“Stockholm Junior Water Prize 2015”

The Secrets of Drinking Water

How to Combat Polyethylene Terephthalate

Márton Czikkely

Tamás Gergely Iványi

Tamás Márkus

Városmajori Grammar School

Budapest, Hungary

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1. Research objectives

The research started from the realisation that the yearly growth in discarded polyethylene terephthalate (PET) bottles combined with misbeliefs surrounding tap water will lead to an ecological catastrophe. Our aim was to define this threat in exact terms, in a case study on the water in Budapest. Parallel to this we wanted to find viable alternatives in water consumption in order to reduce the amount of PET dumped into the environment. To achieve this, we followed the route of water from the Danube to the consumers, in the premises of the Budapest Waterworks. We did this because knowing the nature of PET through our experiments, it became alarming to think about the terrible effects PET may cause. So we asked ourselves a question: *are we really doing this to Earth?*

2. Our poll

At the start of our project we conducted a poll in which we asked different age groups how much tap and bottled water they consumed on a daily basis. In addition, we investigated the reasons of their preferences. The answers and comments given by some of the people led to new research directions.

In our analysis of the poll we were only taking into account the bottles that are thrown away after water consumption, which is only a small percentage of all the discarded PET bottles. This is also shown by the fact that most people we asked said that soft drinks and juices make up the majority of their daily drinks which necessitates the manufacturing of PET bottles in large quantities. Accordingly, we tried to find out the true amount of PET bottle consumption in Hungary by contacting Coca-Cola Hungary Co., Szentkirályi Mineral Water Co., and Visegrádi Mineral Water Co. Out of the three companies, only Coca-Cola asked us to send them written questions. These were about PET bottle consumption and the actions the company takes to protect the environment. Unfortunately, we did not get any answers.

Since we could not get feedback from a large company regarding their PET bottle consumption, we utilized our poll which only dealt with PET bottled water. During the research, we surveyed students, teachers, our families, the colleagues of our parents, and numerous people in various public places in Budapest. Altogether, we investigated the opinions and daily routines of nearly 500 people. At the end of the questionnaire, we broke down the results into three groups: students like us, retired elderly, and working adults. The poll shows that different age groups have very similar proportions of water consumption (see Fig. 1). All three groups show that people drink slightly more tap water than bottled water.

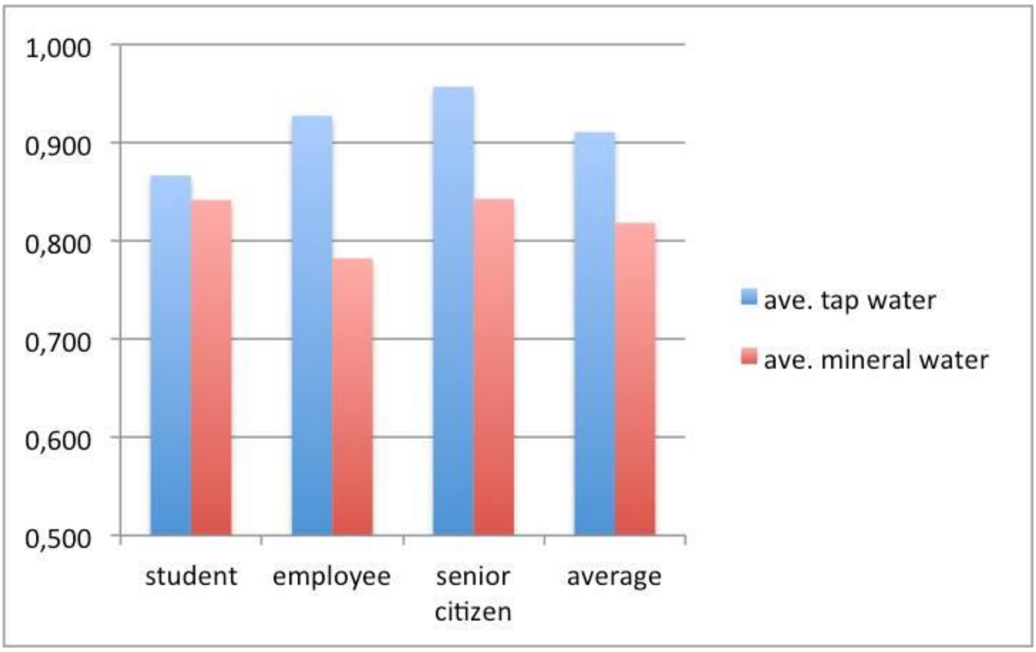


Fig. 1: Consumption of tap and PET bottled mineral water

The smallest difference seems to be in the student group. Various reasons may lie behind it, like the “trendiness” of having a PET bottle of water with you wherever you are, or the possibility that young people are uninformed and naïve, i.e. they generally believe easily whatever they hear.

