environmental Studies Board, National Academy of Sciences, National Academy of Engineering, Washington, D.C., 1972, USA

Water must not contain any organisms or concentrations of substances which have, or could have, negative effects on human health after being used for a long period of time.[8]

The best quality drinking water is usually the groundwater which passes through fine pores of soil layers that changes its composition and properties, absorbing the compounds that are not desirable to be present in drinkable water. Groundwater is free from organic substances, safe from the viewpoint of bacteriology; it has the correct temperature and constant composition. The temperature of groundwater depends on the depth of the layers it is taken from, but common ground waters have temperatures from 5° to 13°C.[9]

3.3 Chemical compounds of water

The main cations in natural waters with the biggest concentrations are *calcium*, *magnesium*, *sodium* and *potassium*, and the most important anions are *hydrogen carbonate*, *sulphate*, *chloride* and *nitrate*.[10]

From a health point of view such compounds as *sodium*, *fluorine*, *sulphate*, *nitrate*, *ammonium*, *chlorine* and *phosphate* are quite important. There are also various elements as *magnesium*, *manganese*, *iron*, *chloride*, *sulphate* and *hydrogen carbonate* that are not hazardous for human health, but they affect the taste of water.[11]

COMPOUND	PRESENCE IN WATER	EFFECT ON HEALTH
Sodium (Na^+)	The third biggest concentration of metals in waters after calcium and magnesium.[12]	In high concentrations it can negatively influence the health of people who are suffering from heart disease.[12]
Fluorine (F^-)	Usually most natural waters contain very low content of fluorine.[12]	Health disorders can occur from both - deficiency and excess of fluorine in drinking water. High concentrations (more than 1.5mg/l) can cause *fluorosis* (spots on teeth), but low concentrations (less than 0.5mg/l) can cause more intensive occurrence in caries, especially for children.[12]

8 Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia, Chapter 3.6.1

9 Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia, Chapter 3.5.3.2 & 3.2.8.1

10 Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia, Chapter 3.4.1.

11 Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia, Chapter 3.4. – reflects information about all compounds mentioned in separate sub-chapters

12 Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia, Chapter 3.4. – reflects information about all compounds mentioned in separate sub-chapters

Sulphate (SO_4^{2-})	Common compound in natural waters and its concentrations can be relatively high – from tens to hundreds of mg/l.[12]	If concentrations are high, it can have laxative effect on humans.[13]
Nitrate (NO_3^-)	Is found in almost all natural waters, but in low concentrations, if water is not polluted.[12]	Has little direct adverse effect on man, but it can become harmful indirectly. It can cause methaemoglobinaemia by being reduced in the gastrointestinal tract by microbial activity into the more toxic nitrites, which react with haemoglobin to methaemoglobin which is not able to transfer oxygen in blood.[14]
Ammonium (NH_4^+)	Should not be found in drinking water, while it is usually found in high concentrations in wastewaters.[12]	Has great importance from viewpoint of hygiene.[12]
Chlorine (Cl_2)	Presence in water is not natural; it is introduced in water in purpose for disinfection.[12]	At higher concentrations it influences sensory properties of water.[12] Chlorine is suspected to be a carcinogenic compound. Consumption of chlorinated water in long-term can accelerate aging, increase vulnerability to genetic mutation and cancer development, disturb cholesterol metabolism and promote hardening of arteries. Moreover, chlorine destroys antioxidant vitamin E, which is needed for cardiac and anti-cancer protection.[15]
Phosphate (PO_4^{3-})	Found in very insignificant amounts in natural waters, e.g. in surface waters – tenths of mg/l. Its presence in groundwaters is possible only due to faecal pollution if they are from organic origin.[12]	Important from viewpoint of hygiene.[12]

Table 1: Chemical compounds in water that can affect human health

13 http://www.water-research.net/sulfate.htm Wilkes University, Center for Environmental Quality Environmental Engineering and Earth Sciences, Title: Sulfates and Hydrogen Sulfide, That Rotten Egg / Sulfur Smell, Sulfate Reducing Bacteria (SRB)

14 Water Quality Criteria 1972, A Report of the Committee on Water Quality Criteria, Environmental Studies Board, National Academy of Sciences, National Academy of Engineering, Washington, D.C., 1972, USA

15 http://www.orthomolecular.org/library/jom/2000/articles/2000-v15n02-p089.shtml
The Journal of Orthomolecular Medicine Vol. 15, 2nd Quarter 2000
Article: The Negative Health Effects of Chlorine
Author: Joseph G. Hattersley

COMPOUND	PRESENCE IN WATER	EFFECT ON TASTE
Magnesium (Mg^{2+})	Together with calcium it is the main cation in natural waters.[12]	Can cause bitter taste in water if there is more than 250mg/l of it; unimportant from the viewpoint of health. Together with calcium it is related to water hardness.[12]
Manganese (Mn^{2+})	Normally it is found in very low concentrations in natural waters.[12]	In concentrations above 0.1mg/l adversely influence the taste of water, but does not have negative effects on health.[12]
Iron (Fe^{3+})	Common component of waters in concentrations of hundredths to tenths of mg/l (mineral waters – above 10mg/l).[12]	Influences the sensory properties and taste of water if concentration is about 0.1-1.5mg/l and is not significant from the viewpoint of hygiene.[12]
Chloride (Cl^-)	Present in all waters in high concentrations, together with hydrogen carbonates and sulphates it is the main anion in waters. In groundwaters it is found in concentrations as tens of mg/l.[12]	Does not have negative effects from viewpoint of hygiene, but it affects the taste of water if the concentration is bigger than 150mg/l.[12]
Hydrogen carbonate (HCO_3^-)	Common compound to all natural waters.[12]	Can favourably affect taste of water depending on concentration.[12]
Calcium (Ca^{2+})	Together with magnesium is main cation in natural waters.[12]	Unimportant from the viewpoint of health, though it makes the water taste better and improves its quality.[12]
Sulphate (SO_4^{2-})	Common compound in natural waters and its concentrations can be relatively high – from tens to hundreds of mg/l.[12]	Can cause bitter taste of water.[16]

Table 2: Chemical compounds in water that have effect on water taste

As described in tables above, various chemical compounds found in water can have different effects whether on taste or water or human health. Nevertheless, there is one more parameter that should be taken into consideration assessing the quality of water from a chemical standpoint, which is *pH.* pH represents the activity of hydrogen ions present in water.

pH value considerably influences the course of biochemical and chemical processes in waters. In clean natural waters pH value is 4.5-8.3, dependent on content of hydrogen sulphide, phosphates etc. pH value can also be influenced by biological processes, water temperature and respiration.[17] pH is an important parameter considering water quality, it is used for calculating concentrations of carbonate, bicarbonate and carbon dioxide in the water.[18]

16 http://www.water-research.net/sulfate.htm Wilkes University, Center for Environmental Quality Environmental Engineering and Earth Sciences, Title: Sulfates and Hydrogen Sulfide, That Rotten Egg / Sulfur Smell, Sulfate Reducing Bacteria (SRB)

17 Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia, Chapter 3.4.1.29.

18 Chemical Analysis of Inorganic Constituents of Water, Editor Jon C. Van Loon, CRC Press, Inc. Boca Raton,

In our empirical part we have decided to focus on the compounds which are important to test, because they are relevant in the viewpoint of human health or they are some of the indicators showing quality of water. One of the criteria was also the ability to test the exact compounds, because some of them are quite hard or not available to test or the concentrations in water are expected to be zero or very close to zero.

We are going to test such compounds as magnesium, calcium, sodium, nitrate, sulphate, ammonium, chloride and hydrogen carbonate, based on the theory part about certain elements that are found in water. Additionally, we are also going to test the values of pH, as this parameter is considered to be relevant assessing the quality of water, as described above.

3.4 Microbiology

This section describes the different microbiological elements that can be found in drinking water.

