

The impact of drinking water on the health of the inhabitants of the Slovak Republic

S. Rapant¹, V. Cvečková², N. Beňová¹

¹Comenius University in Bratislava, Faculty of Natural Sciences, Slovak Republic

²State Geological Institute of Dionyz Stur, Slovak Republic,



GEOHEALTH

*The impact of geological environment
on health status of residents
of the Slovak Republic.*



*The Elimination of Negative Impact of Geological
Compound of the Environment on Health Status
of Residents in the Krupina*



*Improvement of health status of population
of the Slovak Republic through drinking water
recarbonization*

Main conclusions from previous projects

- Carbonate geological environment – limestones, dolomites, carbonate flysch sediments – favorable for human health
- Silicate geological environment – granitoids, crystalline schists, volcanic – unfavorable for human health
- The average life expectancy of people in carbonate geological environments is 4–5 years higher than in silicate geological environments
- In silicate geological environments, mortality, RM, SMR is 30–150% higher than in carbonate environments
- We monitored the influence of rocks, soils, local food chain, groundwater, drinking water – drinking water has the greatest influence
- Of drinking water, the content of Ca and Mg has the greatest influence on human health. Their impact is up to 100–1,000 times higher than the impact of classic contaminants – NO_3 , NO_2 , toxic metals (As, Cd, Hg, Pb, ...)
- A deficient content of Ca and Mg in drinking water ($\text{Ca} \leq 30 \text{ mg l}^{-1}$, $\text{Mg} \leq 10 \text{ mg l}^{-1}$) has an adverse effect on human health
- A sufficient content of Ca and Mg in drinking water ($\text{Ca} \geq 50 \text{ mg l}^{-1}$, $\text{Mg} \geq 25 \text{ mg l}^{-1}$) has a beneficial effect on human health

Proposed limit values for drinking and bottled water compared to Slovak drinking water

Parameter	Recommended values		
	Drinking water for public	Bottled drinking water	Slovak drinking water
	supply		standards
Ca+Mg	2 – 5 mmol l ⁻¹	2.5 – 5 mmol l ⁻¹	1.1 – 5 mmol l ⁻¹
Ca	50 – 180 mg l ⁻¹	60 – 180 mg l ⁻¹	>30 mg l ⁻¹
Mg	25 – 50 mg l ⁻¹	30 – 60 mg l ⁻¹	10 – 30 mg l ⁻¹

We monitored the impact of drinking water - Ca and Mg content - on human health in the project:

Improvement of health status of population of the Slovak Republic through drinking water recarbonization

motto

There are countless cases where drinking water with a low (deficient) content of Ca and Mg has an adverse effect on the health of people who regularly drink it.

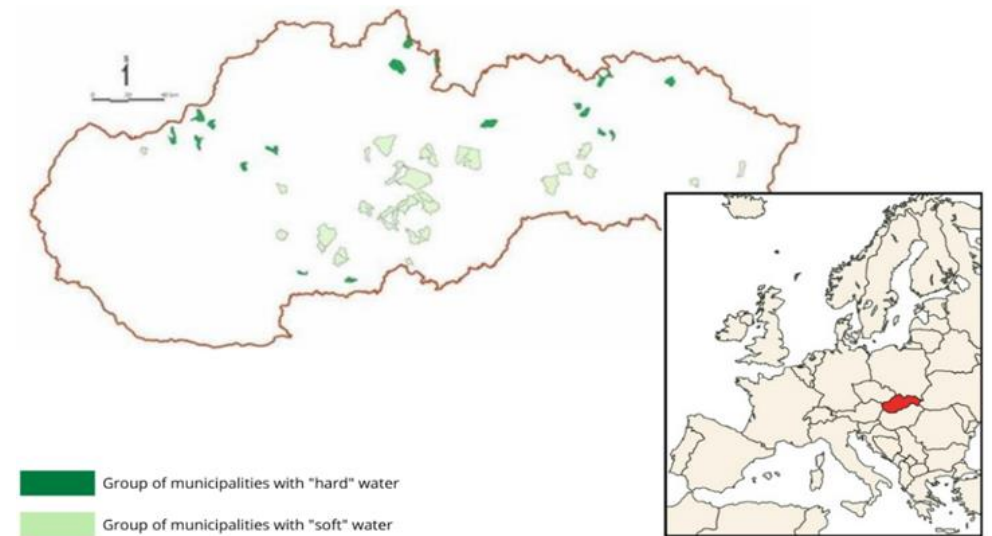
In this project, we will try to prove that people who start drinking hard water regularly instead of soft water will have improved health.