In answer to the question “Why do you not drink tap water?” many responded with “I do not like its taste”. This we cannot remedy. But we were also confronted with a lot of misbeliefs which we endeavoured to refute in our research. These include, amongst others, the following views, all of which will be dealt with in detail in the different sections of our paper:

- “tap water is hard which makes it unhealthy”,
- “I usually do not drink tap water because it is full of synthetic oestrogens”,
- “the chlorine content of tap water is too high”.

However, besides the people who offered these responses, there were those who consume water in an innovative, eco-friendly way. A student said “I do not drink either tap or bottled water. We usually get spring water”. Another comment she made was: “more people have the opportunity to do this than the people who actually do it, and this is just wasting our water resources”. There were also people who preferred to drink tap water for economic reasons, saying that “good bottled water is expensive”. These questions will all be treated in the relevant sections of this paper.

Based on our questionnaire, the following figures show a person’s yearly PET pollution. On a daily average, a person in Budapest consumes 0.911 litres of tap water and 0.822 litres of PET bottled water. This reflects a yearly consumption of 300 litres of bottled water which translates to 200 1.5 litre PET bottles. This means that during the course of one year, an average person pollutes the environment with 7 kg of PET resulting from bottled water.

3. The PET bottle (polyethylene terephthalate)

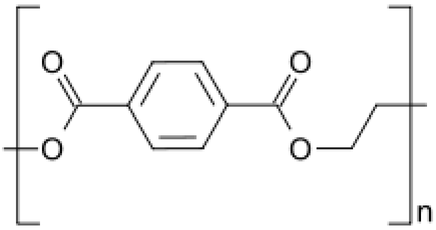


Fig. 2: The skeletal structural formula of PET

The enormous quantity of discarded PET bottles affects adversely not only our environment but also us, as human beings. The qualities which make it a favourite material for industries have an extremely harmful effect on nature.

3.1 PET production:

3.1.1 The dimethyl terephthalate process

In the dimethyl terephthalate process, the compound and excess ethylene glycol react in the melt at 150–200 °C with a basic catalyst. Methanol (CH_3OH) is removed by distillation to drive the reaction forward. Excess ethylene glycol is distilled off at a higher temperature with the aid of vacuum. The second transesterification step takes place at 270–280 °C, with the continuous distillation of ethylene glycol as well.

The reactions are idealized as follows:

First step

$$C_6H_4(CO_2CH_3)_2 + 2\ HOCH_2CH_2OH \rightarrow C_6H_4(CO_2CH_2CH_2OH)_2 + 2\ CH_3OH$$

Second step

$$n\ C_6H_4(CO_2CH_2CH_2OH)_2 \rightarrow [(CO)C_6H_4(CO_2CH_2CH_2O)]n + n\ HOCH_2CH_2OH$$

3.1.2 The terephthalic acid process

In the terephthalic acid process, the esterification of ethylene glycol and terephthalic acid is conducted directly at moderate pressure (2.7–5.5 bar) and high temperature (220–260 °C). Water is eliminated in the reaction, and it is also continuously removed by distillation:

$$n\ C_6H_4(CO_2H)_2 + n\ HOCH_2CH_2OH \rightarrow [(CO)C_6H_4(CO_2CH_2CH_2O)]n + 2n\ H_2O$$

3.2 Stability

“The degradation time of a PET bottle is unknown” – as can be read in all the treatises on this topic. Naturally, it would be strange if the water from PET bottles on the shelves would start to leak because of some effects (like UV rays, microorganisms, etc.) which lead to degradation. At the same time it is also daunting to know that this polymer cannot degrade under normal circumstances in nature. As it does not degrade, carbon cannot get back into the natural cycle and remains in waste containers, or worse, floating on the ocean. There are some species of fungi and bacteria which can decompose PET, such as species of Nocardia, the majority of which, however, cause nocardiosis.

3.3 Resistance

PET bottles not only lack degradation capacities, they also effectively resist to acids, alkalis, and organic solvents. We demonstrated this characteristic in our school’s laboratory in the following experiment. PET bottles of equal size were put into concentrated sulphuric acid (1), hydrochloric acid (2), nitric acid (3), sodium hydroxide (4), acetone (5), hydrogen peroxide (6), and finally chromosulphuric acid (7). Only the last was able to dissolve the plastic bottle in about twenty minutes. A chromosulphuric acid is the concentrated sulphuric acidic solution of potassium dichromate, which is highly corrosive and carcinogenic. If concentrated acids do not usually dissolve this plastic, then we can suppose that acids produced naturally by the roots of plants will not be able to dissolve it either.