Most bacteria grow around the temperature of 30 degrees Celsius, where each of the species have a well defined upper and lower limit where the growth stops. Bacteria that can be found in drinking water falls under the category of **Mesophiles**, which means that the optimum growth temperature for this type of bacteria is within the range of 20 degrees and 50 degrees. The optimum temperature for disease causing bacteria is between 35 and 40 degrees Celsius. As a general rule in microbiology, bacterial growth is at its highest when the temperature is at its upper limit, which is why we refrigerate our food to suppress bacterial growth. This is due to the increased speed of enzymatic reactions, which is approximately doubled for each 10 degrees rise in temperature. Although, this does not mean that all **Mesophiles** grow in the range 20 to 50 degrees, for example, some bacteria grows at 45 degrees Celsius and others do not.[19]

Standard Plate Count 22:

This shows the amount of organisms living of organic material. According to the DHI – Institute for Water (2003-2004) report, some brands reached a value between 1 and 50000 and according to the requirements by Danish Law[20] the limit for tapped water and bottled is 200.

Standard Plate Count 37:

This shows the amount of organisms living in the sample that grows at body temperature. This test is generally conducted for measuring the quality of water and whether or not the sample contains pathogens, according to the textbook Drinking Water Microbiology[21]. According to the requirements from the Danish Law[20] tapped and bottled water has a requirement limit of 20, which is also stated on many other sites that refers to the B.E.K. According to the report from DHI – Institute for Water

Florida, 1982, United States of America, Chapter 1, VII

19 Microbiology: A Human Perspective (second edition), Eugene W. Nester, C. Evans Roberts, Nancy N. Pearsall, Denise G. Anderson, Martha T. Nester, 1998, page 90 and 91

20 Danish Requirements BEK law # 190, 1273, 466 and 570, Foedevaredirektoratet 2003b, EU kommision 1998 & BEK # 1020

21 Gordon A. McFeters, 1990, Drinking Water Microbiology, page 458-459

and the Environment (2003-2004), there has been a case where the brand Aqua had an amount of 540000, but was altered to 11000 after another test 6 months later. This goes to show that the bacteria count can vary significantly depending on the time of test and situation.

Total Coliform Bacteria:

This type of bacteria is generally found in waters that contains contamination from pollution or surface water, but can in some cases be found naturally[22]. This type of bacteria has to be test for bottled water, according to the requirements under the Danish law for bottled water BEK # 1020. But since these are generally found in water that has been polluted or contaminated, and we expect that the bottled water meets the requirements when tapped, we expect that this is not an issue. The requirements state, for both bottled and tapped water, that this bacteria most not be present.

Thermotolerant Coliform and E. Coliform Bacteria:

Water contaminated from fecal sources, for example septic tanks and sewerage. This type of bacteria is defined as coliform bacteria that grow at 44-45 degrees Celsius[23]. Although this type is related to fecal contaminants, which is very unlikely in this case, testing these bacteria is at low priority. Requirements state that these must not be present.

Pseudomonas aeruginosa:

A very resilient type of bacteria which has the ability to multiply in processing units, such as sand filters and active carbon filters, and is considered as a pathogenic bacteria.[24] These bacteria originate from surface waters and must not be present in bottled water and tapped water.[25]

Clostridium Perfringens:

A pathogenic organism with high resistance against disinfectants[26]. This organism is found in water contaminated by fecal deposits. This organism must not be present in any sample[25].

These different types of bacteria mentioned above all play a roll in the overall microbiological quality of drinking water, but since these types, with the exception of standard plate count 22 and 37 (SPC 22 and 37), are only found in water contaminated by either surface runoff or fecal deposits, it would be of more significant to measure the SPC. Water that is pump directly from its source will likely to have a detectable amount of natural bacteria, which can be found by using the technique know as the Danish Standard for testing of the SPC (view methods for more details). The bacteria

22 Assessing Microbial Safety of Drinking Water (OECD, 2003, page 50)

23 Assessing Microbial Safety of Drinking Water (OECD, 2003, page 51)

24 Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia, page 357, 373, 383
Drinking Water Microbiology, Gordon A. McFeters, 1990, page 193

25 Danish Requirements BEK law # 190, 1273, 466 and 570, Foedevaredirektoratet 2003b, EU kommision 1998 & BEK # 1020

26 Drinking Water Microbiology p. 194, Gordon A. McFeters 1990

count at 37 degrees Celsius is the most interesting, since that, evidently, after many years of research, bacteria that is subjected to starvation or nutrient limitations are more resistant to various hazards, such as deleterious agents or disinfectants. Therefore, since water contains significantly less nutrients than other substances, for example our blood, we can expect that natural bacteria from the water source will be present, and preserved, in the water even long after production. This is also true for the bacteria count at 22 degrees, but since these bacteria do not thrive as well at body temperature they thereby do not present a water quality impact as high as those under 37 degrees.[27]

3.5 Water quality requirements description

In this section, we will go through the different requirements associated with tapped water and bottled water, which will give us an understanding in when the different values are reaching an unacceptable limit. Also, the values for the different elements in bottled water displayed on the label have been noted.

Compound	Value Tapped	Example Groundwater Value
Conductivity (mS/m)	<30	81
Total hardness (°dH)	5-30	19
PH	7-8.5	7.3
NVOC mg/l	<4	1.8
Total Iron mg/l	0.1	1.21
Manganese mg/l	<0.05	0.04
Ammonium mg/l (NH_4)	<0.05	0.8
Nitrate mg/l (NO_3)	<50	1.6
Total Phosphorus mg/l (P)	<0.15	0.03
Chloride mg/l	250	115
Oxygen mg/l	>5 (when consumed)	0.3
Nickel µg/l	<20	1.3
Pesticide BAM µg/l	<0.1	<0.012
Sodium mg/l	200	n.a
Sulfate mg/l	250	n.a
Magnesium mg/l	50	n.a
Potassium mg/l	10	n.a
Flourine mg/l	1.5	n.a
Barium µg/l	700	n.a

Table 3: Tapped water requirements from the Danish Requirements BEK law # 190, 1273, 466 and 5 and Foedevaredirektoratet 2003a. n.a. represents not available

27 Drinking Water Microbiology p. 95-101, Gordon A. McFeters 1990

Groundwater Value represents the average annual value of raw groundwater from Lejreborg waterworks. [28]

As shown in Table 3, some of the values for the groundwater (raw water) do not meet the requirements and has to be treated before distribution.

The requirements for bottled water depend on its type. The three existing type of bottled water are Natural Mineral Vand (mineral water), Kildevand (Spring water) and, simply, bottled water. The water that is labeled Emballeret Vand (bottled water) must meet the same requirements as tapped water. Natural Mineral Water and Spring Water have other requirements, except for microbiology which is the same for all types of water. The differences in required values for Natural Mineral Water and Spring Water can be view in Table 4.

Compound	Natural Mineral Water	Spring Water
Conductivity (mS/m)	n.r.	>250
Total hardness (°dH)	n.r.	n.r.
PH	n.r.	4.5-9.5
NVOC mg/l	n.r.	n.r.
Total Iron mg/l	n.r.	0.1
Manganese mg/l	0.05	0.05
Ammonium mg/l (NH_4)	n.r.	0.5
Nitrate mg/l (NO_3)	50	50
Total Phosphorus mg/l (P)	n.r.	n.r.
Chloride mg/l	n.r.	250
Oxygen mg/l	n.r.	n.r.
Nickel µg/l	20	20
Pesticide BAM µg/l	n.r.	n.r.
Sodium mg/l	n.r.	175
Sulfate mg/l	n.r.	250
Magnesium mg/l	n.r.	n.r.
Potassium mg/l	n.r.	n.r.
Flourine mg/l	5	1.5
Barium µg/l	1000	n.r.

Table 4: Bottled water requirements from Foedevaredirektoratet 2003a,b and EU kommision 1998. n.r. represents no requirements

[28] Lerje Waterworks, Ledreborg Alle 1 E-F, 4320 Lejre, Danmark

In Table 5, we have noted all of the value printed on the bottle label. The aim of this is to be able to compare our result later on in the report.

