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The impact of increased calcium and magnesium content in drinking water on arterial stiffness and the cardiovascular system in humans: A case study in Kokava nad Rimavicou, Slovak Republic

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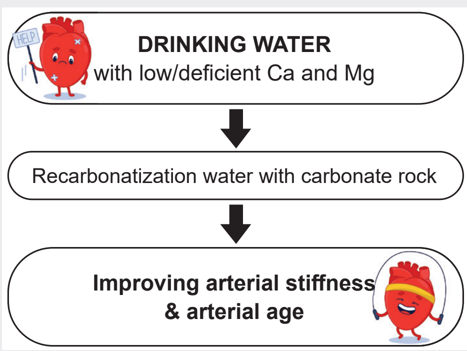
Abstract: In the village of Kokava nad Rimavicou, we enriched the drinking water with Ca and Mg using a recarbonatization reactor (RR). In the RR, carbonate rock is dissolved using CO_2. In the RR, we produce a concentrate with a Ca and Mg content of approximately 100 mg.l^{-1}, which is then added directly to the water reservoir at a ratio of approximately 1 : 10. On average, the Ca and Mg content in the drinking water increased by 10–15 mg.l^{-1}. Subsequently, we monitored the positive effect of the increased Ca and Mg content in the drinking water by measuring the arterial stiffness of the residents, which characterizes the state of the cardiovascular system (CVS) of people. We measured the arterial stiffness four times in six-month intervals. The first time was before the start of the enrichment of the drinking water with Ca and Mg, and subsequently three times after the enrichment. The increased content of Ca and Mg in the drinking water resulted in a significant improvement in the arterial stiffness. The arterial age of the people improved by approximately ten years, and the speed of the pulse wave velocity decreased by 0.9 m.s^{-1}.

Key words: Arterial stiffness, Ca, Mg, cardiovascular system, drinking water, recarbonatization

Graphical abstract



Highlights

- **Cardiovascular Impact:** Increased Ca and Mg content improves arterial stiffness, demonstrating potential health benefits and offering a practical intervention for mineral deficiencies.
- **Innovative Solution:** The study introduces a recarbonatization reactor to address calcium and magnesium deficiency in drinking water.

Introduction

The impact of deficient levels of Ca and Mg in drinking water on the cardiovascular system of humans has been known for over 70 years (Kobayashi, 1957). Since then, this influence has been confirmed by thousands of studies conducted in various countries around the world, including several meta-analyses (e.g., Catling et al., 2008). The deficient levels of Ca and Mg in drinking water have also been associated with increased incidence/mortality of oncological diseases and diabetes mellitus over the past 20–30 years (e.g., Yang et al., 1998; Naumann et al., 2017). Furthermore, it has been confirmed that individuals supplied with “soft” drinking water have a shorter lifespan by 4–5 years compared to those supplied with “hard” drinking water (Rapant et al., 2021). A very illustrative example of the impact of deficient levels of Ca and Mg in drinking water is observed in countries where drinking water produced from seawater using reverse osmosis has been used for drinking purposes. This water is characterized by an extremely low content of Ca and Mg, resulting in increased incidence/mortality of cardiovascular and oncological diseases in these countries (e.g., WHO, 2011; Lesimple et al., 2020).

In this study, we address the issue of deficient levels of Ca (< 30 mg.l^{-1}) and Mg (< 10 mg.l^{-1}) in drinking water by enriching (recarbonating) drinking water using RR. We increase the content of Ca and Mg by approximately

10–15 mg.l^{-1}. Subsequently, we observe how this increased content of Ca and Mg in drinking water affects arterial stiffness. The main objective of this study is to determine whether there is an improvement in the cardiovascular system of individuals (which is monitored by measuring arterial stiffness) originally supplied with "soft" drinking water after enriching this water with Ca and Mg.

Area description

The village of Kokava nad Rimavicou (KnR) has a population of approximately 3,000 inhabitants and is located in the southern part of the Slovak Republic (SR) (Fig. 1). It is supplied with potable water from the Klenovec reservoir. After treatment and disinfection, the potable water is led by pipeline to the local water reservoir in the village Kokava nad Rimavicou. The rock environment around the Klenovec reservoir is mainly composed of granitoid and metamorphic rocks, resulting in water with very low mineralization and very low levels of Ca and Mg (Tab. 1). The reservoir in the village Kokava nad Rimavicou is supplied by water quantity according to the current consumption, which averages at approximately 100,000 m^3 per year. In the summer months, consumption is approximately 20–30 % higher than in the winter months, with an average consumption of approximately 3.0 l.s^{-1}.

