Tap Versus Bottled Water:

Water Preferences in Germany

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1. Abstract

In Germany, tap water has a high quality and is potable water approved. It is commonly used for drinking and cooking. Nevertheless, many people prefer to drink bottled water.

In this project, the students will first conduct a survey at our school to analyze young people's patterns, beliefs and organoleptic appreciations of their peers. Furthermore, they will select a few brands of bottled water, whose springs are located in the surrounding area. Then the contents of the selected bottled water will be compared to our tap water. Based on these results, the students will get information about the general influences of these specific minerals in water. In this context the students will organize a blind tasting of the different kinds of water.

Next, the students will present the results of their theoretical groundwork to their fellow students in the chemistry lesson. The presentation's objective is to raise the students' awareness of the contents of bottled water versus tap water. Following the presentation, the students will perform experiments to analyze mineral content in both kinds of water to support their theory.

The overall aim is to arrive at a conclusion on whether one kind of water is preferable ecologically and economically as well as with regard to health.

2. Keywords

Tap water, bottled water, Germany, drinking water behavior

3. The purpose of research

In Germany, drinking water can be consumed either from a bottle or from the tap. It is a country very rich in water resources. "In total, about a quarter of the available water resources are being used, and four percent of that amount is used as drinking water" [1a]. Groundwater is the most important resource for drinking water, which is also available sufficiently (apart from some regional exceptions). The availability of water resources vary greatly in the different regions because of different amounts of precipitation, the amount of available groundwater and the existence of surface waters.

Germany's drinking water quality is good or very good as it is regularly controlled and inspected at short intervals. Furthermore, it "complies with the stringent quality requirements of the Drinking Water Ordinance. "

The quality of drinking water (tap water) varies in different households due to the dependence of the pipes, fittings and different methods for treatment used in water works (studies carried out for the German Environmental Survey of the Federal Environment Agency proof this). "Since drinking water pipes made of lead were used in private homes up until the 1970s, some households still show higher lead contents in their drinking water because lead gathers in the water standing in the pipes at night"[1b].

Germany's tap water can be consumed safely. Stuttgart tap water has especially high quality and is tested regularly. However, many people tend to drink bottled water and have different opinions regarding dirking water.

The aim of this project is first of all to inform our school community at Dillmann-Gymnasium in Stuttgart about the quality of tap water. Secondly, our goal is to prove that tap water has the same high quality, or potentially even higher quality as mineral water sold in bottles. Moreover, we aim at enlightening our school's students and teachers and convincing them, to drink tap water instead of bottled water and thus hope to persuade them not to buy water in bottles anymore. We want to prove the qualities and advantages of tap water with own experiments and research. Further, we will include the Dillmann-Gymnasium school community in this project by doing surveys, water tasting experiment and presentations.

4. Method of research

Since the aim of the project is to clarify whether it is reasonable to drink tap water or not and to explain why, considering ecological, economical and health aspects, we decided to use different methods. The first thing to do was to find out how people think about mineral and tap water, so we evolved a survey and conducted it with students and teachers from our school. Afterwards we evaluated the survey and compiled statistics.

In addition to that we made a blind water tasting to find out if people could really taste a different between tap and mineral water or if it is more mental that you think it tastes different. Above that we wanted to find out what kind of water people like the most, so we compiled a questionnaire, organized the water testing and evaluated it. The next step was to make an ample research, so we could explain what the ecological and economic advantages and disadvantages of tap water are and to depict how tap water is different from mineral water, when it comes to the quality.

For this we evolved a chemical analysis. Because of missing equipment and on legal grounds, which prohibit students in Germany to work with certain chemicals it was not possible for us to make a quantitative analysis of the ions, so we evolved a semi-quantitative chemical analysis. This experiment can be practised in chemistry lessons as well, that way we could integrate it in class.

We held a presentation in chemistry class to make sure that everyone will know the difference between mineral and tap water and be aware of the advantages and disadvantages of it. In addition to that we will scatter flyer in our school

5. Results of the research

5.1. Survey concerning the drinking behavior

The aim of the conducted survey is to understand the habits and beliefs of the students and teachers of Dillmann-Gymnasium regarding tap and bottled water.

There were 242 participants in total, 111 students (male: 50, female: 61) from 8th to 9th grade, 106 students (male: 51, female: 55) from 10th to 12th grade and 25 teachers (male: 8, female: 17).

Students from 5th to 7th grade didn't participate in the survey in order to not falsify the results of the questionnaire due to the difficulties in understanding the topic.

5.1.1. Results of the survey

Question 1: Do you drink tap water and why/why not?

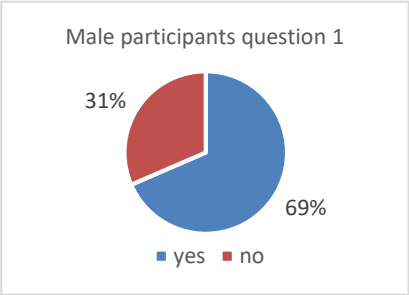

Figure 1: Graph for male participants question 1

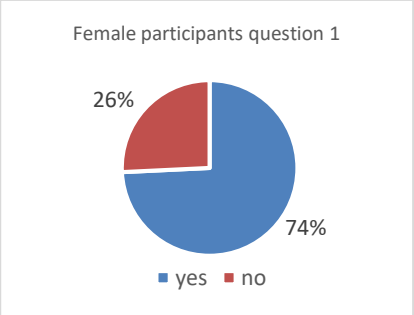

Figure 2 Graph for female participants question 1

How figures 1 and 2 show, 5% more female participants drink tap water instead of bottled water. It is more or less the same but comparing the answers through the three groups, it is noticeable that only 11% of the female students from grade 10th to 12th don't drink tap water compared to 33% of the male students. The other two groups show an equal distribution for both genders.

Some of the reasons why the participants drink tap water are:

Because…

…it is available everywhere. (28%)

…it is cheap. (23%)

…it tastes good. (20%)

…it has a high quality. (11%)

…you don't have to carry heavy boxes. (4%)

In every age group, the top reason is the availability of tap water. The low price and the taste is also a reason often mentioned across all age groups. Notably, only the teachers mentioned the high weight of water bottles which have to be carried to their house.

Some of the reasons why the participants don't drink tap water are:

Because…

…it is non-carbonated. (43%)

…the taste is monotonous. (19%)

…it isn't controlled properly. (26%)

…the water supply system at home is old. (4%)

The majority of the persons don't drink tap water due the missing carbon dioxide. Surprisingly, 26%, all from the 8th to 9th grade group, think that the tap water isn't tested properly and has a poor quality.

Question 2+3: Which mineral water do you like the most and why?

Alltogether 34% of the participants don't prefer a specific mineral water. 21% of them think that all kinds of water taste the same.

The second-most frequent answer (6 % in total) was that participants use tap water and add carbon dioxide with a soda device. The reason for this is that the concentration of carbon dioxide can be varied according to one's own taste.

The third most frequent answer (5.6 %) was that participants buy the mineral water "Saskia," a brand from a discounter. The argument of all persons who choose this water is the cost-benefit-ratio.

Among the participants 14.5 % choose a mineral water brand whose spring is located abroad. Everyone from this group gave the good taste as the reason for this choice.

Question 4: Which mineral water don't you like at all and why?

In total, 63 % of the participants answered this question by stating that they don't dislike a specific mineral water. Many of them couldn't explain why, others mentioned the same reason as in question 3, that all kinds of water taste the same.

14 % name the same mineral water, "Ensinger Sport," on the grounds of it tasting too salty. Compared to other kinds of mineral water the mineral content in this water is extra high, which causes a salty taste.

The other participants chose all different mineral waters and mentioned the taste as the reason, but didn't describe this more precisely.

Question 5: Can you imagine drinking nothing but tap water? Why/Why not?