	Aquad'or	**Evian**	**Kildevaeld**	**Monteforte**	**X-tra**	**Aqua**	**Egekilde**
Hydrogen Carbonate (HCO_3^-) mg/l	120	357	244	339,2	n.a.	n.a.	310
Sulfate ($SO4^{--}$) mg/l	3	10	29	11	9	n.a.	n.a.
Chloride (Cl^-) mg/l	13	4,5	52	16	11	n.a.	n.a.
Magnesium (Mg^{++}) mg/l	2	24	14	6,7	1,1	n.a.	n.a.
Sodium (Na^+) mg/l	10	5	30	9	7,1	n.a.	14
Nitrate (NO_3^-) mg/l	<0,5	3,8	1	0,4	n.a.	n.a.	n.a.
Potassium (K^+) mg/l	1	1	5,9	0,87	0,7	n.a.	3
Calcium (Ca^{++}) mg/l	39	78	76	107	1,7	n.a.	57
Dry residue 180°C mg/l	155	309	363	335,6	n.a.	n.a.	n.a.
Hardness dh	6	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
pH	7,3	7,5	8	7,4	n.a.	n.a.	n.a.
Silicon Dioxide (SiO_2) mg/l	n.a.	13,5	n.a.	10,6	n.a.	n.a.	n.a.
Fluorine (F^-)	n.a.	n.a.	n.a.	n.a.	0,21	n.a.	0,9
Barium (Ba^{++})	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	0,015

Table 5:Water supplier provided chemical composition of water, n.a. represents values which not available.

4 Possible scenarios

We have a few hypothesis how different environment conditions could affect the water quality both from bottles and from the tap. Therefore, we have created a list of scenarios that would closely reflect those changes in water.

The water is stored in dark places at selected temperatures of 5° and 27° Celsius. The water is not exposed to direct sunlight, therefore, photosynthetic bacteria is not tested for. 5° Celsius represents the typical refrigerator temperature, while 27° Celsius represents the worm environment, for example sunny summer day (note, we assume that water is kept in a dark place, for instance, bag).

4.1 Experimental design overview

Further used abbreviations:

- CC (cold closed) – Stored cold, unexposed to environment
- CO (cold opened) – Stored cold, exposed to environment
- WC (warm closed) – Stored warm, unexposed to environment
- WO (warm opened) – Stored warm, exposed to environment

	CC	CO	WC	WO
Storage temperature (Celsius)	5°	5°	27°	27°
Exposed to environment	No	Yes	No	Yes
Exposure time (seconds)	0	30	0	30
Exposed to sunlight	No	No	No	No
Storage place	Refrigerator	Refrigerator	Incubator	Incubator
Storage time (hours)	72	72	72	72

Table 6: Overview of the experimental design

4.2 In depth description of scenarios

Cold closed

Scenario

- The water sample is stored at 5°C.
- Bottled water is production sealed, and tapped water sample is taken directly from the tap, just before tests
- The bottle is opened and the tests are performed immediately

Purpose of scenario

The described scenario reflects the storage of water in cool environments. For instance, when the bottled water is bought and stored in the fridge, and consumed all at once. The tapped water is consumed directly from the tap without storage.

Possible effects

We expect the water not to change its qualities, since the water is consumed in short period of time. On the other hand, we can see how storage and handling have affected the water in comparison to the contents labeled on the bottle, which were measured by the producers.

Cold open

Scenario

- The bottle is opened, and the tapped water is filled into the plastic 0,5 liter bottle
- A small sip of water is taken by the person
- The bottle is closed after approximately 30 seconds
- Water is stored at 5°C for 72 hours
- The bottle is opened and the tests are performed immediately

Purpose of scenario

This scenario reflects the water consumption over a period of time (a few days). For instance, the bottle can be opened, part of the water consumed and then it is put back into the fridge for later use.

Possible effects

We expect the water quality to be affected slightly in this scenario; however, we believe that the contact with air can introduce some changes, for example the change in pH[29] or an increase in bacteria growth. We would not expect the compounds unrelated to pH and bacteria to change at all.

Warm closed

Scenario

- The water sample is stored at 27°C.
- Bottled water is production sealed. Tapped water is stored in a plastic 0,5l bottle
- The bottle is opened and the tests are performed immediately

29 Chemistry and Biology of Water, Air and Soil, edited by J. Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993 Czechoslovakia, Chapter 3.2

Purpose of scenario

This scenario reflects the water consumption during warm days or when it is stored in warm places, for example when the water is carried in the bag pack or it has been exposed to the sunlight for an amount of time. However, the water is consumed in short period of time after the bottle was opened.

Possible effects

Although, we do not expect the warm water to be any different from cool water when all is consumed at once, we think that high temperatures can be subject to bacteria growth due to the positive change in the environment. We expect the pH values to be different from the water samples when they are stored cold[30].

Warm open

Scenario

- The bottle is opened, and the tapped water is filled into the plastic 0,5l bottle
- A small sip of water is taken by the person
- The bottle is closed after approximately 30 seconds
- Water is stored at 27°C for 72 hours
- The bottle is opened and the tests are performed immediately

Purpose of scenario

This scenario reflects the water consumption, when the water is consumed over a period of time when the water is stored in warm environment. For example, water is carried in the bag pack, left in the car, exposed to direct sunlight and is consumed during longer period of time (few days).

Possible effects

We expect this scenario to have the biggest impact on the bottled and tapped water quality, as the water is exposed to both environment and higher temperatures. The local environment can introduce bacteria into the water and warm temperature is a suitable environment for bacteria to grow. In addition, we think that such scenario could have a huge impact on pH values, especially in comparison to the cold water samples[31].

30 Chemistry and Biology of Water, Air and Soil, edited by J. Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993 Czechoslovakia, Chapter 3.2

31 Chemistry and Biology of Water, Air and Soil, edited by J. Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993 Czechoslovakia, Chapter 3.2

5 Methods

5.1 Sampling

We consider using 1 bottle of water for all the scenarios. However after calculation, we discovered that we will have to use 1 bottle of water for each scenario. Hence we have the following decisions on sampling.

Regarding the bottled water, we chose to use bottled water from the same batch and same production time. We assume that the water of same batch should be the same.

As for the tapped water, we take the sample directly from the tap (the water is let run for a while before the sample is taken), assuming that the time period between sampling of the tapped water (the sample for exposed water is taken 72 hours earlier) should have no influence on the quality of the water.

5.2 Techniques

For comparing water quality in different conditions and temperatures, according to previously mentioned four scenarios, we are applying different methods that are suitable for the parameters we have decided to test.

The experiments will be done according to the matrix below:

Closed	Cold 5°C	Aquad'or	Ion chromatograph
Opened	Warm 27°C	Evian	Standard plate count
		Kildevaeld	Gran titration
		Aqua	Nutrient kits
		Tap water	pH meter

As mentioned before, we are expecting such parameters as bacteria, pH and hydrogen carbonate to vary according to four different scenarios, so those parameters are as first priority.

To determine the general amount of bacteria in the different samples, a technique known as the Danish Standard for bacteria count[32] (DS/EN ISO 6222) was applied. The purpose of this test is to measure the enumeration of culturable microorganisms in a given sample, in which will give us a reading of quality of the water from a microbiological standpoint.

Here, the result is determined by the colony count in a nutrient agar culture medium. The samples are put in sterile plates avoiding any contact with the environment, and during incubation period the plates are not subordinated to sunlight or other factors that could influence the amount of bacteria. The plates have been left for incubation at 22 and 37 degrees Celsius. Theoretically, each colony grown in the medium will

32 Standard for Bacteria Count ISO 6222.1999

represent single bacteria. The logic behind this is that initially one bacterium will start multiplying and after the incubation period that single bacteria will have multiplied into a colony big enough to be counted by the naked eye.

The pH values are measured with pH meter during gran titration[33] process, which includes also pH value assignation. Due to measurements made, it will be possible to determine the concentration of hydrocarbonate in the water sample.

To determine the concentrations of anions and cations present in current water sample we are going to use Ion Chromatographs[34]. Using chromatographs, it is only needed to provide the machine with water sample that needs to be tested; the machine itself determines values of cations and anions present.

For measuring phosphate, nitrate and ammonium we will be able to use the laboratory nutrient kits[35], which do not give quite precise results, but still the determined concentrations are reasonable for comparing quality of different water samples.

As listed above, we are going to use five different techniques to test water quality (see Table 7).