Resistance to UV rays is a more complex issue, as there should be a reason for text written with small letters on the bottles of mineral water: “Do not subject to direct sunlight. Store in a cool, dark place.” We corresponded on the subject with Mr. Zoltán Kassai, from the Laboratory of National Food Chain Safety Office, who called our attention to the dissolution of materials used in manufacturing the bottle as a result of UV rays. Accordingly, we decided to carry out an experiment to examine this phenomenon. Our aim was to simulate the circumstances of bottles on the shelves of shops where they are exposed to sunlight through the windows. We filled a PET bottle with distilled water and placed it in the window for two days, while at the same time a second control PET bottle with distilled water was kept in a completely dark environment. Then the samples of water from both bottles were analysed with gravimetric analysis which showed that the concentration of total dissolved material per unit area increased in the UV-treated sample by 12.5%, although it still remained well within the officially allowed limit. This increase, if left unnoticed, can do harm or eventually lead to harm. That is why it seems necessary to follow the instructions concerning the storage of PET bottles.

3.4 Suitability for the development of bacterial colonies

One evening, one of the participants to the research, Márton drank half a litre of water from a PET bottle. In the morning he refilled the bottle with tap water and brought it to school. We took smear from the neck of the bottle in our laboratory and put it on agar-agar medium. After four days, a large number of white colonies and Candida species which develop in the mouth appeared (see Fig. 3).

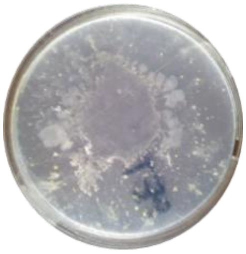


Fig. 3: Bacteria on PET

3.5 The combustion of PET bottles leads to the formation of carcinogens

Our biology and chemistry teacher told us that an elderly couple in her street burnt PET bottles during the cold winter months, because they have good calorific value. The couple did not think, however, that by doing so they were emitting a lot of carcinogens into the environment. Four people died in the street in ten years due to lung cancer. The elderly couple only gave up this habit after several notices. The following carcinogens are emitted during the combustion of PET bottles: methane, acetaldehyde, ethylene, formaldehyde, methanol, acetone, benzene, terephthalic acid, styrene, ethanol, toluene, xylene, ethylbenzene, naphthalene, and phenol.

4. En route to the consumer

4.1 At the Budapest Waterworks

Thanks to the Budapest Waterworks we could spend a whole day collecting information on the route of water from its source until it reaches the consumers. At the laboratory of the Budapest Waterworks we could also get information about the chemical aspect of this route. The Budapest Waterworks caters for the daily water supply of almost 2 million residents in Budapest and its 21 suburbs but it is also responsible for some of the industrial consumers in certain areas with the necessary infrastructure. Water is delivered through a pipeline of ca. 5,100 kilometres.

Drinking water in Budapest is bank-filtered. As a natural filter, the gravel and sandy sediment deposited by the Danube is used. Water reaches the pipes with the help of different pumps from the horizontal filter wells, pipe, and gravel-packed wells. Water flows from there through the pipes to various storage tanks and hydro globes where it is stored for a short time. The most important reservoir of this type in Budapest is the “Gruber József” Pool on Gellért Hill. Water is delivered from there directly to consumers.

4.2 The chemistry of the drinking water's journey

Thanks to the laboratory of the Water Quality and Environmental Department of the Budapest Waterworks we gained insight into the chemistry of the drinking water's journey from the Danube to the consumer. During our visit we consulted with engineers, laboratory workers, and the head of development in the laboratory. Dr. Anikó Brumbauer, the laboratory developmental team leader, showed us the difference between the EU and the much stricter Hungarian legislation. The EU directives regarding drinking water can be read in the council's 98/83 EK decree. All member states have to adhere to these measures, but stricter measures can also be taken. In Hungary, the 201/2001(X.25.) decree describes the regulations regarding water quality in Hungary. These are stricter than the EU ones in several cases:

Fig. 4: The lab of Budapest Waterworks

- Biological, microscopic experiments: in the EU these are not mandatory whereas they are prescribed in Hungary. Suitably-trained personnel is needed for this.
- Lower thresholds: i.e..: total of trihalomethane
    - EU: 100 μg/l
    - Hungarian: 50 μg/l

Apart from these points, the legislation prescribes the physical protection of wells (armed guards, security system). Furthermore, chemical protection is also required, namely keeping the Danube free of chemicals as well as maintaining its surroundings waste-free. In Budapest, the transformation of Danube's water into drinking water starts with a mechanical-biological filtration at the bank-filtered wells. The water is filtered through a gravel sand layer to the wells extensions. The efficacy of this is exemplified by the fact that while the number of colonies at 22°C was 78/mls in samples taken from the Danube, the samples from wells show a negative result for all bacteria except iron and manganese but even these are well below the threshold value and these are not pathogens in any case.