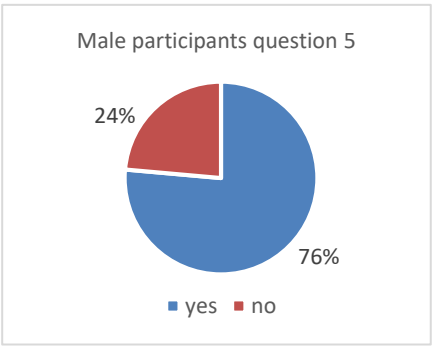

Figure 3 Graph for male participants question 5

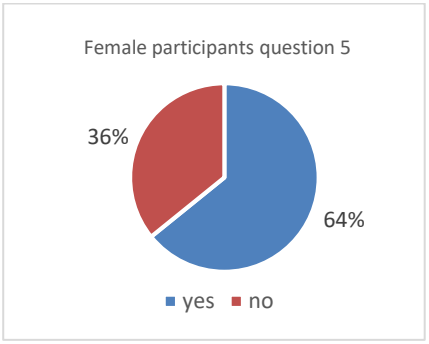

Figure 4 Graph for male participants question 5

Figure 3 and 4 show that 76 % of the male and 64 % of the female participants can imagine drinking only tap water. Some of them added a note to the questionnaire, saying that they would do this only if they didn't have any other choice.

About a quarter of the male participants can't imagine drinking nothing but tap water. The percentage of the female participants is even 12 % higher.

For approximately 36 % of them the reason not to drink tap water is the missing carbon dioxide. 22 % answered that it has a non-descript taste and it is boring to drink only tap water.

Question 6: Which water is healthier, tap or mineral water?

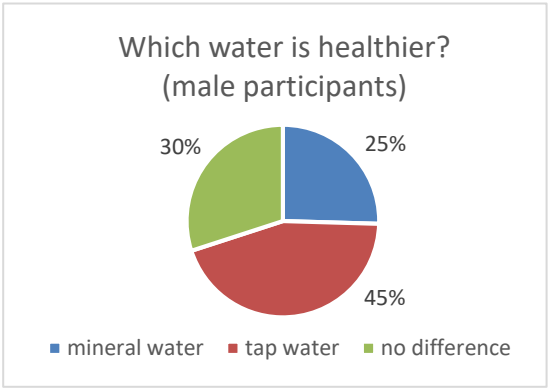

Figure 5 Graph for male participants question 6

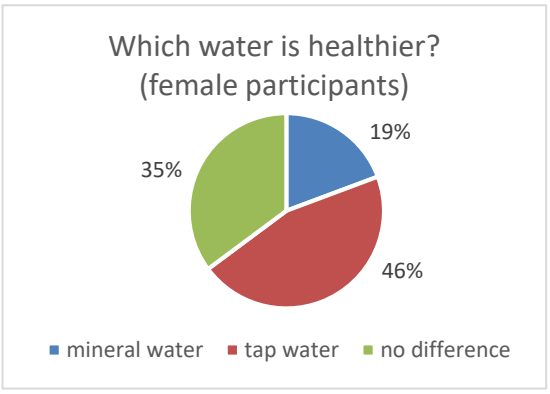

Figure 6 Graph for female participants question 6

As you can see in figure 5 and 6, the percentages are slightly different if you compare the male and female participants. The majority consider tap water to be healthier than mineral water, and more than a quarter think that it makes no difference. The remainder hold the view that mineral water is healthier.

Question 7: How much does one liter of tap water cost?

Although the distribution across the genders is rather equal, the answers on this question are very different in the various age groups.

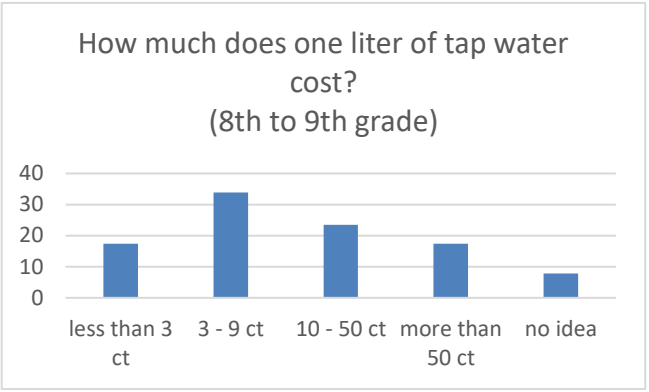

Figure 7 Graph for cost one liter tap water 8th/9th grade

As figure 7 shows, 34 % of the 8th and 9th grade students named a price between 3 and 9 cents per liter. In total, 42 % think that one liter of tap water costs more than 10 cent. That means that only 17% are about right.

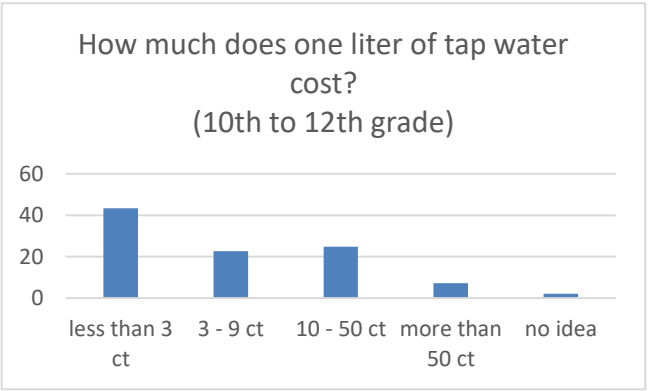

Figure 8 Graph for cost one liter tap water 10th to 12th grade

In comparison to the first age group almost 43 % of the 10th to 12th grade students estimated a price of 3 cents or less how you can see in figure 8. You can see a clear disparity in the estimated costs of up to 50 cents or even more. 10 % of the older students gave this response.

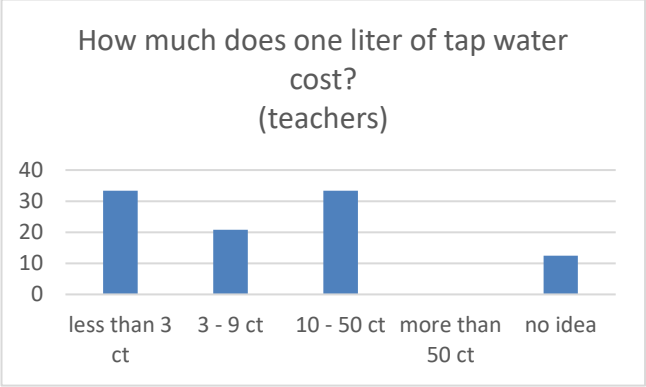

Figure 9 Graph for cost one liter tap water teachers

Almost as many teachers estimate the price of one liter tap water as being between 10 and 50 cents or less than 3 cents, as figure 9 shows. It is eye-catching that none from this group guessed a price higher than 50 cents.

5.1.2. Analysis and interpretation of questionnaire

On the basis of the questionnaire you can see that more than a quarter of the participants don't drink tap water, although it is potable in Germany. The majority of these persons reject tap water because of the missing carbon dioxide. It might be essential to point out to them that there are devices which can be used to add carbon dioxide to the tap water so that they might rather want to drink it.

It is shocking that 26 % of these participants don't drink tap water because they think that it isn't tested properly. All these persons were students from the 8th and 9th grade that's why it is important to inform especially these age groups about the high quality of our tap water.

Another reason which was given for not drinking tap water is the stale taste. As we can see in questions two to four, a lot of participants are of the opinion that all water tastes the same. Here we hope to show to some of them in the blind tasting session that this isn't right and that tap water doesn't have a bad taste. Maybe it will be possible to reduce some prejudices.

Based on the question with which water is healthier we now know that not even half of the participants know that it would be better for our health to drink tap water. According to the answers a lot of them think that there are a lot of bad contents in our tap water compared to mineral water. This is surely connected with the afore mentioned false opinion in question one, about tap water in Germany not being tested thoroughly.

Regarding the costs, we didn't expect the distribution of answers to the last question of the questionnaire. Many participants estimated a price for a liter of tap water that was much too high. We assume that the students of the youngest group had never thought about the price of tap water, so that it was very difficult for them to make a good guess. Surprisingly, many teachers named a price that was too high as well, although most of them pay a water bill for their house and could know it.

Regarding this point it will be important in the following steps to inform the participants about the economic advantage of drinking tap water instead of bottled water. One liter tap water actually costs about 0,2 cents, which is really cheap compared to one liter of Ensinger water, which costs 0,74 euros (without recyclables refund). That means if a person drinks for instance 2 liters of this bottled water per day he would pay 45 Euro per month for drinking water, respectively 540 Euro per year. With the same amount of tap water the yearly costs would be only 122 Euro, that's a saving of 418 Euro per year. For sure this information can change the opinion of some of the participants to change from bottled to tap water.