Parameters	**Method**	**Storage of water samples**
pH value	pH meter	Not freezable
Kimtal 22	Bacteria count	Not freezable
Kimtal 37	Bacteria count	Not freezable
Hydrogen Carbonate HCO_3^-	Gran Titration	Not freezable
Nitrate NO_3^-	Nutrient Kits	Freezable
Ammonium NH_4^+	Nutrient Kits	Freezable
Phosphate PO_4^{3-}	Nutrient Kits	Freezable
Sulphate SO_4^{2-}	Ion chromatograph	Freezable
Chloride Cl^-	Ion chromatograph	Freezable
Calcium	Ion chromatograph	Freezable
Magnesium	Ion chromatograph	Freezable

Table 7: Analysis Methods and sample storage

Due to the restriction of time, we have decided to only measure 4 brands of bottle water and tapped water. To obtain a more appropriate result, we are going to take 2 replicas for each parameter.

33 Stumm and Morgan, 1981 or Libes, 1992
34 Dionex Corporation, IonPac AS14 Analytical Column (for anions), IonPac CS12A Analytical Column (for cations) http://www.dionex.com
35 Visocolor ECO Nutrient Kits, Machery-Nagel GmbH & CO

6 Results

All the final data shown in this result section are the average value of the 2 replicates result data.

6.1 Bacteria Count

Standard plate count 37

For all the bottled waters, there is no significant increase of standard plate count 37 from cold temperature to warm temperature in factory sealed condition (see Figure 1). The highest value is 9cfu/ml (colony-forming units per milliliter) from Kildevaeld in warm closed condition.

However, the value of standard plate count 37 in open condition is much higher than in factory sealed condition, either in cold or warm temperature. In cold temperature, Kildevaeld and tapped water have exceeded the standard requirement of 20cfu/ml, while in warm temperature; all the values are above the limits. Kildevaeld has a considerably highest value which is 150cfu/ml in warm opened condition.

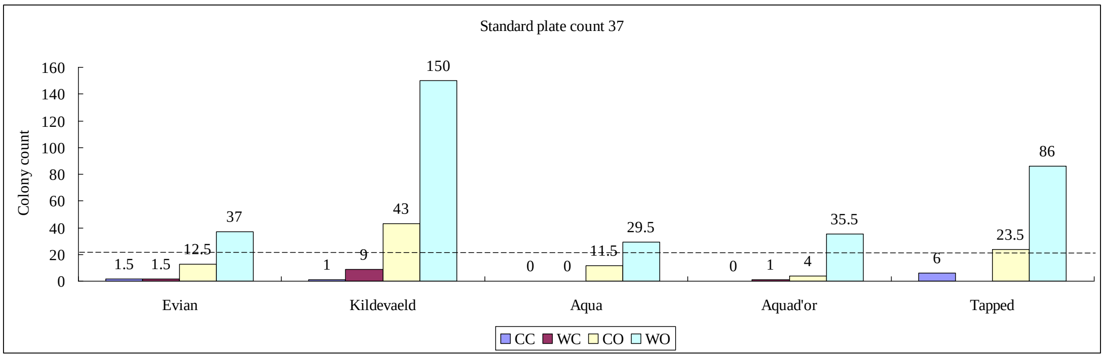

Figure 1: Standard plate count at 37°C. Kildevaeld WO result is estimated from one replica only, due to possible contamination. Dashed line marks the maximum requirement value limit

Standard plate count 22

The standard plate count at 22 degrees has, in 3 out of 4 cases, a significant amount of microorganisms initially (factory sealed). Like the plate count at 37 degrees, the number of bacteria is increased when the water is exposed to the environment. In the case for Aquad'or when factory seal and cold its value exceeds the limit stated in the requirements for bottled drinking water.

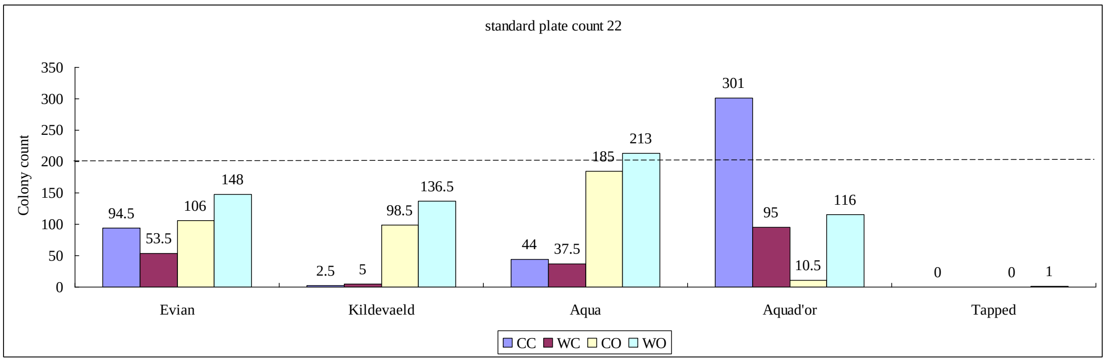

Figure 2: Standard plate count at 22°. Dashed line marks the maximum requirement value limit

6.2 pH and Hydrogencarbonate

There is not a big difference about the pH value for any type of water sources regardless of the scenarios; the range of pH value is from 6.7-7.3. Comparing the open condition to closed condition (see Figure 3), Evian, Aqua, and Tapped water have a slightly decrease of pH value; Aqua D'or remains almost the same value, while Kildevaeld has increased by a small amount of pH value.

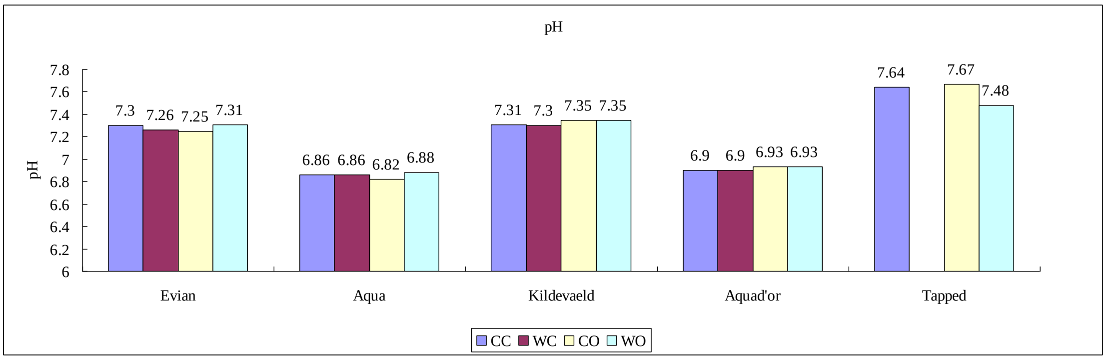

Figure 3: pH values

Evian, regardless of the scenarios, has the highest concentration of hydrogen carbonate and the values are all above 400 mg/l (see Figure 4). The concentration for the rest of the water samples remains quite the same and is close to 300 mg/l.

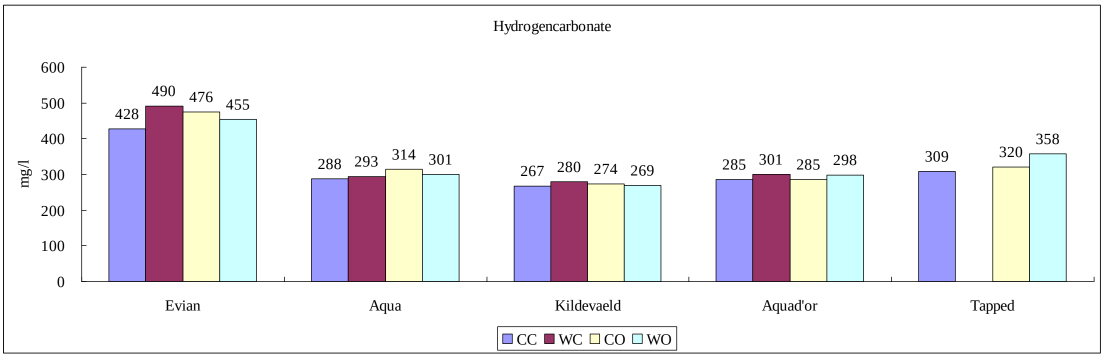

Figure 4: Hydro Carbonate

6.3 Nutrient Kits

The concentration of nitrate remains constant in all scenarios from the same water source in our experiment, it differs only regarding to sources (see **Error! Reference source not found.**). The concentration of ammonium and phosphate are almost the same.