The Slovak drinking water standard only provides recommended values for Ca and Mg contents and water hardness (measured as Ca + Mg in mmol.l^{-1}). As shown in Tab. 1, the values for these parameters are at the lower end of the recommended range. The health status of the inhabitants of the village of KnR is significantly worse compared to the average of the Slovak Republic, especially regarding cardiovascular diseases (CVD). The relative mortality rate from CVD in the KnR village is 882.4 (period 1995–2006), almost 65 % higher compared to the SR average of 531.2 (Rapant et al., 2019; Cvečková & Rapant, 2022). The aforementioned increased mortality from CVD is mainly associated with low content of Ca (19 mg.l^{-1}) and Mg (3.5 mg.l^{-1}) in drinking water. Based on the risk analysis, an increased health risk from Ca and Mg deficiency and low hardness of water for the local population has been confirmed (Rapant et al., 2020; Cvečková & Rapant, 2022). The mean hazard quotient level for deficient elements (HQ_d) was found to be 1.59 for Ca, 1.59 for Mg, and 1.56 for hardness water, which is a medium level of health risk. The hazard index for deficient elements (HI_d) for these three parameters was 4.7, which is at a high risk level of developing chronic diseases. To reduce the level of health risk to a low risk level, it is necessary to increase the content of Ca and Mg in drinking water in the KnR village by approximately 10 mg.l^{-1}.

Fig. 1. Position of studied locality Kokava nad Rimavicou in Slovakia.

Ta b. 1

Ca, Mg and water hardness contents of drinking water in Kokava nad Rimavicou compared to the standard values of the Slovak drinking water standard and proposed concentrations of Ca, Mg and water hardness after recarbonatization (RC)

	Ca	Mg	Water hardness
	[mg.l^{-1}]		[mmol.l^{-1}]
Kokava nad Rimavicou	19.1	3.52	0.62
Slovak drinking water standard*	> 30	10–30	1.1–5.0
Proposed values after RC**	25–30	8–12	1.1–1.3

* Decree of the Ministry of Health No. 247/2017 Coll.
**The proposed values are based on a risk analysis.

Materials and Methods

Carbonate Rock Leaching

To increase the mineral content of drinking water, Half-burnt dolomite (HBD) is utilized as a rock material due to its high solubility of carbonatic rocks (Tuček et al., 2017). HBD is produced by annealing dolomite [$CaMg(CO_3)_2$] at a temperature range of 600–800 °C, which results in the conversion of magnesium carbonate to magnesium oxide. When HBD is dissolved in the liquid phase, magnesium ions are preferentially released due to the higher solubility of magnesium oxide compared to magnesium carbonate. Magno-Dol, a type of HBD with a size fraction of 2.0–4.5 mm and approved for drinking water treatment in the European Union (EU), contains approximately 98.2 % Ca and Mg oxides and carbonates, 0.9 % Si, Al, and Fe oxides, 0.8 % water, and less than 0.1 % of other elements. Only trace amounts of toxic heavy metals are present. For dissolving HBD, food CO_2 from Messer Tatragas, which is approved for food purposes by the EU and contains over 99 % CO_2 is used.

Design of a Fluidized Bed Recarbonatization Reactor

The process of recarbonatization is used to increase the content of Ca and Mg in drinking water. Various processes and carbonate rocks are used for RC, typically under CO_2 saturation. Flow-through systems are often used, where carbonate rock is added to a device through which the treated water flows (e.g., Al-Rqobah & Al-Munayyis, 1989; Withers, 2005; Luptáková & Derco, 2015). To enrich the drinking water in the village of KnR with Ca and Mg, a prototype of a fluidized bed recarbonatization reactor (RRF) was developed (Fig. 2, 3). The RRF contains a layer of solid particles of half-burnt dolomite, which is kept in motion by the bottom-up flow of water to intensify the dissolution process of the carbonate rock. The recarbonatization reactor was placed directly into the water reservoir without any technical interventions. The device consists of two main parts, the reactor and a circulation tank. The reactor is approximately 3.5 meters tall, cylindrical with a diameter of 40 centimeters, and has a dosing tank on top for adding HBD. The volume of the reactor is approximately 2 m^3, and it is connected to the circulation tank with a volume of approximately 10 m^3. The system is powered by two pumps: one serves as a circulation pump to circulate water between the reactor and the circulation tank, while the other pumps the produced concentrate into the water reservoir. Carbon dioxide is supplied from pressurized bottles with serial concentration. Three circulation pumps with a capacity of 6.8 $m^3.sec^{-1}$ were used. The dosing pump has a capacity of up to 2 $m^3.h^{-1}$, while the output of the circulation pump is approximately 10 times higher.