5.2.Chemical Analyis

5.2.1. Procedure: semi quantitative method

By means of comparison of the intensity of the solutions, you can suggest the concentration of the ions. To minimize the failure it is important that the amount of water of all samples is the same (for example 100ml). We chose to examine a few parameters, for instance the water hardness, which is often a problem in Germany.

Tap water in comparison to different varieties of still water:

- Ensinger
- Black Forrest
- Gerolsteiner
- Adelholzener
- Tap water

Since you have to work semi-quantitative it is important to always use the same amount of water.

5.2.1.1. Total water hardness (in °e):

To determine the total water hardness of the different water sorts analytical test stripes have been held into the water. Depending on the hardness of the water the colour of the stripes changed. There are five boxes on one stripe, if one box is red and the other four are green it means that the water is really soft and if all five boxes are red the water hardness is high, so the water hardness is higher if mire boxes are red.

5.2.1.2. pH value:

To determine the pH value you can add approximately four drops of an universal indicator to the water and it will change its colour. If the colour is orange or red the water is sour, if it is blue the water is basic and if it is green the water is neutral.

5.2.1.3. Proof of Hydrogencarbonate

Preliminary test:

For the assessment of the hydrocarbonate concentration you can occupy the release of carbon dioxide by acidification with half-concentrated hydrochlorid acid. (But this can only work if the bottles are opened freshly.) Therefor you merge 10 ml of the water with 2 ml hydrochlorid acid. Now you can observe which sort of water has the maximum gas release and which one has the least.

Titration to prove Hydrogencarbonate:

Before you can start you should wait until the outgassing is finished. (For this the bottles have to be opened freshly as well)

Now you can pour the dilution into an erlenmeyer flask and titrate with sodium hydroxid (c = 0,1 mol/l) against Phenolphthalein as indicator. You have to titrate until the water changes its colour to pink.

5.2.1.4. Sulfate

To the acidulated water samples (from the preliminary hydrocarbonate test) you must add 2 ml barium chloride dilution (c = 0,5 mol/l). After some time colourless, fine crystals of barium chloride fall down. Now you can compare the water samples, to find out which one has the most and the least crystals in it.

5.2.1.5. Chlorid

For the proof of chlorid you need 10 ml water, which you have to merge with 2 ml half-concentrated nitric acid. While merging it you can observe the release of carbon dioxide. Then you add 2 ml silver nitrate dilution. A white desposit is formed, if you shake the test tube a little it will be easier to see the desposit.[1]

5.2.2. Results of the research

5.2.2.1. Total water hardness (in °e)

- Soft: 0 - 20 mg/L calcium
- Moderately soft: 20 - 40 mg/L calcium
- Slightly hard: 40 - 60 mg/L calcium
- Moderately hard: 60 - 80 mg/L calcium
- Hard: 80 - 120 mg/L calcium
- Very Hard >120 mg/L calcium

Table 1:Results of water hardness

Kind of Water	Total Water Hardness in °e	mmol/l alkaline earth ions	mg/l calcium
Ensinger	Over 30	4,29	171,4
Black Forest	Over 6	0,858	34,4
Gerolsteiner	Over 30	4,29	171,4
Adelholzener	Over 30	4,29	171,4
Tap Water	Over 25	3,58	142,9

Conversion to mg/L calcium: divide by 0.175.

One degree Clark corresponds to one grain of calcium carbonate in one Imperial gallon of water which is equivalent to 14.28 parts calcium carbonate in 1,000,000 parts water.

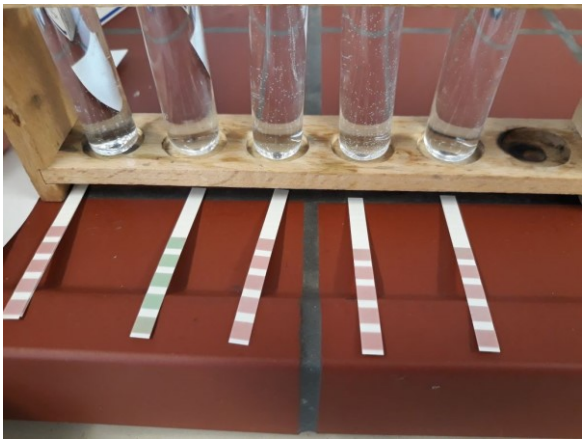

Figure 10 Water hardness test. From left to right: Ensinger, Black Forest, Gerolsteiner, Adelholzener, tap water

5.2.2.2. Measure of the pH value

Table 2: Results of pH value

Kind of Water	pH value
Ensinger	7
Black Forest	6-7
Gerolsteiner	7
Adelholzener	6-7
Tap water	7-8

Figure 11 pH test. From left to right: Ensinger, Black Forest, Gerolsteiner, Adelholzener, tap water

5.2.2.3. Hydrocarbonate

- Ensinger: water became pink after 1,58 ml caustic soda was added
- Black Forrest: water became pink after 0,15 ml caustic soda was added.
- Gerolsteiner: water became pink after 2 ml caustic soda was added.
- Adelholzener: water became pink after 1,7 ml caustic soda was added.
- Tap water: water became pink after 0,3 ml caustic soda was added.

Considering the reaction equation (1) you can calculate the mass concentration of hydrocarbonate in the water.

$$HCO_3^- + OH^- \rightleftharpoons CO_3^{2-} + H_2O \qquad (1)$$

Calculation in general:

Because of the Eq. (1) is is valid:

$$n(HCO_3^-) = n(NaOH) = c(NaOH) \cdot V(NaOH) \quad (2)$$

$$c(HCO_3^-) = \frac{n}{V} \quad (3)$$

By using the Eq. (2) and Eq. (3) you can calculate the required variables to calculate the mass concentration with Eq. (4).

$$\rho(HCO_3^-) = c(HCO_3^-) \cdot M(HCO_3^-) \quad (4)$$

Example with Ensinger:

V(water sample) = 0,1 l, c(NaOH) = 0,1 mol/l, $M(HCO_3^-)$ = 61020 mg/mol,

V(NaOH) = 1,58 ml = 0,00158 l

$$n(HCO_3^-) = n(NaOH) = 0{,}1\,\frac{mol}{l} \cdot 0{,}00158\,l = 0{,}000158\,mol$$

$$c(HCO_3^-) = \frac{n}{V} = \frac{0{,}000158\,mol}{0{,}1\,l} = 0{,}00158\ \frac{mol}{l}$$

$$\rho(HCO_3^-) = c(HCO_3^-) \cdot M(HCO_3^-)$$

$$= 0{,}00158\,\frac{mol}{l} \cdot 61020\ \frac{mg}{mol} = 96{,}41\ \frac{mg}{mol}$$

Table 3: Results of massconcentration hydrogencarbonate

Kind of Water	Hydrocarbonate (mg/l)	Amount of caustic soda (ml)
Ensinger	96,41	calculation from above
Black Forest	9,153	same calculation with V(NaOH) = 0,15
Gerolsteiner	122,04	V(NaOH) = 2
Adelholzener	103,735	V(NaOH) = 1,7
Tap water	18,306	V(NaOH) = 0,3

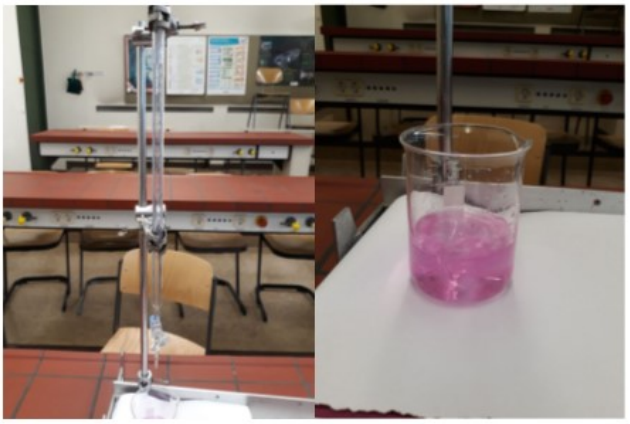

Figure 12 Titration for Hydrocarbonate concentration

5.2.2.4. Sulfate

- Ensinger most deposit
- Black forrest least desposit
- Gerolsteiner a little desposit
- Adelholzener a little desposit
- Tap water a little desposit

Figure 13 Sulfate test: From left to right: Ensinger, Black Forest, Gerolsteiner, Adelholzener, tap water

5.2.2.5. Chlorid

- Ensinger most deposit
- Black forrest least desposit
- Gerolsteiner 3. most desposit
- Adelholzener the last but one most desposit
- Tap water 2. most desposit

Figure 14 Chlorid test. From left to right: Ensinger, Black Forest, Gerolsteiner, Adelholzener, tap water

5.2.3. Experiment Conclusion

Table 4: Literature Data [3]

Kind of Water	Hydrocarbonate mg/l	Sulfate mg/l	Chloride mg/l
Ensinger	403	1463	28,9
Black Forest	18	3	0,9
Gerolsteiner	1816	38	40
Adelholzener	342	27	21
Tap water	247	112	55

In comparison to our results there is a huge deviation from the literature data of the hydrocarbonate value of Ensinger, tap water and especially Gerolsteiner. A reason for this could be an inaccuracy of the determination of hydrocarbonate. Since you titrate until the water changes its color, a source of error could be the rough estimation of the added amount of caustic soda and an inaccurate estimation of when the water is pink.