Water source	Nitrate (NO_3^-)	Ammonium(NH_4^+)	Phosphate (PO_4^{3-})
Evian	5	0	0.9
Aqua	1	0	1.5
Aquad'or	1	0	1.1
Kildevaeld	3	0	1.2
Tapped	3	0	1.8

Table 8: Nutrient analysis results (mg/l)

6.4 Ion chromatograph

No matter in which scenario, all in all Kildevaeld (see Figure 5) has the highest concentration of sodium and calcium; Evian (see Figure 6, Figure 7) has the highest concentration of magnesium. The deviation among scenarios is insignificant.

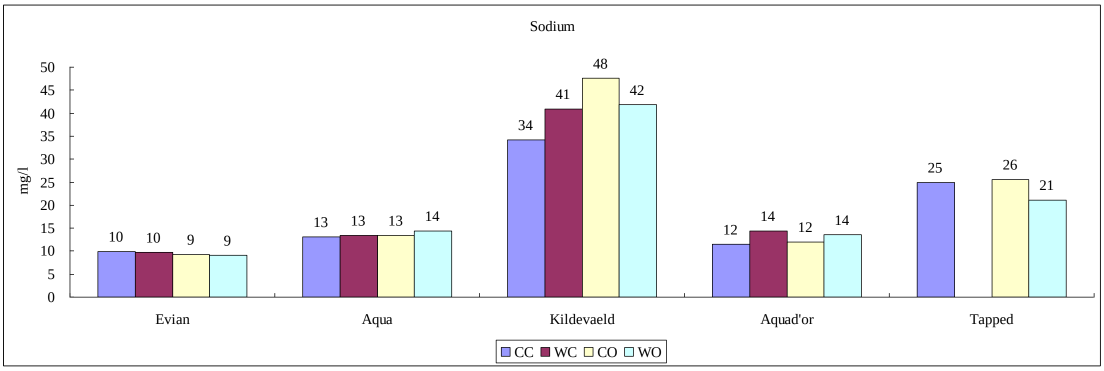

Figure 5: Sodium

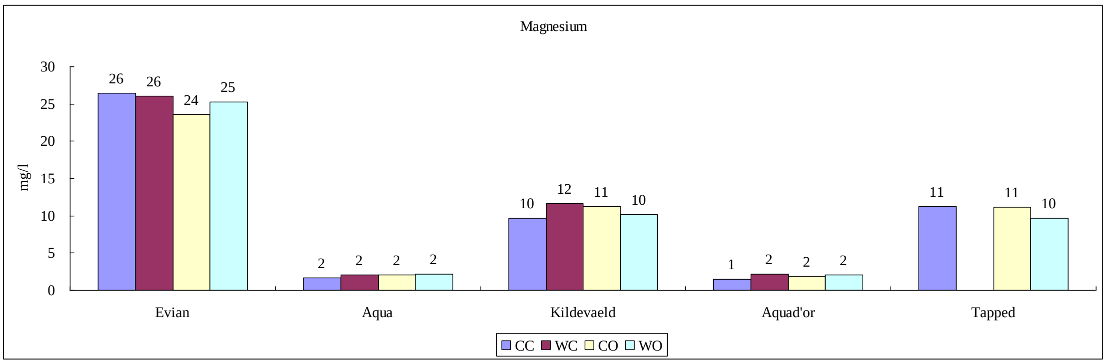

Figure 6: Magnesium

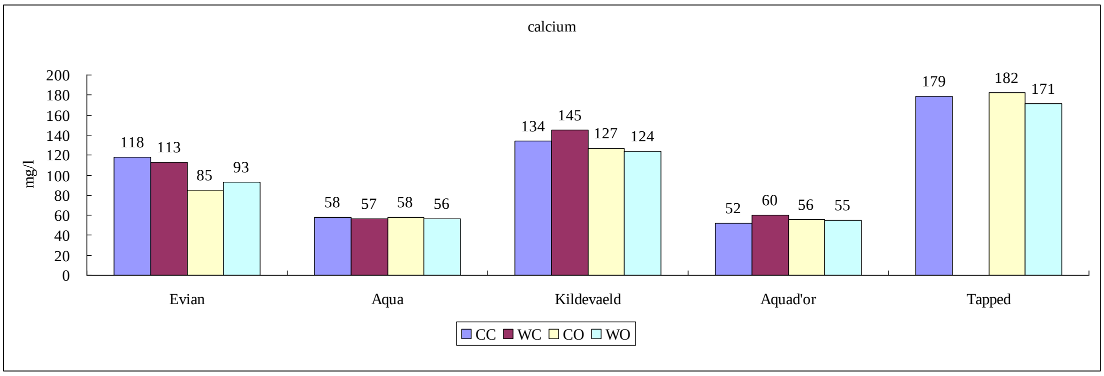

Figure 7: Calcium. All values for tapped water and CC Evian are calculated individually by studying the raw date due to calculation error done by the ion chromatograph. Therefore, these values must be considered as approximations.

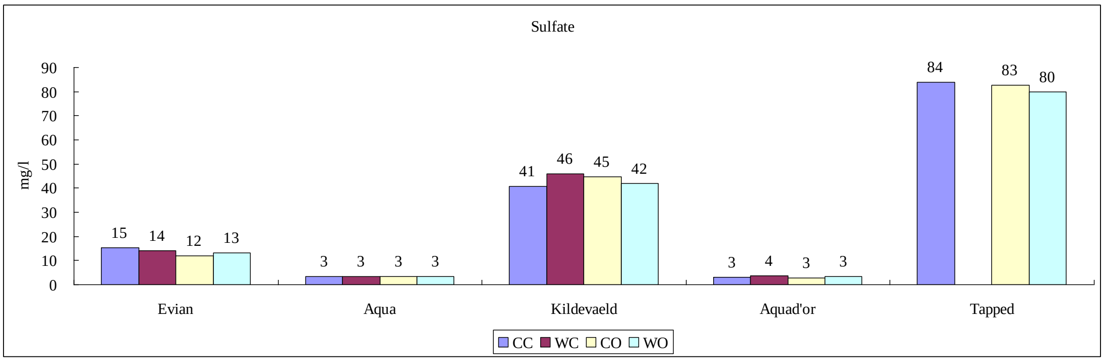

Figure 8: Sulfate

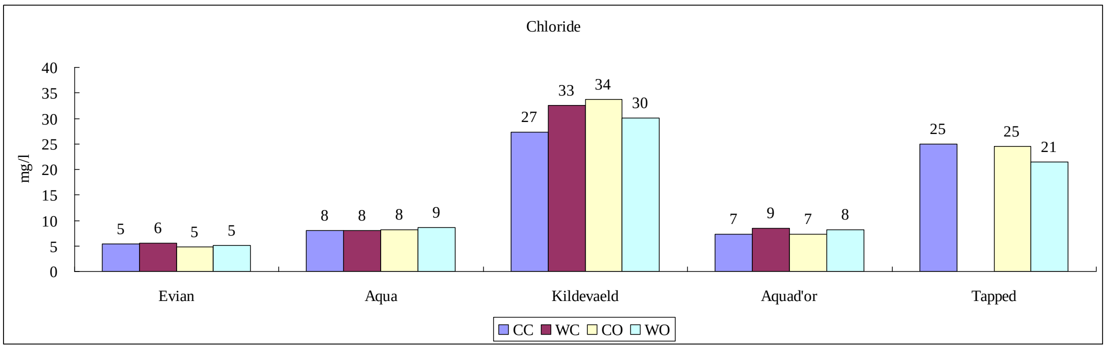

Figure 9: Chloride

7 Discussion

7.1 Microbiology results

As expected, the count for the amount of microorganisms in the samples will deviate due to the different treatments and source. The standard plate count at 37°C clearly shows an increase in count after exposure to air and bacteria from mouth. This is also true to the samples subjected to a warm temperature, which increased the amount of organisms. All of the unexposed (closed) samples did not exceed the requirement of 20 cfu/ml, which may indicate that there were little to none bacteria living a 37°C in the water initially. As an example, the unexposed samples for the brand Aqua have no bacteria, even at a warm temperature, where the exposed samples, on the other hand, experienced a significant increase. This is due to the fact that the water has been subjected to environment.