Fig. 5: Tamás measuring the chlorine

Starting from the bank filtration wells, the water undergoes preventative chlorination which prevents the appearance of potential bacteria colonies. Nevertheless, it is worth asking why chlorine is used out of all the possible disinfectants. For instance, sodium or calcium hypochlorite [$NaOCl$] or [$Ca(OCl)_2$], chlorine dioxide [ClO_2], bromine monochloride [$BrCl$], ozone [O_3] could be used, and the disinfecting process would be also possible using UV radiation. Nonetheless, chlorine is used because it is toxic to animals only in higher doses whereas it is lethal to microorganisms in smaller quantities as it destroys bacteria cells in direct contact. Having diffused the cell membrane it inactivates enzymes and destroys metabolism. It is also good for sterilization because it is a stable material, dissolving well in water. On the downside however, it is fairly corrosive so it may damage the pipes. When disinfecting water with chlorine we actually use the germicidal effect of the hypochlorous acid resulting from the contact with water rather than chlorine itself. The similar structure of the hypochlorous acid to water enables it to act as an antiseptic ($Cl_2 + H_2O \leftrightarrow HOCl + HCl$).

In order to prove this we executed a series of experiments on bacteria colonies. We formed three groups. One of these was the control group, which was left to grow under normal conditions on agar-agar. The second group was cultivated on soil that had been previously sprinkled with chlorinated water. The third group was sprinkled with chlorinated water once the colonies have evolved. We experienced how fewer colonies evolved on the soil that had been sprinkled with chlorinated water than on that of the control group, proving that chlorine indeed has an antiseptic effect. Nevertheless, we found it truly fascinating that in the second group (the one pre-treated with chlorine), the total number of germs was much lower than in the third group which was treated with chlorine only post factum. Therefore the preventative use of chlorine is the most effective method of all.

control previously chlorinated sprinkled with chlorine

Fig. 6: Bacteria colonies

When visiting the Waterworks we could all examine the chlorine. We carried out free active and all chlorine examination on samples taken from a channel after bank filtration and preventive chlorine usage, using a photometric method of DPD reagent (N-N-diethyl-phenylenediamine). Essentially, DPD results in a pinkish purple colour in reaction with chlorine. The more vivid the purple is in the sample, the higher the chlorine concentration. Having done this, we put it in a small machine, covered it with a tap so that it would not be affected by external light. In the dark, a lamp lights the purple sample of the cuvette and the machine calculates the chlorine concentration of the sample based on the refraction of the light. The more purple the sample is after adding the reagent, the more it will refract light which is directly proportional to the

Fig. 7: Gergely titrating hardness

chlorine content, thereby making it calculable. The chlorine content in the chlorination room was 0.89 mg/l, right after it was added. We made measurements on a pipe a few hundred meters away and the result was half compared to this one, which shows how much chlorine disappears from water even within such a short distance. After bank filtration and chlorination, the water is transported to the water reservoir of the Gruber basin. Only the hardness of the water can change from here to the consumer. As water meanders in the pipes, its CaO and MgO concentration vary. Many people claim to prefer mineral water to tap water. This is probably due to their higher hardness which slakes thirst better. In order to illustrate this, we examined a few samples. In our school laboratory, we measured samples from the Danube, the school tap water, and two different mineral water types (one was still the other was sparkling) using complexometric titration. We also received a sample from the no. 16 well at Tahi from the Waterworks. As a calk solution, EDTA (ethylenediamine tetraacetic acid) was used, which forms a complex with almost all metal ions. All samples were measured three times. The average result of these measurements can be found in Fig. 8 below.

Sample	Hardness (°dGH)
Danube	3.9
Tahi well	4
Tap water	13.2
Mineral water	43.8

Fig. 8: Hardness of water samples

5. Mineral water, tap water

5.1 Public views, the reality

Márton Czikkely’s parents told us that anything can be sold using the necessary amount and quality of commercial – even water in bags. Nobody would have thought 25 years ago that many people would buy water in bottles instead of using tap water or, in villages, water out of wells. So why do most people consume bottled water when the quality of the tap water in our capital is excellent? We asked several people, who do not drink tap water, about their reasons:

> “Because I do not like how it tastes and if you let it settle a little bit you can see the chlorine in it, at least in our neighbourhood you do, even though here in Budapest the water’s quality is the best in the country. And if I know it right, Hungary ranks high up amongst the countries which drink most contraception pills, so tap water contains what women pee. And this can cause infertility if we drink it with the tap water – to women if they drink a lot, but also to men, even more easily.” (Girl, 18 years)

> "If I do not have any water on me, I can just walk into the store and buy mineral water easily. Apart from this, there is tap water, which is turbid when it comes out of the tap and you need to let it settle, which is disgusting." (Boy, 17 years)

All these explanations sound eloquent but not even half of them are true. Chlorine cannot be seen in water because it is either present in a bound, ionic form or as a dissolved gas, never in solid form. The girl quoted above might have seen a lime scale in the water which does not damage our health and can be prevented with the necessary maintenance measures. Turbidity is caused at some places by slightly more active chlorine and what the boy described as settling is actually when the physically dissolved chlorine is released from the water and exits into the air.

During our visit at the Waterworks, all colleagues at the bank filtered wells (from the laboratory workers to the retired, decorated engineer who worked in this profession for his entire life) greeted us by asking us if we drank tap water. We answered the best we could but always asked back why they were so interested in this. Their reply was simple: "Because that is the best. The tap water of Budapest!"

During the summer, it is often reported in the Hungarian media that contraception pills, hormonal products, steroids, and painkiller agents can be detected in the capital's tap water. Journalists usually seek sensational subjects so the following statement does not create a lot of surprises: "There is nothing to report during the summer months so here is a topic which will be of interest to everyone and induce panic." On the service provider's website the following short calculation can be read, which illustrates the situation very well:

> "Let us assume that a laboratory detects 100ng ibuprofen in one litre of drinking water, an agent of a commercially-available antifebrile and painkiller. One pill contains 400 mg of this agent, meaning that this is how much ibuprofen is found in one single pill. 400 mg = 400 000 000 ng. If 100 ng of the agent was found in one litre of water supposedly contaminated with ibuprofen, then the amount equivalent to that in one pill, would be contained by 4 million litres of water that is 20 million glasses of water. In other words this is how much we would have to drink in order to get the agent of one pill into our body."

It is well-known that a large part of medical agents is released with urine. The issue that drug derivatives get into the environment has been discussed in the United States and Western Europe for 15 years. It turned out that when the sewage water's quality is examined with highly sensitive equipment, such derivatives were found, which did not disappear during the treatment of the sewage water. "In Hungary, however, this topic is a fairly new one as here only recently acquired equipment can detect such small concentration of derivatives" – Margit Varga, associate professor of the Department of Inorganic and Analytic Chemistry at Eötvös Loránd University (ELTE), told us. Moreover, microbiological studies conducted abroad, suggest that the derivatives of drugs and hormones that appear in water may affect organisms living there, together with the whole food chain, thereby influencing the ecological balance. Residues of antibiotics may influence the reproduction of bacteria and can induce the appearance of bacteria that are resistant to the currently-applied antibiotics. Certain hormonal products – female sex hormones that appear after the degradation of contraception pills – may decrease the proportion of male fishes in relation to the females and can also change the reproduction of frogs. If there are fewer tadpoles – the nutrition of several other species – that may disrupt the food chain.

In Budapest, the drug content of water was checked in a large scale test. During this test, the Budapest Waterworks in cooperation with the Budapest University of Technology and Economics (BME) have checked the whole water-supply system. As it turned out, most known steroid- and non-steroid based pharmaceutical compounds can indeed be found in the Danube, but no trace of any of these could be found in the water-supply system. Although they searched for the most frequently-used medicines, contraceptive pills and painkillers, they were not found in measurable quantities in the network. Many are not aware of the purpose that chlorine serves in water, what hardness precisely is, or what pesticides and all the bacteria with exotic names are. Furthermore, even if some people are familiar with these concepts, they might not be aware of their effects on the human body. This problem should be remedied within school education. Through smaller projects children could familiarize themselves with the importance of such ordinary matters. Any book, website or article related to the topic is bound to mention these basic concepts**.**

5.2 The precise difference between the two types of water

5.2.1 Hardness

First of all, mineral water is usually much harder than tap water. We conducted an experiment to illustrate this and showed the difference in Ca^{2+} levels between the two samples. We added the same amount and concentration of ammonium-oxalate to two half litre samples. Reacting to calcium ions, this produced calcium-oxalate, a white residue which does not dissolve in water. Then we filtered this result through filtering paper to obtain pure calcium-oxalate. By measuring this, we were able to deduce the calcium content of the original samples, i.e. their hardness: $(NH_4)_2C_2O_4 + Ca^{2+} = CaC_2O_4 + 2NH_4^+$