This allows for multiple rinsing of the carbonate rock, which results in the formation of a concentrate with a Ca and Mg content ranging from 500 to 1,000

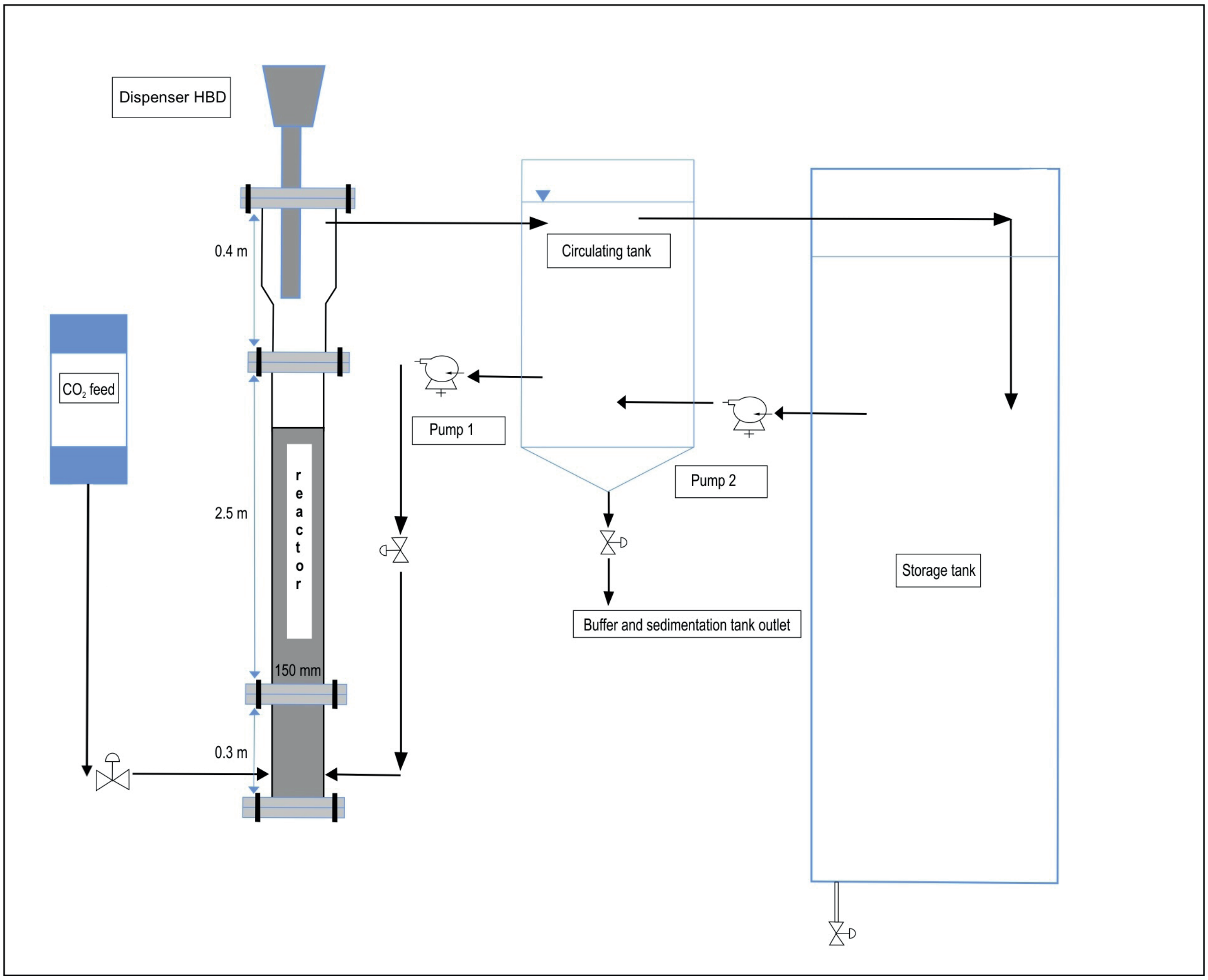


Fig. 2. Schematic diagram of the drinking water recarbonatization plant at the water source in the village of Kokava nad Rimavicou.