The plate count at 22°C shows a slightly different pattern. Although the count generally rises after environmental exposure and experiences a warm temperature, there are some aspects that must be discussed. First, the plate count for the cold closed Aquad'or exceeds the standard limit of 200 cfu/ml, which indicates that this particular bottle might have been contaminated at a time during production; while the cold opened Aquad'or has shown a quite low count. This point to the fact that there are different amounts of natural bacteria in the four bottles used to test Aquad'or. While we know that these bottles come from the same batch we do not know the temperature history prior their purchase, which could affect the amount of organisms before testing.

Second, the tapped water does not show any bacterial development throughout the different treatments, where the bottled samples shows a clear reaction. This could be due to the fact that natural bacteria in the tapped water were non-existent and the water was not exposed long enough to be significantly contaminated. The tapped water would be able to support bacteria growth, since the result attain on nutrients do not show any major difference from the bottled water that contain bacteria.

7.2 Result Reliability

Judging from some of the plates that did not have any bacteria indicates that we have successfully been working under sterile conditions, although there are some cases where the samples have been subjected to contamination. Plates with a high count (higher then its replica and diluted version) could indicate contamination, since the reproduction time for bacterium in favorable conditions can be as short as 20 minutes.[36] Therefore, a sample with a higher count than its replica can indicate significant contamination. This may have been the case for Aqua (Cold Closed 22°C) which saw high counts in one sample, which deviates with more than a 1000 cfu/ml from its replica and diluted versions. This high value was thereby discarded. This was also the case for Aquad'or (Warm Closed 22°C) where the undiluted sample was 1200 cfu/ml and its replica at 2300 cfu/ml, which do not agree compared to the diluted versions. The undiluted samples were thereby discarded. As for the high

36 Principles of Water Quality Control page 38 and 44

bacteria count for Aquad'or (Cold Closed 22°C), which exceeded the requirements with 300 cfu/ml, the test samples did not show high deviations and is thereby considered reliable.

7.3 Chemical results

7.3.1 pH and hydrogen carbonate

pH value does not differ significantly from different treatments, but from different sources. This may be due to a fact that water had too little contact with the environment, not allowing water to evaporate and reduce the CO_2 level in the samples. Thereby the pH level did not deviate as much as we expected.

There are also no significant differences in the values of hydrogen carbonate for each water treatment. This parameter was also expected to change, because it is pH related, but according to results the deviation is very low between different treatments. On the other hand, the values change from source to source, which indicates the differences in water composition when tapped or produced. According to the results, Evian has the highest value of hydrogen carbonate, which can favorably affect the taste of the water, comparing to other types of water, as Evian has the highest value of hydrogen carbonate, about 200 mg/l higher, than other water brands and tapped water. For tapped water the recommended value is above 100 mg/l[37], but as the results show, all the water samples exceed this value.

7.3.2 Nutrients and Chemical Compounds

Such nutrients as nitrate, ammonium and phosphate (see table 8) do not deviate significantly from different scenarios, the deviation is noticeable only regarding to different water sources. As expected, there was no ammonium in any water sample, as this nutrient is usually found only in wastewaters or treated waters. The values of nitrate do not exceed the values recommended, but the highest value is for Evian, which is 5mg/l. Phosphate also has quite low values in different water types, but as it is not stated in the requirements of water quality the values are not considerable relating to water quality.

Comparing these results we can assume that all selected water types are safe for consumption, as they do not exceed any values mentioned in requirements.

The values of sodium, magnesium, calcium, chloride and sulfate are also below the stated requirements, so it is just the matter of preference which kind of water is the best to consume.

According to results, Kildevaeld has the highest values of such compounds as sodium and chloride (see figure 5 and figure 9), but those values are not that big to be considered as health hazardous, as they meet the requirements. Evian has the highest concentration of magnesium (see figure 6) and relatively high concentration of calcium (see figure 7), which means that Evian has the highest water hardness

[37] Danish Drinking Water Standards for Tapped Water BEK 130, date 26.02.1999,

value, as water hardness is related to these two compounds.[38] The highest value of sulfate and calcium (see figure 8 and figure 7) is for the tapped water, but the value is not high enough to cause some negative effects for health, but it can still make the water taste more bitter.

All in all, the values of various compounds do meet the requirements and are not hazardous for human health. However, there are some significant differences between different types of water, e.g. Evian water is the one with highest water hardness value (because of highest amounts of calcium and magnesium); tapped water can be the one with the most bitter taste.

If we focus on chemical aspects that reflect the quality of the water, the best water to drink from health point of view would be Aqua and Aquad'or, while those two water types show the lowest concentrations of chemical compounds that might have some effect on human health, as sodium, sulphate, nitrate and phosphate (see table 1).

For almost all chemical compounds there are no significant differences of the values between different water treatments (four scenarios), but the visible deviations may be observed due to having different bottles for each scenario, as the amount of different compounds can not be completely constant in each bottle of water.

7.3.3 Result Reliability

Such compound concentration as phosphate, nitrate and ammonium were tested using the special laboratory kits[39]. Those kits are originally designed for testing the concentrations of those compounds in wastewater or polluted water, so the scale of measuring the concentrations was not so suitable to get very precise information about the concentration. But, obviously, the data is reliable, as the values are the same for both the scenarios and replicates. There were no extreme values measured, so we assume the tests were done properly.

Comparing the results of the pH values, most of the data differed from the data shown on the bottle labels (except Aqua that does not have data about pH on the label). However, the differences may be observed due to manufacturer's data approximations, while the pH values are not measured for each bottle.

The values that were got using Gran titration[40] and ion chromatograph[41] are quite precise and reliable. However, there were minor errors measuring concentrations of calcium of tapped water and Evian (cold closed). In many cases the value measured differed from the value shown on the label of the bottle.

[38] Chemistry and Biology of Water, Air and Soil, Edited by J.Tolgyessy, ELSEVIER Amsterdam-London-New York-Tokyo 1993, Czechoslovakia, Chapter 3.4.
[39] Visocolor ECO Nutrient Kits, Machery-Nagel GmbH & CO
[40] Stumm and Morgan, 1981 or Libes, 1992
[41] Dionex Corporation, IonPac AS14 Analytical Column (for anions), IonPac CS12A Analytical Column (for cations) http://www.dionex.com

	Evian		**Aqua**		**Kildevaeld**		**Aquad'or**		**Tapped water**	
	Bottle label	Test result	Bottle label	Test result	Bottle label	Test result	Bottle label	Test result	Water works	Test result
Hydrogen Carbonate (HCO_3^-) mg/l	357	428	n.a.	288	244	267	**120**	**285**	n.a.	309
Sulfate ($SO4^{--}$) mg/l	10	15.32	n.a.	3.385	29	40.72	3	2.993	n.a.	83.77
Chloride (Cl^-) mg/l	4.5	5.42	n.a.	7.995	**52**	**27.34**	**13**	**7.26**	n.a.	25
Magnesium (Mg^{++}) mg/l	24	26.43	n.a.	1.72	14	9.67	2	1.44	n.a.	11.24
Sodium (Na^+) mg/l	**5**	**9.97**	n.a.	13.17	30	34.21	10	11.5	n.a.	24.92
Nitrate (NO_3^-) mg/l	3,8	5	n.a.	2	1	3	<0,5	1	n.a.	3
Potassium (K^+) mg/l	1	n.a.	n.a.	n.a.	5,9	n.a.	1	n.a.	n.a.	n.a.
Calcium (Ca^{++}) mg/l	78	n.a.	n.a.	58	**76**	**134**	39	52	n.a.	n.a.
pH	7,5	7.3	n.a.	6.86	**8**	**7.31**	7,3	6.9	n.a.	7.64

Table 9: Comparison of dissolved compounds stated by the water supplier against the results acquired during the experiment. "n.a." values were not available or were not acquired

The red numbers show the significant difference between the values stated on the label and the values from the test results. This indicates a reliability issue in either our test results or with the information provided on the label, which raises the question whether or not our data can be trusted. Although, we cannot be one hundred percent certain, we believe that the testing equipment were functioning properly during the experiments (ion chromatograph, pH meter and nutrient kits), since in most cases the values from the tests are close to the values stated on the bottle labels. However, the ion chromatograph did have difficulties in calculating the amount of calcium in tapped water and in one of the scenarios for Evian, which could questions the reliability of the data attained by this equipment.