The results of the sulfate amount conform on the whole the literature data. Ensinger water had definitely the most deposit and Black Forest the least.

The findings of chloride deviate a bit from the literature data, which says that Gerolsteiner and tap water should have more chloride than Ensinger, but the results of the experiment show that Ensinger has the most chloride. A reason for this could be an imprecise concentration of half-concentrated nitric acid or an imprecise amount of water in the samples.

5.2.4. Meaning of the examinated parameters for the health

5.2.4.1. Water hardness

Water hardness is basically the amount of dissolved calcium and magnesium in the water. So if the water is hard it is high in dissolved minerals, calcium as well as magnesium. The human body is in need of mineral. The National Research Council (National Academy of Sciences) asserts that hard drinking water concurs a small amount in comparison to the amount calcium and magnesium humans needs.

But on the other hand the hardness of water is a topic many people are concerned about. Solid deposits of calcium carbonate can arise, when you heat hard water. This is a reason why the costs of heating the water can be increased and clog pipes and household aids can take damage. [4]

Ensinger, Gerolsteiner and Adelholzener have a really high water hardness, which means that they consist of many dissolved minerals, but might not be convenient to be heated.

Interestingly the water hardness of tap water, which is used by most of the Germans for example for tea (what means its heated) and which runs through our pipes, is a little less, but still also really high. So in fact, as mentioned before, it is not implausible that our tap water reduces the life of equipment, raises the costs of heating the water, lowers the efficiency of electric water heaters, and clogs pipes. Black Forest has in contrast to the other sorts a really low water hardness, so it might not contain as much minerals as the other sorts, but might be more convenient to be heated.

5.2.4.2. pH value

The pH value of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be used by aquatic life) of chemical constituents such as nutrients (like carbon) and heavy metals (like lead). In addition to affecting what form of phosphorus is most abundant in the water and how much of it pH also determines if aquatic life can occupy it. For example in the case of heavy metals, the degree to which they are soluble determines their toxicity. Metals tend to be more toxic at lower pH because they are more soluble.

Extremely high and low pHs can be crucial for the use of water. High pH causes a bitter taste, water pipes and water-using appliances become encrusted with deposits, and it lowers the effectivity of the disinfection of chlorine, thereby causing the need for additional chlorine when pH is high. Low-pH water will corrode or dissolve metals and other substances.

Drinking water must have a pH value between 6,5 and 8,5 [5] which is an incredibly huge margin considering, that the human body is constantly holding up the pH value of the arterial blood between 7,35 and 7,45 [6]. If humans drink water with a huge deviation from that value their body has to correct this with a big energie expenditure, so the body has less energy at its disposal.

Optimal water, which boosts the metabolism and stimulates the kidney activity, should have a pH value between 6,5 and 6,8. So it should be a little acid. All the bottled water sorts are having a similar pH value, which is with approximately 7 or between 6 and 7 an optimal value. Tap water has in contrast a higher pH value between 8 and 9. This value still conforms the drinking water ordinance, but is for the human body not as healthy as it would be with a lower pH value (which does not mean that it is unhealthy).

5.2.4.3. Hydrocarbonate

The human body generates hydrocarbonate itself to regulate the pH value of the blood and to keep the acid-base metabolism in balance, but in certain situations the body is not able to balance a hyperacidity itself. If humans drink water with

a high hydrocarbonate concentration this can help to balance the acid-base metabolism. [7]

Again the results of Ensinger, gerolsteiner and Adelholzener are similar. All three seem to have a high hydrocarbonate content, which can be helpful but is in most cases not necessarily needed by the human body. Tap water and Black Forrest are having a way lower hydrocarbonate content, Black Forrest even a little fewer than tap water.

5.2.4.4. Sulfate

The maximum level of sulfate in drinking water should be 500 mg/l, as the World Health Organization (WHO) recommends. Since the EU standards are way more stiff, they recommend a maximum of 250 mg/l of sulfate in drinking water.

There are certain health risks for humans who drink water containing high sulfate levels. Dehydration and diarrhea are often negative consequences when people who are not used to drinking water with a high level of sulfate. Especially children react often more tetchy to sulfate.

Water gets a bitter or medicinal taste, if sulfate passes a concentration of 250 mg/l, what might give the water an unpleasant taste. [8]

Ensinger water definitely contains the most sulfate, which explains why many people would say that it has a bitter and unpleasant taste. Above that Ensinger water should better not be used to preparate baby food. Black Forest has the least amount of sulfate, while Gerolsteiner, Adelholzener and tap water contain nearly the same amount of sulfate.

5.2.4.5. Chlorid

Chloride is an anion which tap water contains, and it mostly plugs with magnesium or sodium and salts like sodium chloride are generated. After some time, the high corrosivity of sodium chloride will damage white goods like water heaters. Water which is used for irrigation and contains a lot of sodium chloride can damage plants, and can make water unpleasant to drink, even if chlorides are not dangerous at low levels. But still there is no general standard for chlorides in drinking water. Levels no higher than 250 mg/L are suggested by the EPA, so the water does not taste salty or has a distasteful odors. At levels higher than 250 mg/L it can have a negative influence on the health of the human body, for instance existing heart problems can get worse. [9]

Again Ensinger water contains the most chloride, so it should better not be used in a water heater or for gardening. Tap water has indeed the second most chloride, but it has still way less than Ensinger, which means there should not be a problem with plumings and water heaters or irrigation. Since the other three sorts are having an even lower chloride value there should not be a problem as well.

So now we have seen how much minerals different water sorts contain and whether and how they are good for the human body or not. But still that leaves us with the question, if the human body really needs those minerals and if it can use them.

Minerals are inorganic substances (like rocks), but if they are useful to the human body is questionable. Most of the minerals people get from dairy products, fruits and vegetables, which can be for instance calcium. That way the minerals come from a organic source and can be processed by the human body very well. Milk, cheese and oranges for example can be processed very efficiently. Since minerals from inorganic sources can not be absorbed that well it seems to be much less efficient to get them from inorganic sources like water. So it seems that the inorganic minerals that water contains aren't very useful to the body. And in addition to that water does not even contain very much minerals considering the amount that the human body needs. [10]

5.3.The water-testing experiment

After the survey regarding the drinking water preferences and habits of students and teachers from Dillmann-Gymnasium (year 8-12) and the analysis of tap water in comparison to four other types of water regarding their chemical substances, we conducted a water tasting experiment with 42 test persons (students from year 11-12; teachers). The aim of this experiment was to detect and determine the test persons' taste preferences regarding water types. As they know more about water in general, these adult members of our school community seemed to us suitable participants of our experiment.

The four types of water and the tap water each have different chemical substances, as our own experiment before has shown. Due to the differences in minerals, we wanted to find out if the test persons were able to detect the tap water based on its taste. Furthermore, it was important to know their taste preferences regarding water (from the four water types plus the tap water from our school) because we wanted to find out how attentive they are when drinking water in their daily life: Do they know the different tastes of water? Can they detect tap water based on its taste?