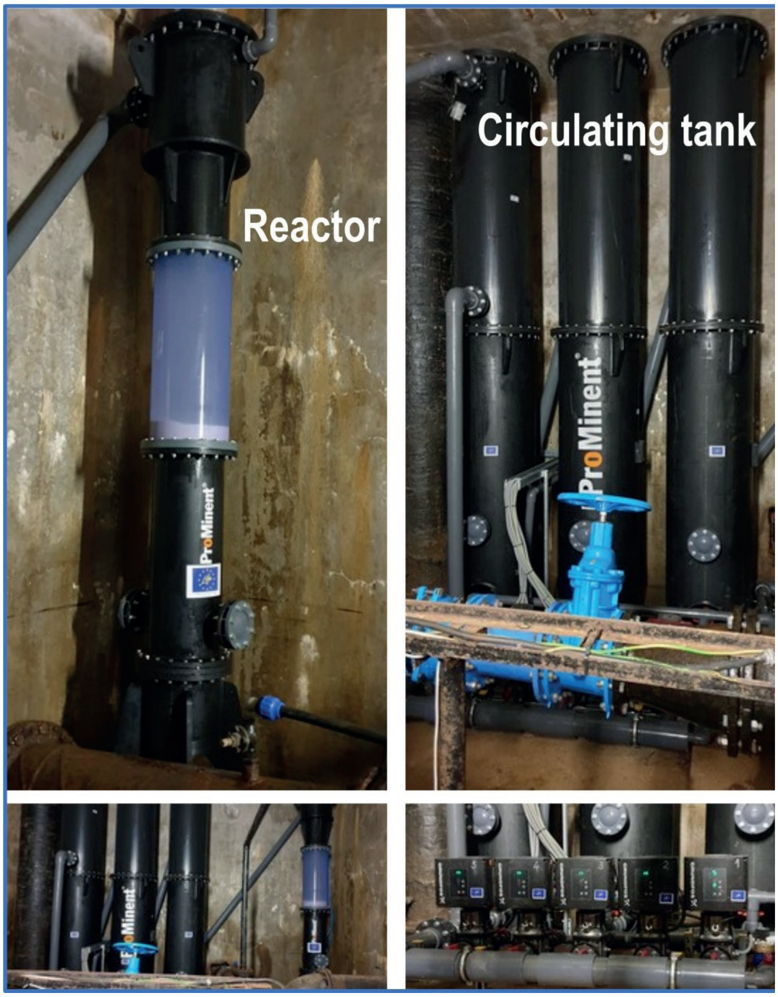


Fig. 3. Recarbonatization reactor at the Kokava nad Rimavicou water source.

milligrams per liter. The concentrate is added directly to the water reservoir in a ratio of approximately 1 : 10 to the water consumption. The circulation and dosing pumps are equipped with frequency converters, which can be easily adjusted as needed. A photovoltaic system was built to provide electricity for powering the pumps. Detailed technical documentation of the recarbonatization reactor is available on the website https://fns.uniba.sk/lifewaterhealth/or Cvečková & Rapant (2022). The production of RR in KnR drew upon the expertise gained from manufacturing a comparable RR in the village of Devičie (Rapant et al., 2022).

Measurement of arterial stiffness

The concept of "arterial stiffness" has only entered our awareness in the last 20–30 years. This phrase is a general term that refers to the loss of arterial compliance or changes in vessel wall properties, or both (Shirwany et al., 2010). The measurement of arterial stiffness is a simple technique that has become a useful non-invasive approach to health prevention in the past 20 to 25 years (DeLoach et al., 2008). Markers of arterial stiffness, such as increased aortic pulse wave velocity and increased central aortic pressure, are independent predictors of cardiovascular risk (Illyes, 2005). These markers represent tissue biomarkers of the arteries and have been shown to be better prognosticators than traditional blood pressure measurements, as well as biomarkers in the bloodstream. Furthermore, their significant predictive value specifies the risk assessment provided by traditional risk factors. The measurement of arterial stiffness provides insights into the actual pathological processes through the evaluation of the loss of elasticity of the aorta. Over time, endothelial damage progresses and causes damage to the arterial elasticity, resulting in the loss of elasticity of the vessel wall. In this study, measurements were performed with an arteriograph (Fig. 4) developed in Hungary and patented in over 30 countries (Arteriograph, TensioMed Ltd., Budapest, Hungary). The arteriograph can easily measure, without any health risk, physiological parameters characterizing the state of arteries that are independent of other known risk factors (age, sex, blood pressure, cholesterol, smoking) and can reliably assess the state of the car-

Fig. 4. Arterial stiffness measurement with arteriograph.

diovascular system and predict the risk of complications in asymptomatic, apparently "healthy" patients. These parameters are also confirmed by international guidelines for the diagnosis of target organ damage (Williams et al., 2018). The influence of Ca and Mg content in drinking water on the improvement of arterial stiffness has been demonstrated in the work of Rapant et al. (2019). The Ca and Mg content in drinking water had a greater impact on arterial elasticity than other factors such as obesity, BMI index, smoking, and so on.