Fig. 9: Mineral water

Fig. 10: Tap water

Our results visibly illustrated the difference which can be translated into figures as follows: 480 mg of calcium-oxalate was obtained from mineral water, whereas only 211 mg from tap water. Based on the equation, we calculated that the original Ca^{2+} concentration level was 300 mg/l in the mineral water, whereas 131.87 mg/l in the tap water. This is the equivalent of 30°dGH and 13.2°dGH respectively. Besides, we also titrated the hardness of both tap and mineral water and independently of brand, and the total hardness was four-five times higher in the samples of the latter. From a drinking water perspective, this is an advantage of the mineral water as harder water can quench your thirst more easily. Consider the feeling of drinking distilled water, whose hardness is 0°dGH. It feels as if nothing was pouring down our throat while we disrupt our osmotic system with this hypotonic fluid.

5.2.2 Chlorine

Chlorine content is another interesting factor. It is well-known that tap water is treated with chlorine. This is not necessary because there would be any germs in the water after the bank filtering but because it provides preventative treatment against bacteria that may reside in the long pipe system. This is not needed in case of bottled water as that goes into the bottle immediately after sourcing it from the spring. This, however, may not provide complete sterility. In August 2014, twelve types of mineral water had to be removed from the market because the bacterium *Pseudomonas aeruginosa* was detected in them. This is why a small amount of chlorine is needed – to prevent such problems. That being said, this is a single case only. In Hungary, drinking water is the most strictly-regulated food product. Furthermore, the amount of chlorine which reaches the consumer is much below the health threshold. Also, most of this is free, active chlorine which disappears from the water if it is shaken – that is why samples have to be measured immediately. Silver nitrate when reacting with chlorine produces silver chloride, which is a white residual, rendering the content of the test tube opalesque in our case. During our experiment, we filled five test tubes with tap water. We immediately added silver nitrate to the first one. The reagent was added to the second one following 3 minutes of shaking, to the third after 6, to the fourth after 9 and to the last one after 12 minutes of shaking. It can be well seen that the fluid becomes less and less opalesque and lets more and more light filter through (see Fig. 11).

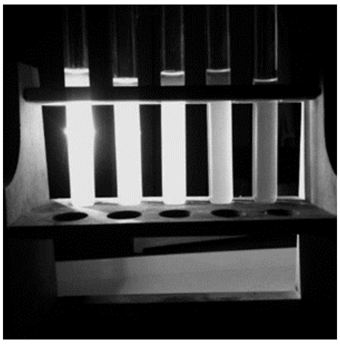


Fig. 11: The gradual disappearance of chlorine

5.2.3 Price

Nonetheless, the price is the most striking difference. Should we make a small calculation, the result is surprising. In Budapest, in case of private customers, the Budapest Waterworks provides tap water at a price of 218.95 Ft/m^3 as of the 1st July 2013. The same volume of still mineral water, if bought in 1.5 litre bottles, costs 50,000 HUF on average. That is a 228 times higher price than that of tap water. As a conclusion to the subject matter we would like to present a unique initiative. Five regional water-providers started a campaign to raise awareness, called “Up for taps!” to motivate the tap water consumption in the Hungarian population. “Consuming tap water is not only healthy but also an environmentally-conscious approach” – stated László Koszorús, Deputy Secretary of State of Consumer Affairs, at the start of the campaign in Budapest, on the 2nd of December 2014.

6. Conclusion, solutions

It can be concluded that in Budapest, in Hungary, and even in the entire world, a lot of PET bottles are released into the environment endangering it and our health. Fortunately, the tap water in Budapest is of high-quality which does not jeopardize our health.

To conclude our project, we would like to present four alternatives in order to reduce the release of PET bottles into the environment. At least one of these can be implemented wherever one dwells in or around the capital.

6.1 Choose the largest container possible

If you feel it is necessary to purchase PET bottled products then you should try to choose the largest container possible. It is not the most ideal solution, but it is still a way to reduce the release of PET into the environment. This choice would result in a much better water/container ratio. On average, half a litre of bottled water needs 19.58 grams of PET, while 5 litre containers only need 107.09 g. Thus, while the amount of water purchased is 10 times larger, the required PET bottle weighs only 5.47 times more. So if everyone would choose a larger container, current PET-release could be reduced up to 50%.

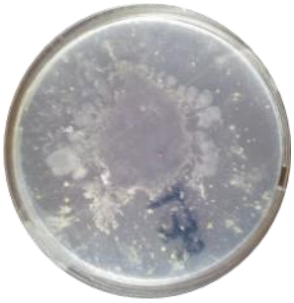
6.2 Buy glass instead of PET

Each characteristic of glass is better than that of PET bottles with the exception of price. It would, therefore, mean a rise in consumer prices.