Then, we compared these results with the results of the survey and our own experiment. We chose different kinds of water because each shows a different amount of minerals which influence the taste. The different kinds of water brands were: Ensinger naturelle (A), Black Forest still/naturelle (B), Gerolsteiner naturell (C) and Adelholzner naturell(D); non-carbonated. The last water being tested was the tap water from our school (E).

Furthermore, we wanted to see how students and teachers would assess the taste of the different water kinds, especially the tap water: if the majority actually also preferred the taste of tap water (E) over the mineral water sold in bottles (A-D), we wanted to present them with the results afterwards and thus persuade them to start drinking tap water instead of bottled water.

Water test procedure:

We invited 43 test persons from our school to take part at this project. They were each given 5 glasses filled with water tagged with the letters A-E. Each glass contained a different kind of water (see above). Hence, the test persons were not aware which letter represented which kind of water. Moreover, they didn't know which glass contained the tap water. Then they were given a questionnaire with the following questions:

Question 1: Which glass contains tap water? (At least one glass is filled with tap water)

They were not given the water brands or the number of the tap water samples; they were only told that at least one glass was filled with tap water, meaning that more glasses could contain tap water. We did this on purpose to see the taste of which water brand would be most similar to tap water. We also aimed at finding out how they imagined the taste of tap water based on their experience.

Question 2: Why do you think that tap water is in ___?

Here we wanted to know the reason for their guess. For instance, because of the taste, the smell or the consistency...

Question 3: Which water tastes the best? And why?

This question helped us to find out about taste preferences of the test persons. Further, we analysed which water is actually the best one and why. It also leads us to a conclusion of what kind of water the test persons like.

Question 4: Which water does not taste good at all? And why?

This question aimed at revealing taste preferences of the test persons. Further, we were able to analyse which water is actually the least preferred one and why. It also leads us to a conclusion on how test persons would like tap water to taste and if mineral waters actually taste worse to them.

5.3.1. Results of the water-tasting experiment

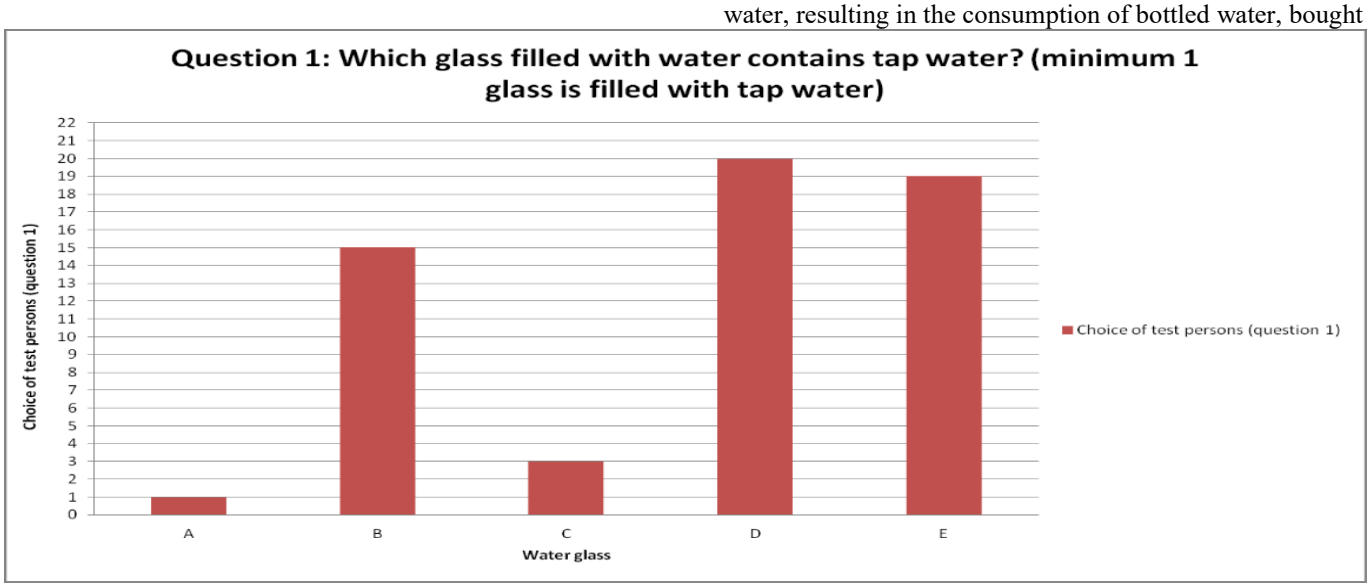

Figure 15 Graph: Results question 1 water-tasting

Table 5: Results question 1 water-tasting

Water glass	A	B	C	D	E
Number of test persons	1	15	2	20	19

Common answers to question 2 (quotes from the questionnaire):

Tap water is in ___ because…

…it tastes like a pipe, like limescale and metallic.

…it doesn't taste fresh and a bit like iron.

…it tastes like the most bitter and hardest one.

…it tastes natural and neutral.

…it has an strange aftertaste.

…it taste the most different.

…it tastes mouldy, as the pipes are old and rusty.

…it tastes as if no minerals are in the tap water.

…it tastes fresh.

All in all the answers were very different and diverse. Some have positive opinions on tap water and many others have a more negative view on tap water.

This shows that our school community has a more negative opinion on drinking tap water, prooving their ignorance about tap water and its quality. In most cases, their negative opinion also influenced their evaluation: they identified the waters they disliked the most (bitter taste, "unsanitary" taste, etc.) as the tap water. The general negative opinion about tap water influenced their answers. The majority seems to dislike tap water and hence prefers to drink bottled water.

Tap water has a bad reputation, is seen as insufficiently tested unhealthy and mineral-lacking – hence the test persons think that the taste is bad, bitter and "metallic," creating an aftertaste. This negative opinion influences their drinking habits and leads to the rejection of any kind of tap water, resulting in the consumption of bottled water, bought in supermarkets.

However, some students and teachers guessed the tap water based on its fresh and natural taste. They are probably already aware of the qualities of tap water, drinking it at home or also preferring its taste over bottled water.

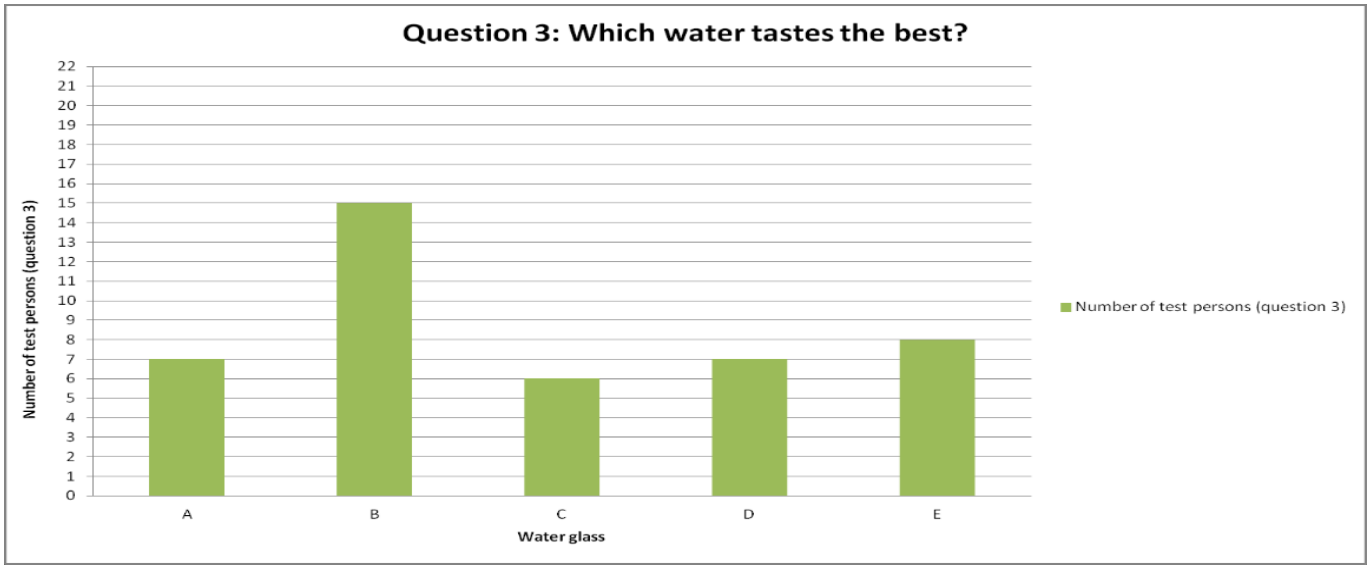

Figure 16 Graph: Results question 3 water-tasting

Table 6: Results question 3 water-tasting

Water glass	A	B	C	D	E
Number of test persons	7	15	6	7	8

Common answers to question 3 (quotes from the questionnaire):

Water ___ tastes the best because...