We measured arterial stiffness on approximately 60 volunteers in the village of KnR. The basic condition was that the volunteers had a permanent residence in the village for at least five years. People who had been treated for cardiovascular diseases and other diagnoses (especially diabetes mellitus and kidney diseases) were excluded from the measurements. All participants in the measurement gave written consent for the study, and before the measurement, they completed a short questionnaire about their health status, age, height, weight (BMI index), smoking, and alcohol consumption. For the purpose of the study, an ethical commission was established at the Regional Public Health Office based in Zvolen (minutes 1/2021 dated 05. 09. 2021). The basic characteristics of the volunteers from the KnR village are presented in the Tab. 2.

Tab. 2

Basic characteristics of volunteers from the KnR village

Age	BMI	Gender	Smoking habbits	Alcohol consumption
53*	28.5*	Male 15	Yes 14	Regularly 0
56**	27.45**	Female 41	No 41	Occasionally 31
16–69***	19.5–53***			Abstinent 25

* average ** median *** dispersion

Selected volunteers underwent four measurements of arterial stiffness. The first measurement was conducted before the enrichment of drinking water with Ca and Mg, and the following three measurements were conducted approximately every six months after the enrichment of drinking water with Ca and Mg. The results of arterial stiffness measurement are expressed using pulse wave velocity PWVao ($m.s^{-1}$) and arterial age. The lower the pulse wave velocity, the better the condition of the arteries. Similarly, the lower the arterial age (age of the arteries), the better the condition. In a normal case, arterial age corresponds to the actual age. If the condition of the arteries is unfavorable, the arterial age is higher than the actual age and vice versa. Therefore, the results of arterial age are expressed as the difference between arterial age and actual age. The lower this difference, the more favorable the condition of the arteries. In the best case, this difference takes negative values, which means that the age of the arteries is lower than the actual age. Further details on the methodology of arterial stiffness measurement depending on the content of Ca and Mg in drinking water are available in the work of Rapant et al. (2019) and directly in KnR in the work of Cvečková and Rapant (2022).

Results

Recarbonatization of drinking water

The recarbonatization reactor in the KnR village was put into operation on July 12, 2021.

The basic conditions for recarbonatization were as follows:

- Average daily water consumption in KnR: 275–300 m^3.
- Average daily dose of produced and added concentrate: 25–30 $m^3.day^{-1}$.
- Mixing ratio of concentrate and water from the reservoir: 1 : 9 (1 : 10).
- Performance of the circulation pump: approximately 10 $m^3.h^{-1}$.
- Average dose of added HBD: 50 kg per week.
- Average amount of added CO_2: 230–240 kg per week.
- Total volume of the reservoir: 1,300 m^3.
- Target values for recarbonatization: Ca 25–30 $mg.l^{-1}$, Mg 8–12 $mg.l^{-1}$, (Ca + Mg) 1.1–1.3 $mmol.l^{-1}$.

After the RR was put into operation, a malfunction occurred in the reactor hydraulics. The reactor operated at only about 20 % capacity. Due to the COVID-19 pandemic, it took approximately 90 days to resolve the issue and ensure the reactor was operating at full capacity. After that, the RR worked reliably until the end of the LIFE-WATER and HEALTH project (December 31, 2022). The results of the recarbonatization of drinking water in KnR for the years 2021–2022 are shown in Tab. 3.

The Tab. 3 shows values of Ca, Mg, water hardness, and conductivity at the output in the village (in the branch of the local waterworks center), approximately 2 km from the water source. From April 2022, the local water company began to enrich drinking water with Ca using calcium hydroxide [($Ca(OH)_2$]. This was reflected by an increase in the content of Ca in drinking water in KnR.

Tab. 3

Results of drinking water recarbonatization in KnR for the years 2021–2022

Month	Ca	Mg	Water hardness	Conductivity
	[mg.l⁻¹]		[mmol.l⁻¹]	[µS.cm⁻¹]
2021				
Original state	19.1	3.5	0.62	110
August	19.9	4.1	0.66	116
September	25.6	4.9	0.83	145
October	30.7	6.9	1.04	165
November	30	8.8	1.11	202
December	32.5	9.2	1.18	222
2022				
January	32.9	14.0	1.39	202
February	33.2	13.2	1.33	210
March	35.6	12.8	1.41	225
April	46.4	12.6	1.68	259
May	31.3	9.9	1.19	205
June	42.7	12.5	1.58	235
July	44.8	13.2	1.64	242
August	38.6	11.7	1.44	250
September	42.4	12.8	1.58	239
October	39.6	11.1	1.44	225
November	44.8	15.2	1.74	261
December	40.2	12.8	1.53	229