Since we do not have a strong reason to believe that the results we acquired are incorrect, the reliability of the data stated by the water supplier can be questioned. We do not believe that the provided data is false; however, we think that it might be too general, for example the data is not update frequently enough to represent the potential change in he water composition. In order to test the reliability of the provided information, our experimental design would have focused on more samples for same brand, instead of the changes during different treatments.

7.4 Experimental design

Test scenarios were designed to reflect the reality as close as possible. As mentioned before, the selected temperatures, storage conditions and different treatments, were common in typical water consumption. The observed changes in the acquired results clearly indicate that the experimental design was a success. Since the experiment conditions were not “perfect” (such that would most likely affect the water sample), we believe, that the results from this experiment can be directly compared to the real life examples.

On the other hand, we believe that the experiment could be improved, in order to provide even more reliable results. To begin with, the tests could have been designed so the same sample could be reused for all four scenarios. This would eliminate the question, of how reliable the comparison of the test results between the scenarios is. Secondly, we chose to do replicates from the same water sample. While this ensures that our tests are performed correctly, it is nearly impossible to tell if the water sample was contaminated or otherwise affected before the tests were performed. Therefore, we believe that the replicates taken from different bottles would be a better test design.

8 Conclusions

Returning to the question "How does the quality of drinking water differ from each water source" stated in the problem formulation, we can conclude that the quality differs significantly for each source, both chemically and biologically.

Looking at whether or not the quality differs due to the treatments we can also conclude that this does not have a significant impact on the chemical aspect, where the biological aspect saw significant changes during the those treatments.

This can give us an understanding about water quality for regular water consumers, reflecting the changes in water when it gets exposed to different treatments. We feel that the scenarios reflect what could happen in reality.

None of the waters exceeds the requirements, except Aquad'or (cold closed condition, amount of standard plate count at 22℃). From chemical point of view it is just the matter of preference which type of water is the best to drink, because the amounts of chemical compounds do not vary significantly from different treatments and none of the values exceed the requirements.

By analyzing the collected data, we can clearly see that chemical composition of water differs significantly. Some of the chemical element concentrations were up to three times higher than in water coming from other sources. It is also quite easy to spot a tendency that spring water (Evian and Kildevaeld) have nearly two times higher concentrations of compounds, e.g. magnesium, calcium, in comparison to mineral water (Aqua, Aquad'or) and tapped water. The observed results suggest that the water quality is very dependent on the source it is coming from, especially for spring waters.

Moreover, mineral water seems to remain more constant in comparison to spring water, during different treatments. The concentrations of some of the chemical elements in spring water can vary compared to mineral water. This can be observed in the test results of calcium and magnesium, for Evian and Kildevaeld (spring water). However, this tendency cannot be observed for microbiological tests. These tests show clear dependence on the environment conditions. Increase in the temperature shows a significant increase in the bacteria count for both mineral, spring waters and tapped water.

In addition, the microbiological tests clearly suggest that any type of water should be consumed cold and in a short period after opening the bottle or when the water has been tapped.

9 Perspectives

Our report gives a general understanding about the changes in the water composition and microbiology. In order to acquire more comprehensive understanding of the water quality, we believe that the focus could be shifted to the other aspects mentioned in the report.

To begin with, during our experiment we focused on water quality with samples that have not been exposed to direct sunlight and, whether or not, it has an impact on the chemical composition and the microbiology, for example photosynthetic bacteria, in the water.

Secondly, the results acquired throughout our experiments can be analyzed in more depth to find the relation between how different chemical compounds affect the water's taste and color characteristics.

Lastly, the reliability of the provided information from the water supplier can be checked further. An experiment with more samples for each brand would generate more reliable data.

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11 Appendix

11.1 Appendix A: Standard Plate Counts

	Kimtal 22															
	CC		WC		CO		WO		CCD		WCD		COD		WOD	
Evian	95	94	54	53	120	92	118	178	2	5	1	4	1	0	1	4
Tapped	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Aqua	44	1200	28	47	68	302	213	776	0	0	4	43	3	0	65	65
Aquad'or	272	330	1248	2360	16	5	55	177	52	20	11	8	0	3	23	15
Kildevaeld	1	4	4	6	108	89	163	110	0	0	0	0	42	26	24	4

	Kimtal 37															
	CC		WC		CO		WO		CCD		WCD		COD		WOD	
Evian	0	3	1	2	5	20	44	30	0	0	1	0	1	0	1	2
Tapped	6	6	-	-	29	18	82	90	1	0	-	-	1	2	0	2
Aqua	0	0	0	0	14	9	17	42	1	6	0	0	2	1	3	5
Aquad'or	0	0	1	1	3	5	35	36	0	2	0	2	0	0	2	2
Kildevaeld	2	0	9	9	52	34	150	1092	1	3	0	0	4	5	155	3

11.2 Appendix B: Nutrient Analysis

	NO3							
	CO		CC		WO		WC	
Evian	5	5	5	5	5	5	5	5
Aqua	1	1	1	1	1	1	1	1
Aquad'or	1	1	1	1	1	1	1	1
Kildevaeld	3	3	3	3	3	3	3	3
Tapped	3	3	3	3	3	3	3	3

	NH4							
	CO		CC		WO		WC	
Evian	0	0	0	0	0	0	0	5
Aqua	0	0	0	0	0	0	0	1
Aquad'or	0	0	0	0	0	0	0	1
Kildevaeld	0	0	0	0	0	0	0	3
Tapped	0	0	0,1	0,1	0	0	0,1	3

	PO4							
	CO		CC		WO		WC	
Evian	0,9	0,9	0,8	0,8	0,9	0,9	0,8	0,8
Aqua	1,5	1,5	1,5	1,5	1,5	1,5	1,5	1,5
Aquad'or	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1
Kildevaeld	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2
Tapped	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8