…it has a sweet, fresh and natural taste.

…it has a neutral taste.

…it is the "softest" and mildest one.

…it tastes "clean".

…it has no aftertaste.

The results of the most common answers of the test persons points out the general preferences of the taste of water: they prefer a sweet, fresh, natural and mild taste which indicates that it is clean and not polluted with chemicals.

Table 7: Results question 4 water-tasting

Water glass	A	B	C	D	E
Number of test persons	19	9	6	1	8

Common answers to question 4 (quotes from the questionnaire):

Water ___ does not taste good at all because…

…it tastes like nothing.

…it has an aftertaste (bitter).

…it has a salty and bitter taste.

…it has a "metallic" taste.

…it tastes too artificial.

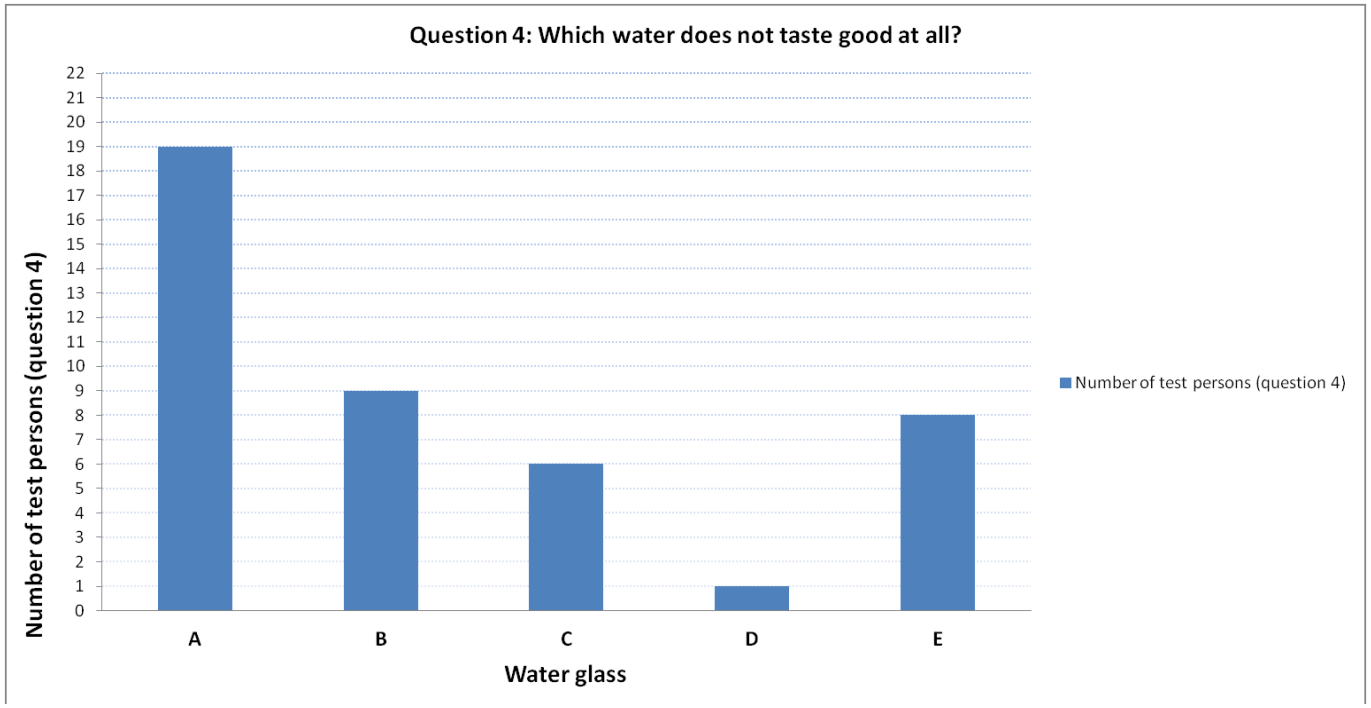

Figure 17 Graph: Results question 4 water-tasting

Comparing the answers from questions 2 and 4, a pattern of similarities can be detected: for the majority a bitter, "metallic" taste including an aftertaste are the most unpleasant tastes of drinking water. This means that they dislike water with a high amount of minerals, as Ensinger naturell has the highest amount of minerals.

The tap water was ranked in 3rd place, meaning that it was generally neutral for the test persons, meaning not too bad as it was described by the majority in questions 1 and 2. This blind water tasting shows that in general the test persons like the taste of tap water and don't consider its tastes as unpleasant as as the taste of e.g. Ensinger naturell (A) or Black Forest (B). Both of the latter are bottled waters and still weren't chosen as the tastier ones.

If these results were shown to the school community, their rather negative opinion about tap water could change and hence their drinking preferences and behaviour might change too. Their negative opinion of tap water clearly influences their water drinking habits: instead of drinking tap water, they buy bottled water because they think it is better than tap water (with regard to health benefits, purity and quality tests). Many are not aware of the fact that tap water is actually the better choice and has more advantages than the water bought in supermarkets: it is tested more often, is cheaper, eco-friendly, etc. (see above in the research report "Advantages of tap water and disadvantages of bottled water").

Therefore, the school community needs to be informed about these results and those facts about drinking water in general, especially tap water.

In the future, their psychological disposition regarding water preferences should change. Their current negative view on tap water can be transformed into a positive opinion – the facts must be presented.

5.3.2. Analysis and interpretation of the water-tasting

For question 1, the order of choice (which one was identified as tap water), is: D (20); E (19); B (15); C (3); A (1).

The glass which contained tap water (E) came up in 2nd place. So many could detect the tap water by guessing the type of water based on their imagination and experience of how tap water tastes.

Comparing those answers with answers from question 3, they vary a lot, except for sample B. Firstly, the majority (15 persons) liked water B the most. Secondly, tap water (E) was ranked 2nd, with 8 people choosing it as the best water. D was ranked in 3rd place with 7 votes, which shows that many couldn't decide between D and E, like in question 1. C (5 test persons) is liked the least out of these five kinds of water.

Outstanding are the numbers for question 4: Water A is disliked most, by 19 votes, which leads to the conclusion that this kind of water (Ensinger - type of bottled water) tastes worst for the majority of our school community. A is a type of mineral water very high in minerals, which the analysis of the minerals in these different kinds of water has already show. B (9) came in second, although it had been chosen as the tastiest water before (question 3). The tap water E was ranked in 3rd place with 8 votes. Without knowing what water (A-E) is tap water, 8 test persons chose tap water as the least tasty water. Water D is in last place with 1 vote. Both D and E have quite similar tastes, according to their amount of minerals and the taste evaluations. This shows that some bottled waters and tap water taste the same because they have a similar amount of minerals. In conclusion, people don't need to buy bottled water if it tastes similar to tap water and has the same or an even better quality (advantages of tap water).

Black forest (B) is a mineral water, containing the least minerals, which gives B a neutral and sweet taste. The majority preferred water B and it was chosen as the tastiest water from samples A-E. Many people argue that they drink bottled water due its high content of minerals, thinking it is healthy. They assume that tap water doesn't contain enough minerals for the human body and therefore don't drink it – they buy bottled water. However, the water with the least minerals was chosen as the tastiest one. Hence, the argument concerning the amount of minerals should be rethought.

This experiment including the questionnaire points out that various kinds of water also taste differently due to the different amount of minerals they contain. Moreover, the school's taste preferences show that all in all tap water is liked by many. But for instance water A (Ensinger) with most minerals, was chosen as the worst water out of the 5 different kinds. This shows that bottled water with many minerals, which is supposed to be healthy for the human body, doesn't match the taste preferences of our school community. Besides, it was already explained (see above) that the intake of minerals with water doesn't influence our health negatively of positively – the amount of minerals consumed with our daily food is enough for the human body.