Measurement of arterial stiffness

The first initial measurement of arterial stiffness was carried out in the village of KnR in May 2021. Sixty-four volunteers participated in the measurements. Due to their advanced age (over 67 years), four volunteers were excluded from the sample. This stage took place during a period when the residents were supplied with "soft" drinking water (Ca 19 $mg.l^{-1}$, Mg 3.5 $mg.l^{-1}$). The next three stages of arterial elasticity measurements were carried out at approximately six-month intervals after enriching drinking water with Ca and Mg (Ca 45 $mg.l^{-1}$, Mg 10–15 $mg.l^{-1}$). Due to the COVID-19 pandemic, we could not follow the planned six-month interval for the measurements. Measurements were conducted at 5–7 month intervals due to quarantine. Additionally, not all respondents who participated in the first arterial stiffness measurement were able to participate in the measurements of the II.–IV. stages due to COVID-19. Therefore, we also used a smaller sample of substitute volunteers. For this reason, we present the results first without substitute volunteers, and also with substitute volunteers. The results of the arterial stiffness measurement of the inhabitants of the KnR village are shown in tables 4 and 5, and the entire arterial stiffness measurement database is available on the project website (http://fns.uniba.sk/lifewaterhealth/).

Tab. 4

Results of the arterial stiffness measurement of respondents in the village of Kokava nad Rimavicou, all respondents

	Measurement date	Number of respondents	PWVao	Actual age	Arterial age	Difference Arterial age – actual age
			[m.s⁻¹]	[years]		
I.	May 2021	60	**9.7**	54.11	64.18	**10.07**
II.	December 2021	53	**9.54**	53.69	62.77	**9.08**
III.	June 2022	56	**9.37**	52.3	61.35	**9.5**
IV.	December 2022	73	**8.91**	54.43	55.58	**1.15**

Tab. 5

Results of the arterial stiffness measurement of respondents in the village of Kokava nad Rimavicou, excluding substitute respondents

Measurement stage	Measurement date	Number of espondents	PWVao	Actual age	Arterial age	Difference Arterial age – actual age
			[m.s⁻¹]	[years]		
I.	May 2021	60	**9.7**	54.11	64.18	**10.07**
II.	December 2021	46	**9.42**	53.74	61.24	**7.5**
III.	June 2022	49	**9.25**	53.4	59.76	**6.36**
IV.	December 2022	52	**8.83**	54.53	54.67	**0.14**

Discussion

Calcium and magnesium are very important essential elements. For healthy human development, their content in drinking water should be at least at the level of Mg 10–20 $mg.l^{-1}$ and Ca 30–50 $mg.l^{-1}$ (e.g., Rosborg & Kožíšek, 2020). As can be seen from Tab. 3, after the initial technical problems (first 90 days of operation), the reservoir operated reliably. We increased the Ca and Mg content in the drinking water in KnR to the desired level without any problems, by approximately 10–20 $mg.l^{-1}$. We then tested the reactor, varying the performance of the circulation pumps, the amount of concentrate discharged, the amount of HBD added, and also the amount of CO_2. The process of dissolving HBD is mainly influenced by the performance of the circulation pump and the amount of added rock. The amount of added CO_2 needs to be limited to such an extent that the residual free CO_2 does not exceed the level of 60–80 $mg.l^{-1}$. A relatively large amount of rock micro-particles is released during the fluidization process. The produced concentrate is turbid. However, these micro-particles dissolve in the reservoir water due to the residual free CO_2, thereby increasing the Ca and Mg content in the drinking water by 10–15 %. Therefore, there is no risk of acidification. The resulting pH of the water in the village increased only slightly, from about 7.2 to 7.3 and the free CO_2 content from about 4 $mg.l^{-1}$ to 8 $mg.l^{-1}$. The optimal reactor setting, at which we can ensure an increase in the Ca and Mg content in drinking water by 10–15 $mg.l^{-1}$ at the lowest possible operating costs, was a circulation pump performance in the range of 7–9 $m^3. h^{-1}$, the amount of added HBD of 7–8 $kg.day^{-1}$, and the amount of CO_2 of 15–17 $kg.day^{-1}$. It is clear from the above that the reactor operated at only about half power, and at maximum reactor output, we can increase the Ca and Mg content by up to for Ca 50 $mg.l^{-1}$ and for Mg 25 $mg.l^{-1}$. An advantage of the RRF prototype we developed is the relatively low operating costs, which are approximately €0.1 per m^3 of drinking water. More detailed results of recarbonatization under different conditions are available on the website http://fns.uniba.sk/lifewaterhealth/ and in the work of Cvečková and Rapant (2022). From the results of the measurements of arterial stiffness (Tab. 4, 5), it is evident that there was a significant improvement in the condition of the arteries of the residents of the KnR village after enriching the drinking water with Ca and Mg. This was reflected in the decrease in the pulse wave velocity and the reduction in the arterial age of the people. The pulse wave velocity decreased in all volunteers (9.7 to 8.91) and also in the case of volunteers without replacements (9.7 to 8.83). Similarly, the arterial age of the people, expressed as the difference between the arterial age and the actual age, was significantly reduced. In the case of all volunteers, it decreased from 10.07 to 1.15 years and in the case of volunteers without replacements, it decreased from 10.07 to 0.14 years. The values of PWVao and arterial age of the KnR residents have already approached the level of the Central European average (Rapant et al., 2019). Improvement in arterial age and PWVao is truly significant. It can be explained only by the fact that we increased the content of Ca and Mg in drinking water, up to 2–3 times compared to their original levels. These results can hardly be confronted with other works because, to our best knowledge, there is no literature documenting the relationship between arterial stiffness and water hardness, with the exception of older publications by the authors (Rapant et al., 2019). However, it should be noted that medical studies clearly show the protective role of Mg and Ca for arteries (Hruby et al., 2014; Uemura et al., 2014). Magnesium deficiency has been shown to have a detrimental effect on arterial elasticity (Joris et al., 2016; Kostov & Halacheva, 2018), and it is well known that the state of arteries has a direct relationship to the development of cardio-vascular diseases (Shirwany et al., 2010).