11.3 Appendix C: Gran Titration

	pH	NaOH (ml)	pH (Start)	pH #1	pH #2	pH #3	pH #4	pH #5	pH #6	HCL #1	HCL #2	HCL #3	HCL #4	HCL #5	HCL #6	HCO3
C.C. Tapped #1	7.62	0	7.62	7.41	7.05	6.7	4.17	3.92	3.75	0.1	0.3	0.6	2.65	2.69	2.73	314.55
C.C. Tapped #2	7.65	0	7.65	7.37	7.01	6.64	4.35	4.04	3.75	0.1	0.3	0.6	2.55	2.6	2.65	303.66
C.O. Tapped #1	7.6	0	7.6	7.37	7.04	6.7	4.12	3.99	3.78	0.1	0.3	0.6	2.65	2.67	2.71	315.8
C.O. Tapped #2	7.55	0.1	7.61	7.36	7	6.66	4.37	4.11	3.82	0.1	0.3	0.6	2.71	2.75	2.8	324.49
W.O. Tapped #1	7.44	0.3	7.61	7.37	7.02	6.69	4.35	4.07	3.79	0.1	0.3	0.6	2.9	2.95	3	348.27
W.O. Tapped #2	7.5	0.3	7.62	7.02	7.02	6.7	4.38	3.99	3.74	0.1	0.3	0.6	2.88	2.95	3	366.83
C.C. Evian #1	7.3	0.4	7.61	7.37	7.04	6.78	4.04	3.83	3.79	0.1	0.31	0.6	3.5	3.54	3.57	419.81
C.C. Evian #2	7.29	0.6	7.61	7.39	7.06	6.77	4.4	4.15	3.89	0.1	0.3	0.6	3.6	3.65	3.7	436.47
C.O. Evian #1	7.25	0.9	7.6	7.35	7.05	6.78	4.37	4.19	3.75	0.1	0.3	0.6	3.96	4	4.1	483.72
C.O. Evian #2	7.26	1	7.6	7.41	7.05	6.7	4.39	4.17	3.93	0.1	0.3	0.6	3.9	3.95	4	467.4
W.C. Evian #1	7.26	1	7.61	7.28	7.06	6.77	4.4	4.2	3.97	0.15	0.3	0.6	4	4.05	4.1	482.03
W.C. Evian #2	7.26	1.1	7.62	7.41	7.09	6.8	4.34	3.99	3.83	0.1	0.3	0.6	4.12	4.2	4.25	498.28
W.O. Evian #1	7.27	0.8	7.6	7.37	7.07	6.76	4.33	4.09	3.86	0.1	0.3	0.61	3.8	3.85	3.9	459.99
W.O. Evian #2	7.35	0.9	7.63	7.39	7.06	6.76	4.35	4.17	3.73	0.1	0.3	0.6	3.71	3.75	3.85	449.56
C.C. Aqua #1	6.87	1.3	7.63	7.2	6.78	6.69	4.32	3.98	3.8	0.1	0.3	0.4	2.27	2.32	2.35	272.45
C.C. Aqua #2	6.86	1.4	7.64	7.27	6.99	6.84	4.3	4.04	3.81	0.1	0.3	0.4	2.5	2.54	2.58	303.31
C.O. Aqua #1	6.81	1.5	7.64	7.23	7.01	6.85	4.34	4.04	3.77	0.1	0.2	0.3	2.7	2.75	2.8	326.73
C.O. Aqua #2	6.84	1.4	7.6	7.21	6.98	6.82	4.38	4.07	3.78	0.1	0.2	0.3	2.49	2.54	2.59	300.87
W.C. Aqua #1	6.86	1.4	7.62	7.25	6.99	6.81	4.34	4.03	3.79	0.1	0.2	0.3	2.43	2.48	2.52	290.86
W.C. Aqua #2	6.86	1.7	7.63	7.21	6.97	6.8	4.35	3.99	3.72	0.1	0.2	0.3	2.46	2.52	2.57	295.18
W.O Aqua #1	6.88	1.5	7.63	7.22	6.99	6.82	4.39	4.11	3.82	0.1	0.2	0.3	2.55	2.6	2.65	307.18
W.O. Aqua #2	6.88	1.4	7.62	7.23	7	6.81	4.38	4.08	3.79	0.1	0.2	0.3	2.45	2.5	2.55	294.14
C.C. Aqua D'or #1	6.9	1.3	7.61	7.16	7.93	6.76	4.38	4.05	3.76	0.1	0.2	0.3	2.22	2.27	2.32	260.28
C.C. Aqua D'or #2	6.9	1.2	7.6	7.17	6.94	6.78	4.35	4.02	3.74	0.1	0.2	0.3	2.26	2.31	2.36	272.76
C.O. Aqua D'or #1	6.92	1.2	7.61	7.24	6.98	6.82	4.39	4.06	3.77	0.1	0.2	0.3	2.27	2.32	2.37	273.05
C.O. Aqua D'or #2	6.95	1.2	7.66	7.23	6.98	6.81	4.37	4.05	3.76	0.1	0.2	0.3	2.28	2.33	2.38	274.02
W.C.Aqua D'or #1	6.9	1.3	7.61	7.18	6.95	6.78	4.39	4.03	3.75	0.1	0.2	0.3	2.31	2.37	2.42	278.24
W.C.Aqua D'or #2	6.9	1.3	7.63	7.19	6.95	6.78	4.39	4.1	3.8	0.1	0.2	0.3	2.34	2.39	2.44	281.45
W.O.Aqua D'or #1	6.94	1.2	7.62	7.25	6.95	6.8	4.33	4.01	3.78	0.1	0.2	0.3	2.26	2.31	2.36	269.79
W.O.Aqua D'or #2	6.91	1.2	7.61	7.21	6.96	6.75	4.37	4.07	3.76	0.1	0.2	0.3	2.25	2.3	2.35	268.5
#1 C.C. Kildevaeld	7.3	0.6	7.62	7.24	7.03	6.88	4.33	3.99	3.73	0.1	0.2	0.3	2.3	2.35	2.4	280.31
#2 C.C. Kildevaeld	7.32	0.6	7.63	7.25	7.03	6.88	4.19	3.97	3.76	0.1	0.2	0.3	2.4	2.44	2.48	290.41
#1 C.O. Kildevaeld	7.33	0.5	7.61	7.24	7.02	6.87	4.38	4.04	3.77	0.1	0.2	0.3	2.34	2.39	2.44	285.04
#2 C.O. Kildevaeld	7.37	0.5	7.64	7.27	7.05	6.9	4.34	4.01	3.75	0.1	0.2	0.3	2.34	2.39	2.44	284.76
#1 W.C. Kildevaeld	7.3	0.7	7.6	7.23	7.01	6.85	4.34	4.04	3.71	0.1	0.2	0.3	2.43	2.48	2.54	295.35
#2 W.C. Kildevaeld	7.3	0.8	7.61	7.26	7.04	6.87	4.39	4.08	3.8	0.1	0.2	0.3	2.53	2.58	2.63	306.58
#1 W.O. Kildevaeld	7.34	0.7	7.64	7.29	7.06	6.89	4.37	4.06	3.78	0.1	0.2	0.3	2.49	2.54	2.59	301.33
#2 W.O. Kildevaeld	7.36	0.6	7.62	7.25	7.02	6.88	4.37	4.03	3.75	0.1	0.2	0.3	2.41	2.46	2.51	293.92

Initial pH table

	pH							
	CO		CC		WO		WC	
Evian	7.25	7.26	7.3	7.29	7.27	7.35	7.26	7.26
Aqua	6.81	6.84	6.87	6.86	6.88	6.88	6.86	6.86
Aquad'or	6.92	6.95	6.9	6.9	6.94	6.91	6.9	6.9
Kildevaeld	7.33	7.37	7.3	7.32	7.34	7.36	7.3	7.3
Tapped	7.6	7.55	7.62	7.65	7.44	7.5	-	-

Hydrogencarbonate table

	HCO3							
	CO		CC		WO		WC	
Evian	483.717	467.39905	419.813	436.47	459.99298	449.5613	482.03303	498.28
Aqua	326.728	300.87005	272.449	303.31	307.18051	294.1416	290.86414	295.18
Aquad'or	273.045	274.01531	260.278	272.76	269.7851	268.5037	278.2389	281.45
Kildevaeld	285.041	284.76256	280.312	290.41	301.33118	293.9159	295.348	306.58
Tapped	315.8	324.48966	314.554	303.66	348.26945	366.828	-	-

11.4 Appendix D: Ion Chromatograph

	Sodium			
	CC	WC	CO	WO
Evian	9.968	9.667	9.217	9.0419
Aqua	13.17	13.43	13.49	14.369
Kildevaeld	34.21	40.91	47.59	41.866
Aquad'or	11.5	14.33	12.04	13.63
Tapped	24.92	-	25.63	21.112

	Magnesium			
	CC	WC	CO	WO
Evian	26.4316	26.0316	23.5917	25.2781
Aqua	1.7251	2.0718	2.078	2.1615
Kildevaeld	9.6781	11.6892	11.2928	10.1407
Aquad'or	1.4406	2.1644	1.8808	2.0871
Tapped	11.2429	-	11.1079	9.6537

	Calcium			
	CC	WC	CO	WO
Evian	118	112.8187	85.0637	93.089
Aqua	57.6692	56.7694	57.9326	56.1906
Kildevaeld	134.2505	144.7279	126.7284	124.1408
Aquad'or	51.7352	59.784	55.5285	54.8937
Tapped	179	-	182	171

	Sulfate			
	CC	WC	CO	WO
Evian	15.32	14.16	12.02	13.22
Aqua	3.385	3.433	3.239	3.447
Kildevaeld	40.72	45.85	44.8	41.89
Aquad'or	2.993	3.8	2.801	3.287
Tapped	83.77	-	82.76	79.94

	Chloride			
	CC	WC	CO	WO
Evian	5.419	5.6106	4.7799	5.0467
Aqua	7.9948	8.0638	8.2227	8.6299
Kildevaeld	27.3368	32.5651	33.6959	30.1229
Aquad'or	7.2568	8.5032	7.2768	8.1848
Tapped	25.004	-	24.5906	21.3973