5.4.Water protection and quality in Germany

The water for the Stuttgart districts West (where our school is locatet) and South comes primarily from Lake Constance. Since 1917, water has been delivered from rather distant water supplies. In Stuttgart itself the local water provider is the EnBW. In the laboratory of the waterworks, water samples are constantly being examined. Besides water from Lake Constance, the district of Stuttgart North is also supplied with water from the Danube, from the Buchbrunnquelle at Dischingen and from the "Donauried".[11]

As in other EU countries, most of the standards applicable to the sector are set in Brussels. Further, The Drinking Water Ordinance (Trinkwasserverordnung) of the Federal Ministry of Health determines the quality of drinking water, the most important foodstuff there is. The ordinance is enforced at states level. [12]

The German protection policy's long-term aims:[13]

- to protect the "good ecological and chemical quality of water bodies"
- to retain enough drinking water and process water (quality and quantity)
- to ensure that water which is for the public is available, also in terms of long-term
- In order to achieve these goals, water protection policy is based on:
- "the precautionary principle"

- the polluter is in charge of principle and costs,
- "Cooperation among all water users and stakeholders in water protection"

In order to implement these principles of water protection policy, the federal government and the states have developed a set of powerful legal instruments.

5.5. Taste of water

Salty or bitter: Sodium and chloride are responsible for a salty taste of water, a lot of sulphate can lead to a bitter taste. The mineral make-up determines the taste. The more calcium ions and magnesium ions drinking water contains, the harder it is.

Chlorine is permitted. According to the Water disinfection application standards (for EU), Germany uses ozone or chlorine dioxide as a primary oxidant and disinfectant. Chlorine is added for residual disinfection [14]. The Drinking Water Control permits the usage of chlorine to process water. Every third sample of drinking water we tested revealed a treatment with chlorine. However, the low contents can't be tasted.

Disinfection applications in the European Union for Germany (1998) [14]

Table 8: Disinfection application in the European Union for Germany (1998) [14]

Chlorine	Chlorine dioxide	Chloramines	Ozone	UV
1	1	-	2	3

1: Most commonly used, 2. Commonly used, 3. Used occasionally

5.6. Advantages of tap water and disadvantage of bottled water

5.6.1. Controlled tap water

In Germany, tap water is controlled by the federal environment office (UBA). Everyone is able drink the tap water which fulfils the standards for drinking water. Many people are sceptical and not aware about tap water's qualities or aren't informed correctly, but controlled tap water is safe because it is tested regularly. It always depends on the individual's predilections/ preferences, knowledge, comfort and the expenses. [15]

5.6.2. Misleading labels on the bottles

The water bottle industry is not controlled in the same manner as the tap water. Hence, it could arise from the same (off)spring as the tap water. However, the company selling bottled water don't need to indicate it's origin and spring. Although some companies have started naming(giving) the water spring voluntarily by write it on the label, there are still many that do not do this. In consequence the consumer is not informed about his/her bottled water's spring. But they can always know where their tap water comes from, by checking with their landlords, by contacting their city's water supplier or by doing own research.[15]

5.6.3. Tap water saves time, labor and money

First of all, going to the supermarket to buy bottled water is time-consuming. Many germans need to go by car or take public transport to reach their "nearest" supermarket.

Furthermore, usually bottled water is bought in packages and in big amounts. To transport, carry and to lift those heavy bottles is energy-sapping, which could lead to health damages on the body (e.g. low-back pain).

Moreover, one litre of bottle water costs on average 0,70 Euros [16], while tap water costs only 0,002 Euros per litre [17]. Consequently, the way, time, effort and money spent on buying bottled water means it is a lot more comfortable and energy-saving to drink tap water instead.

5.6.4. Ecological consequences of bottled water

The German Environment Facility claims that

-" In Germany 2 million disposable plastic bottles are used every hour"

- "The usage per day is about 46 million pieces"

- "Per year approximately 17 milliard plastic bottles are used"

- "On an average every German uses 207 disposable plastic bottles per year"

- "The number of consumers of plastic bottles rises steadily. Disposable plastic bottles are the dominating stack regarding drinks and have a whole portion of about 54 percent." [18]

As the German Environment Facility points out, many people use plastic bottles. Many of them are one-way PET-bottles as it is presented in figure X. Hence, approximately millions of plastic water bottles are thrown away in Germany and generally affect the environment in a negative way. Although the bottles are mostly recyclable, only a small amount actually is recycled.

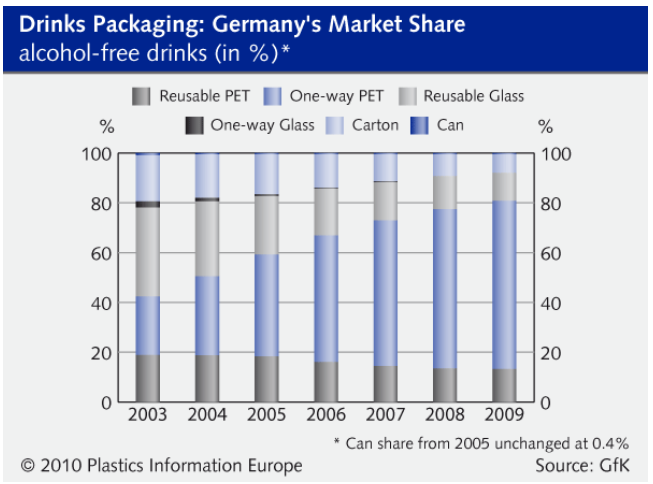

Figure 18 Drinks packaging Germany's market share

Therefore, plastic bottles heap on the landfills. A dramatic result is the *Great Pacific garbage patch* caused by plastic thrown into the oceans. The plastic floating in the sea is destroying the habitat of sea animals, killing them because they mistake plastic debris with food or they are caught in

the garbage. Furthermore, it is a danger to humans as well: sea food like fish that ingest plastic carry the toxins in their body. Hazardous toxins are entering the food chain and could cause humans harm (cancer, dysfunction of the endocrine system, etc.). Plastic which isn't being recyled inevitably results in pollution, ending up in the oceans or on land, like beaches, forests and more.

The damage to the eco-systems is not only directly caused by the bottles. Other environmental problems which one should consider are the raw materials (resources) that are needed for the production (extraction) of the water, as well as the transport and the distribution (sales). Trucks transporting loads of boxes with water bottles emit a lot of greenhouse gas and dangerous smoke in the atmosphere polluting it.

5.6.5. Disadvantages of recycling

Although many water bottles can be recycled, recycling also requires resources, energy and has its own disadvantages [19]:

5.6.5.1. High costs

Although recycling is good for our environment, it costs a lot of money: we must buy the materials for proper recycling and incur potential additional costs (transportation); factories must be built for storage and cleaning the recycled products in order to be re-used.

5.6.5.2. Lack of safety in recycling sites

The sites where recycling takes place are often unclean and unsafe for the staffs who work at them. The employees work under bad working condition. Recycling plants are just as hazardous as any landfill. The construction of factories promotes increased pollution, which is what recycling is used to avoid.

Where the recycling materials are dumped fertile breeding grounds for disease are created and there are a large number of inherent dangers that come with the amount of debris that is created. Waste is produced at recycling sites and this waste is often mixed with bodies of water, which causes mass pollution, including the drinking water.

5.6.5.3. Recycled Products are not durable

Products crafted from raw materials are much more durable than those created from recycled goods.

The fact that most recycled items are made from piles of waste that have been allowed to sit for long periods of time, compromising the durability of the materials, is problematic. Hence those products are fragile. Recycled products are cheaper because they are not built to last for a long time.

5.6.5.4. Hard implement on a large scale

Recycling mostly takes place on a smaller scale, as homeowners and some small business owners have implemented recycling related policies. However, larger industries and other major enterprises still need to integrate recycling into their business plans. Recycled products can't be produced on a large scale until larger companies adapt to this more eco-friendly process.

5.6.5.5. Bottled water often contains poisonous chemicals

Bottled water often contain poisonous chemicals from the PET bottles themselves.

In 2006, Shotyk et al. reported [19] high antimony levels in bottled water. In the article it says that, "Antimony (Sb_2O_3) is used as a catalyst in 90% of PET manufacturing world- wide." Although antimony was found, their levels of antimony leaching were deemed below EPA maximum contamination levels in water.