Other risk factors for the development of cardiovascular diseases, such as stress, genetic predisposition, BMI, excessive alcohol consumption, and smoking, also influence the cardiovascular system and consequently the arterial stiffness, in addition to the content of calcium and magnesium in drinking water. However, statistical testing has shown that the content of Ca and Mg in drinking water has a much greater impact on arterial stiffness than, for example, BMI and smoking (Rapant et al., 2019).

Conclusion

The results presented in the article clearly confirmed the improvement of arterial stiffness, thus the cardiovascular system of KnR residents, after consuming drinking water enriched with Ca and Mg. This improvement was reflected in a significant reduction in pulse wave velocity and arterial age of people. The findings unambiguously substantiate that, beyond the conventional risk factors associated with the onset of CVD, such as stress, obesity, genetic predisposition, smoking, and excessive alcohol consumption, the content of Ca and Mg in drinking water constitutes an equally significant contributing factor to the emergence of CVD. The deficient content of Ca and Mg in drinking water not only worsens the condition of the human cardiovascular system but also increases the mortality rate from other diseases, especially cancer and diabetes mellitus. It also results in a shorter lifespan by up to five years compared to people who are supplied with "hard" drinking water. Therefore, we believe that, based on many studies published in the world literature, Ca and Mg should be included among the regulated parameters of drinking water. We also believe that the content of Ca and Mg in bottled drinking water should be regulated, especially in cases where bottled drinking water is produced by desalination of seawater.

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Vplyv zvýšeného obsahu vápnika a horčíka v pitnej vode na arteriálnu tuhosť a kardiovaskulárny systém u ľudí: prípadová štúdia v Kokave nad Rimavicou, Slovenská republika