The fundamental constituent of glass is silica (SiO_2), so even with its large scale manufacture, no material essential to life would be extracted from the environment in the same way carbon is extracted during the production of PET bottles. In addition, the manufacture of glass requires sodium, potassium and calcium carbonate, which are non-carcinogenic, and found in large quantities in nature.

Contrary to PET bottles, bacteria do not thrive on glass, and it can also be easily disinfected. This is demonstrated in Fig. 12 and Fig. 13.

Fig. 12: Sporadic bacteria on glass



Fig, 13: Large amount of bacteria on PET

6.3 Drink spring water if you can

During the evaluation of the questionnaires a comment caught our interest:

> "We go to Szentendre and Visegrád for spring water. Everyone who takes advantage of this opportunity can drink spring water."

We contacted the girl who made this comment and asked her to tell us how they bring this water to their home:

> "Every weekend the family goes by car to the spring with large cans of 10-20 litres to take home enough water for a week. At home my mother fills several bottles with the water so that we can take it with us to school every day. The spring can be used for the trifle sum of a few thousand forints per year."

Encouraged by this solution, we contacted an organization which has recently set a new long-term goal to locate and clean all Hungarian springs from which water reaches the surface so that people can make use of this eco-friendly and inexpensive option. Joining the movement (With Children for Nature Association) we took part on the 12th of April in the tidying of the Kárpát Spring in the Pilis Mountains.

Fig. 14: The Kárpát Spring

Fig. 15: Our team doing the BISEL test

We conducted tests of water chemistry and a BISEL test for invertebrate monitoring to determine the status of the water source. Our data suggest that the spring is not contaminated by agricultural activities. On the basis of the number and species of invertebrates found, the spring belongs to class I habitat with a biotic index of 8 (moderate pollution caused by people who disturb the habitat when taking water from the source, diminishing the number of invertebrates living there).

Fig. 16: Water chemistry at the spring

In order to ensure that the organization's objectives can be met as soon as possible, we signed a contract between our school and the association. Accordingly, students can take part in the tidying of various springs every year thereby satisfying the requirement of compulsory 50 hours of social work in an activity for the environment.

We would be happy if the news about this opportunity reached as many people as possible, because we believe that students are not fully taking advantage of this opportunity.

6.4 Drink tap water

The most comfortable but still eco-friendly solution is to drink tap water instead of PET-bottled mineral water. During the day we spent at the Budapest Waterworks each colleague asked us whether we drank tap water, because it is the best we can have. We were asked the same question at the bank-filtering wells, at the laboratory, and at the Gruber basin. Concluding, we also suggest that this solution is the best one and hope that the readers of this work will look differently at products in PET bottles.

7. Acknowledgements

We are grateful to many people without whose help our research could not have been realised. Special thanks are due first and foremost to our teacher of biology and chemistry Dr. Anna Jánossy-Solt who encouraged us to participate in this competition and who stood by us until the end. We would also like to express our gratitude to Mr. Csaba Haranghy, the general manager of the Budapest Waterworks for allowing us to enter the premises of this company for the purpose of our research. His friendly staff in all venues also deserve to be mentioned. Last but not least, Ms. Katalin Sass, the mother of Tamás, should be mentioned who helped us in many ways.

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8.2 Interviews and correspondence with specialists

- Brumbauer, Anikó (head of development, Laboratory, Water Quality and Environmental Department of the Budapest Waterworks): *Interview*
- Employees at the different premises of the Budapest Waterworks: *Interviews*
- Kassai, Zoltán (Laboratory of National Food Chain Safety Office): *Correspondence*
- Varga, Margit (associate professor of the Department of Inorganic and Analytic Chemistry at Eötvös Loránd University): *Interview*

9. Summary

Our interest in water-related issues started in the autumn of 2014 when we entered a project competition organized by the Austrian Association of Chemistry Teachers. Then our aim was to present water as a versatile material, but it was also during that work that we noticed the harmful effects of PET bottles. The present project grew out of this realisation which we carried further including several measurements, surveys, and experiments.

We started from the fact that each year more and more PET bottles are released into the environment. These pollute nature for a long time. They create floating islands on the oceans. If combusted, carcinogens get into the atmosphere. If put under UV light, toxic materials dissolve from PET into the mineral water. In addition, bacteria grow at the neck of the bottles.

We also examined the route of water in Budapest, from the Danube to the consumers, and the treatment used by the Budapest Waterworks in the different premises where we spent a day. After studying the chemical and biological aspects of this journey we became satisfied that the tap water in Budapest is of impeccable quality.