"However, in an 2007 Arizona State University study it was revealed that the amount of antimony that leached exceeded the EPA levels while being stored or used at higher temperatures like in a garage in the summer or in the microwave."

When PET plastic bottles are incinerated antimony is released as a gas.

The Department of Health and Human Services, the International Agency for Research on Cancer, and the Environmental Protection Agency (EPA) have not rated Antimony as a human carcinogenicity. Their Antimony FAQ site says that,

"Lung cancer has been observed in some studies of rats that breathed high levels of antimony. No human studies are available. We don't know whether antimony will cause cancer in people."

But if you breathe high levels for a long term it will cause for example diseases of your heart and lungs. This was proved by short and long-term studies with animals.

This year Germany found estrogenic compounds leaching out of the plastic water bottles with the help of a study by Martin Wagner and Jörg Oehlmann from the Department of Aquatic Ecotoxicology at the Goethe University in Frankfurt am Main [20].

These studies and researches collected by "Green Talk" consider the consumption of bottled water as bad because it can damage the human body and health. The Antimony might not be classified as a human carcinogenicity, but still other health problems can occur. In order to avoid any body damage tap water is the better choice than bottled water. PET bottles have a negative impact on the water which is being stored in those. Furthermore, plastic bottles are often bought in big amounts for consumption. Sometimes the water inside of the bottles is kept there for many weeks. Then high temperature could increase the amount of poisonous chemicals such as Antimony. In consequence, people who drink this water containing poisonous compounds are damaging their health by consuming just water. Therefore, a safe way would be the alternative to choose tap water.

In Figure X disadvantages of bottled water (ecological) are summarized and presented from the South African view. It clearly shows all points for Germany also listed before which proofs that all over the world PET bottles are a problem and threat to the environment.

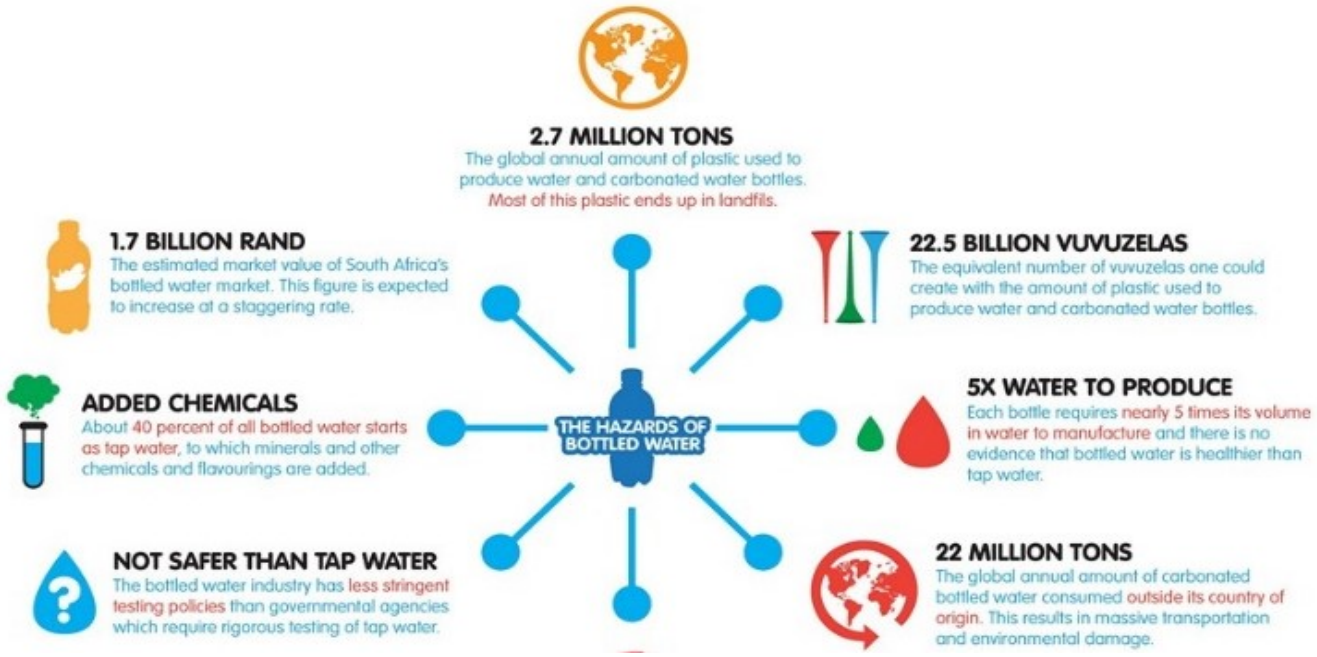

Figure 19 Hazards of bottled water (from South Africa)

5.7. Comparison of German tap water and bottled water

In Germany, there are several organizations and foundations which test products. One is called “Stiftung Warentest”, an independent foundation which is testing different products on the German market like food, cosmetic products and also drinking water.

In August 2016 [21], they conducted a research comparing the quality tap water with bottled water in order to find the differences and determine which one has more advantages concerning taste, safety and costs.

Therefore, 30 bottled waters from different producers and tap water from 13 different federal states were tested.

The results of all tested tap waters showed all in all no negative and illegal signs: none contined any residues of hormones or glyphosate or AMPA (a broad-spectrum systemic herbicide and crop desiccant used in agriculture/farming). However tap water to which minerals had been added from Munich for instance contained traces of anticorrosive, uranium, nitrate and chrome. It was the only kind of tap water with such results.

In contrast, in some of the purchased bottled waters glyphosate (ampa) could be found. Furthermore, some were contaminated with germs.

Not just the “Stiftung Warentest” has tested different water types or tap water: “Ökotest”, the World Health Organization and others have conducted similar tests and have come to similar results.

Other organizations also tested the taste differences between tap water (from the waterworks in Siegen, Hochkirchen and Lüdge) and bottled water (Gerolsteiner, Mond-Quelle and Saskia-Quelle Leissling): the results showed that there were no remarkable differences in taste [21].

For drinking water the nitrate limit is 50 milligram per litre. If it is higher than that, water suppliers need to mix it with clean water or it has to undergo a special cleaning process.

At the most, tap water may contain 10 µg / litre of lead and arsenic, while mineral water is permitted to contain up to 50 µg of arsenic and 40 µg of lead per litre.

Water suppliers in Germany are forced to conduct frequent tap water checks, in order to test its quality or to detect any pollution. Contrarily, bottled water is not tested as frequently as tap water. So tap water is safer than bottled water.

6. Conclusion

As the survey has shown there are already many people who drink tap water and also many who don´t think that tap water is unhealthier than bottled water, but still a certain percentage is still not convinced that tap water has a high quality. Rather than drinking tap water they prefer bottled water. It seems that many people are not aware of the advantages of tap water. Many people had no idea how much bottled water in comparison to tap water actually costs and how much cheaper it is to drink tap water. In addition to that many people never thought about the consequences for the environment when they bought bottled water. Further, they were not aware of other disadvantages of bottled water.

We analysed both types of water and came to the results:

Bottled water seems to be not even reasonable to buy, since the minerals are normally not needed by the body and can above that not be processed really well. However, as researches have shown the PET bottle has a negative influence on the health (poisonous/ toxic substances from plastic).

In general our research has shown that tap water has especially economic and ecologic advantages. Moreover, even though it might has not as many minerals as e.g. “Ensinger naturelle”, it doesn’t affect the human body negatively.

Now it is our goal to educate as many people as possible: One step was the survey and to hold a presentation in our chemistry class. In the future we want to use flyers and posters which we want to exhibit in our school for the students and teachers to make sure that everyone will become aware of the advantages of tap water. Furthermore, we want to convince the students to choose tap water over bottled water. Hence, we want to install a drinking fountain in our school.

7. Acknowledgements

We would like to thank our teacher Mrs. E. Giuseppino who has supported us all the time and who helped us to participate in the Water is life conference 2018.

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8.2.Figures

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[5] Graph: created by writers of report.

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[7] Graph: created by writers of report.

[8] Graph: created by writers of report.

[9] Graph: created by writers of report.

[10] Photograph taken on Dezember 6, 2017

[11] Photograph taken on Dezember 6, 2017

[12] Photograph taken on Dezember 6, 2017

[13] Photograph taken on Dezember 6, 2017

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