Negatívny vplyv deficitného obsahu Ca (približne 30 mg . l^{-1} a menej) a Mg (približne 10 mg . l^{-1} a menej) v podobe zvýšenej incidencie kardiovaskulárnych ochorení (KVO) a zvýšenej mortality na tieto ochorenia je známy už takmer 70 rokov (Kobayashi, 1957). Tento vplyv bol potvrdený približne v 50 krajinách sveta vrátane Slovenskej republiky. Potvrdil sa aj viacerými metaanalýzami (napr. Catling et al., 2008). Hlavným cieľom príspevku je zistiť, či sa kardiovaskulárny systém (KVS) u ľudí, ktorí pôvodne konzumovali mäkkú pitnú vodu, zlepší, keď začnú konzumovať pitnú vodu so zvýšeným obsahom Ca a Mg. Obohacovanie pitnej vody o Ca a Mg sme realizovali na vodárenskom zdroji v obci Kokava nad Rimavicou (KnR) v rámci riešenia projektu *LIFE – WATER and HEALTH*. Pitná voda na vodárenskom zdroji KnR sa vyznačuje veľmi nízkym obsahom Ca (18 – 20 mg . l^{-1}) a Mg (3 – 4 mg . l^{-1}), ktorý je výrazne nižší ako odporúčané hodnoty slovenskej vyhlášky pre pitnú vodu (tab. 1). Relatívna úmrtnosť na KVO u obyvateľov v KnR je 882,4, čo je takmer o 65 % vyššia hodnota ako priemer Slovenskej republiky (531,2). Kardiovaskulárny systém obyvateľov KnR sme sledovali pomocou merania pružnosti ciev (MPC). Meranie pružnosti ciev sa realizovalo pomocou arteriografu (obr. 4), ktorý bol vyvinutý v Maďarsku a patentovaný vo viac než 30 krajinách sveta. Veľkou výhodou MPC je, že sa ním dajú odhaliť riziká a náchylnosť na KVO ešte pred klinickými príznakmi (Illes, 2005). Pri MPC sa meria rýchlosť pulznej vlny aorty a hlavných tepien (PWVao). Čím je rýchlosť PWVao nižšia, tým je stav tepien lepší a sú priechodnejšie. Z hodnôt PWVao sa následne pri zohľadnení priemerných hodnôt pre stredoeurópsku populáciu vypočíta arteriálny vek (AV) ľudí. Následne sa stanovuje rozdiel medzi arteriálnym vekom a skutočným vekom. V prípade priaznivého stavu KVS ľudí je tento rozdiel záporný a naopak. Obohacovanie pitnej vody na vodárenskom zdroji v obci KnR sme realizovali pomocou rekarbonatizačného reaktora (RR), v ktorom sa rozpúšťa karbonatická hornina – polovypálený dolomit za pôsobenia CO_2 (obr. 2, 3). V RR sme vyrábali koncentrát približne so 100 mg . l^{-1} horčíka, ktorý sa pridával priamo do vodárenského zdroja v pomere približne 1 : 10. Takto sme zvyšovali obsah Ca a Mg v pitnej vode vo vodárenskom zdroji v obci KnR približne o 10 – 15 mg . l^{-1}. Tým sme zvýšili pôvodný obsah dva- až štyrikrát (tab. 4). Vplyv zvýšeného obsahu Ca a Mg na KVS ľudí bol sledovaný pomocou MPC. Meranie sme realizovali približne na 60 vybraných respondentoch z obce KnR. Vybraní občania museli mať najmenej päť rokov trvalý pobyt v obci a nesmeli byť liečení na KVO a ďalšie závažné diagnózy, najmä na diabetes mellitus a ochorenie obličiek. Merania sme realizovali štyrikrát v šesťmesačných intervaloch – prvýkrát pred obohacovaním pitnej vody o Ca a Mg a trikrát po obohacovaní pitnej vody o Ca a Mg. Druhá až štvrtá fáza merania pružnosti ciev bola negatívne ovplyvnená pandemickou situáciou spojenou s ochorením COVID-19. Nie všetci respondenti, ktorí sa zúčastnili na prvej fáze merania, sa mohli pre karanténu zúčastniť na ďalších fázach merania. Aby sme splnili technické zadanie projektu *LIFE – WATER and HEALTH* (60 respondentov), museli sme pružnosť ciev zmerať aj náhradným respondentom z obce KnR. Určite to mohlo čiastočne negatívne ovplyvniť dosiahnuté výsledky. Preto výsledky MPC podávame dvakrát – najprv len z merania respondentov, ktorí sa zúčastnili na prvej fáze merania (tab. 5), a potom výsledky všetkých meraných respondentov aj s náhradnými (tab. 4). V obidvoch prípadoch je však zrejmý pokles PWVao, pokles arteriálneho veku a pokles rozdielu medzi arteriálnym vekom a skutočným vekom. Dosiahnuté výsledky presvedčivo potvrdili výrazné zlepšenie KVS ľudí. Došlo k výraznému poklesu PWVao, a to z 9,7 na 8,8 m . s^{-1}, a veľmi výraznému zníženiu hodnôt rozdielu medzi arteriálnym vekom a skutočným vekom, a to z 10,07 na 0,14. Tento rozdiel (0,14), zistený po 18-mesačnej konzumácii pitnej vody obohatenej o Ca a Mg, je už na úrovni stredoeurópskeho priemeru. Zlepšenie hodnôt PWVao a AV po 18-mesačnej konzumácii pitnej vody obohatenej o Ca a Mg je naozaj signifikantný. Preto je možné plne ho spájať so zvýšenou dennou dávkou Ca a Mg z pitnej vody. Výsledky jednoznačne potvrdzujú, že okrem tradičných rizikových faktorov vzniku KVO (stres, obezita, genetické faktory, fajčenie a nadmerná konzumácia alkoholu) je obsah Ca a Mg v pitnej vode rovnako významným faktorom rizika vzniku KVO.

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