In our poll on water consumption habits, we learnt that people consumed about the same amount of tap water and bottled water. From this, the amount of PET water bottle discarded by a person could be calculated. In addition, the analysis of the comments written on our questionnaire showed that the majority of people consume tap or bottled water instinctively without having a precise cause and without caring for the possible consequences of their decisions. This realisation also convinced us about the necessity of our research.

In order to avoid the growth of PET dumped in landfills, rivers, and oceans, we came up with four easily implementable solutions: (1) purchasing PET bottled water in the largest possible container; (2) using glass instead of PET; (3) drinking water captured from a natural spring; and (4) drinking tap water, especially where tap water is of excellent quality, like in Budapest.

While developing the solutions, we were not only thinking and writing about ecological problems, but we actually took an action to achieve our objective for the first time in our lives. On the 12th of April, we joined the "With Children for Nature Association" in cleaning the Kárpát Spring in the Pilis Mountains, thereby also initiating a relationship to perform community service.

After this intensive work, all three of us observed that we pay more attention to our environment than before, and we consume far less PET bottled water. We also hope that one of our solutions will be adopted by those who read the text of our research.

10. Appendix

10.1 Questionnaire

? Tap water ? Mineral water ?
Please underline your answer

1. Gender: Male/Female

2. Age: 6-15; 16-25; 26-35; 36-45; 46-55; 56-65; 66-75; 76-85

3. Do you drink tap water? yes / no
   a) If yes, how many litres a day?
   - less than 1 litre
   - 1-2 litres
   - more than 2 litres

   b) If no, why?
   ....
   ....

4. Do you drink mineral water? yes / no
   a) If yes, how many litres a day?
   - less than 1 litre
   - 1-2 litres
   - more than 2 litres

   b) If no, why?
   ....
   ....

5. Further views, opinions:
   ....
   ....

10.2 Chemical analysis of the water of the Kárpát Spring

date	Δt	experiment	result	
12 April 2015	3 hours	chemical composition of water	ammonium ion : 0 mg/l	
			nitrite ion : 0 mg/l	
			nitrate ion : 0 mg/l	
			phosphate ion : 0 mg/l	
			total hardness : 9.2°dGH	
			pH : 6.75	
			O_2 : 7.5 mg/l	
		physical characteristics of water	temperature	
			air : 25°C	water : 11°C
			colour : colourless	
			odour : odourless	
			taste : sweet	
			transparency : transparent	

11. Participants' Introduction

We are students and friends at the Városmajori Grammar School in Budapest. We have already taken part in several competitions and projects together which helped us in our professional development.

Márton Czikkely (18). My main interests lie in the fields of biology and chemistry. I am interested in healthcare and biomedical research. I have been participating in the talent programme of the University of Szeged as a "Szent-Györgyi youth" since 2013. Throughout the present project my task was to plan and implement the experiments, and also to draw conclusions from these experiments.

Tamás Gergely Iványi (17). My main interests lie in the fields of chemistry and physics but I am also fascinated by some aspects of biology. In the future I would like to study molecular bionics. I have been a member of Szent-Györgyi programme since 2014, as a Szent-Györgyi youth. In this project my main task was to plan and conduct chemical experiments and to come to conclusions.

Tamás Márkus (17). I enjoy physics, but it is mathematics to which I am always ready to dedicate my time. Both my parents are civil engineers, so I might also continue in their footsteps or study economics. It was thanks to my mother's connections that we were allowed to conduct our research partly within the Budapest Waterworks. In this project, I mainly dealt with the poll and its analysis.

12. Statement of Work

We got acquainted with the route of tap water at Budapest Waterworks, and ascertained its quality. This was made possible by Katalin Sass, Tamás' mother. Further on, we analysed the difference between mineral and tap water at our school laboratory, also testing PET. Here we received technical support from our teacher, Dr. Anna Jánossy-Solt and the lab-assistant, Mrs. Berényi. For the research on soluble substances and the way they are affected by UV rays, we asked Mr. Kassai who works in the Laboratory of National Food Chain Safety Office. All the tests, polls, and analyses were planned and made by us.

13. Short summary

The research started from the realisation that the yearly growth in discarded polyethylene terephthalate (PET) bottles combined with misbeliefs surrounding tap water will lead to an ecological catastrophe. On the one hand, we proved the negative characteristics of PET (like non-degradation, etc.) in our experiments and analyses. On the other hand, we monitored the journey of water and its treatment in Budapest from the Danube to the consumers, and ascertained the excellent quality of tap water. In the conclusion, we proposed four easily implementable ways to diminish the dumping of used PET into the environment, thereby contributing to the protection of our planet.