- Which diseases/diagnoses are affected by the content of Ca and Mg in drinking water
- How much does it take to increase the content of Ca and Mg in drinking water to make the water healthy
- Development of technological equipment for increasing the content of Ca and Mg
- Monitoring the positive impact of increased content of Ca and Mg in drinking water on human health (Arterial stiffness)

The influence of Ca and Mg on various diagnoses according to the International Classification of Diseases

- All diseases and their diagnoses are classified in the International Classification of Diseases (ICD)
- A total of 2,037 diagnoses, which are categorized in 21 chapters.
- We evaluate the first 17 chapters that can be affected by the content of Ca and Mg in drinking water
- We created two groups of municipalities (approx. 52,000 inhabitants) that are supplied with drinking water with different contents of Ca and Mg in drinking water



Average hardness content (Ca + Mg), Ca and Mg

„SOFT“ WATER

$$\text{Ca} + \text{Mg} = 0.77 \text{ mmol l}^{-1}$$

$$\text{Ca} = 20.7 \text{ mg l}^{-1}$$

$$\text{Mg} = 6.05 \text{ mg l}^{-1}$$

„HARD“ WATER

$$\text{Ca} + \text{Mg} = 2.84 \text{ mmol l}^{-1}$$

$$\text{Ca} = 70.12 \text{ mg l}^{-1}$$

$$\text{Mg} = 26.43 \text{ mg l}^{-1}$$

We evaluated the 15-year period 1994–2008 for which data were available (Statistical Office of the Slovak Republic)

Basic demographic and health characteristics of selected groups of municipalities

Parameter	Soft water	Hard water	SR
Number of person-years	804,450	776,959	80,799,554
Number of deaths	10,740	5,796	785,328
Number of premature deaths	3,167	1,521	225,518
Life expectancy	70.01	74.58	72.65
Age-standardized mortality	114.49	87.82	100
Years of lost life	5,770	2,773	3,941

The number of deaths, the number of premature deaths, the age-standardized mortality rate, and the years of life lost are significantly more unfavorable in the soft water group, and life expectancy is significantly higher in the hard water group.

Basic characteristics of health indicators for designated water groups

ICD			Soft water			Hard water			SR		
Mortality											
Chapter	Diagnosis code	Title	N	RM	SMR (%)	N	RM	SMR (%)	N	RN	SMR (%)
I.	A00- B99	Infectious and parasitic diseases	46	0.62	129.39	24	0.26	98.99	3, 217	0.3	100
II. a	C00- C97 D00-D09	Malignant neoplasms	2, 241	278.59	104.77	1, 223	157.49	83.53	172, 995	214.05	100
II. b	D10-D48	Benign neoplasms	11	1.37	100.03	9	1.16	1, 001	1, 221	1.51	100
III.	D50-D90	Diseases of the blood	11	1.37	100.82	7	0.9	99.41	860	1.06	100
IV.	E00-E90	Endocrine, nutritional...	150	18.65	102.27	89	11.46	98.52	11, 478	14.2	100
V.	F00-F99	Mental and behavioural...	1	0.12		0	0		220	0.27	100
VI.	G00-G99	Nervous system	111	13.8	117.58	27	3.48	94.1	7, 678	9.5	100
IX.	I00-I99	Diseases of the circulatory system	6,564	816.08	116.58	3, 253	418.91	95.55	429, 239	531.11	100
X.	J00-J99	Diseases of the respiratory system	750	93.25	120.75	302	38.89	80.85	46, 435	57.46	100
XI.	K00-K93	Diseases of the digestive system	573	71.24	114.49	229	29.49	87.82	38, 994	48.25	100
XII.	L00-L99	Diseases of the skin	0	0		2	0.26		46	0.06	100
XIII.	M00-M99	Diseases of the musculoskeletal...	8	0.99	100.11	7	0.9	99.98	682	0.84	100
XIV.	N00-N99	Diseases of the genitourinary sys.	138	17.16	95.38	64	8.24	80.78	10, 874	13.45	100
XV.	O00-O99	Pregnancy, childbirth...	2	0.25		0	0		50	0.06	100
XVI.	P00-P96	Perinatal period...	22	2.74	100.21	25	3.22	101.72	3, 205	3.97	100
XVII.	Q00-Q99	Congenital malformations...	33	4.1	101.73	14	1.8	98.2	2, 543	3.15	100

Note: N-number of deaths. In group diagnoses VII. Eye diseases and VIII. Ear diseases, not a single death was recorded, therefore we do not list them

The number of deaths, RM, SMR is significantly higher in the soft water group:

Infectious and parasitic disease (chapter I)
Oncological disease (chapter II a)
Blood diseases (chapter III)
Endocrine and nutritional disease (chapter IV)
Nervous system (chapter VI)
Circulatory system (KVD) (chapter IX)
Respiratory system (chapter X)
Digestive system (chapter XI)
Genitourinary system (chapter XIV)
Congenital malformations (chapter XVII)

Virtually no differences were noted in the case of chapters:

Benning neoplasms (chapter II b)
Mental and behavioural system, (chapter V)
Diseases Eye (chapter VII)
Diseases Ear (chapter VIII)
Diseases of the skin (chapter XII)
Pregnancy, children birth (chapter XV)

From the literature data, increased **mortality/incidence** has been confirmed many times only for **CVD, OD, endocrine diseases (DM)**. Regarding other diseases, there is no knowledge in the world literature about increased mortality due to deficient Ca and Mg content.

Notable diagnoses

G-80 – cerebral palsy (34-2) in soft water is 17 times higher mortality

G-40 – epilepsy (44-10) in soft water is 4,4 times higher mortality

The statistical significance of the results achieved – the difference in mortality between soft water and hard water – was monitored using three different methods:

CHI – square test

ODDS ratio analyse

Clopper - Pearson's exact 95% confidence interval

The results of the statistical analysis clearly show that there is a significant statistical dependence in the number of deaths in the 9 ICD chapters.

CONCLUSION

From the results obtained, it is clear that the content of Ca and Mg in drinking water causes an increased number of deaths not only in the three diagnoses (chapters) confirmed in the literature: CVD, OD, DM, but also in six other chapters according to the ICD.

Rapant, S., Cvečková, V., Fajčíková, K., Sedláková, D., Stehlíková, B. (2017). Impact of Calcium and Magnesium in Groundwater and Drinking Water on the Health of Inhabitants of the Slovak Republic. - In: International Journal of Environmental Research and Public Health. 14, 278.

Fajčíková, K., Stehlíková, B., Cvečková, V., Rapant, S. (2017): Application of artificial neural network in medical geochemistry. In: Environmental Geochemistry and Health. Vol. 39, No. 6, s. 1513-1529. - ISSN 0269-4042.

Rapant, S., Letkovičová, A., Jurkovičová, D., Kosmovský, V., Kožíšek, F., Jurkovič, L. (2021): Differences in health status of Slovak municipalities supplied with drinking water of different hardness values. Environ Geochem Health. <https://doi.org/10.1007/s10653-020-00664-6>.

	CHI-Square test			ODDS Ratio			
Chapter ICD	Value of the test statistic	P-value	Statistical significance	OR	Interpretation	95% CI	Statistical significance
I.	5.57	0.018	++	0.540	Yes	0.315 0.904	yes
II. a	263.95	<2.2e-16	+++	0.564	Yes	0.526 0.606	yes
II. b	0.021	0.885	0	0.848	No	0.310 2.250	no
III.	0.39	0.527	0	0.659	No	0.216 1.863	no
IV.	12.99	0.000	+++	0.614	Yes	0.467 0.804	yes
V.	2.98	1	0	0.000	No	0.000 40.422	no
VI.	47.01	7.0e-12	+++	0.252	Yes	0.159 0.386	yes
IX.	1007.30	<2.2e-16	+++	0.511	Yes	0.490 0.533	yes
X.	174.44	<2.2e-16	+++	0.417	Yes	0.363 0.477	yes
XI.	134.78	<2.2e-16	+++	0.414	Yes	0.353 0.483	yes
XII.	0.53	0.463	0	Inf */	No	0.194 Inf	no
XIII.	7.87	1	0	0.906	No	0.279 2.861	no
XIV.	23.84	1.0e-06	+++	0.480	Yes	0.351 0.651	yes
XV.	0.46	0.495	0	0.000	No	0.000 5.518	no
XVI.	0.17	0.678	0	1.177	Yes	0.637 2.191	yes
XVII.	6.26	0.012	++	0.439	Yes	0.217 0.844	yes

TARGET VALUES FOR RE-CARBONATIZATION IN DRINKING WATER

Determine the minimum required Ca and Mg content to which we must re-carbonatise drinking water in the municipality of Devičie and in the municipality of Kokava nad Rimavicou in order to eliminate or reduce the health risk posed to local residents from low/deficient Ca and Mg content in drinking water.

We set the re-carbonatization target values based on the methodology for calculating the risk for deficient biogenic elements.
This is a supplement and modification of the US EPA Health Risk Assessment methodology.

US EPA health risk assessment is widely used to calculate and evaluate health risks for toxic and harmful elements/components exceeding limit (recommended) values.

$$HQ = ADD/RfD$$

We have innovated the methodology for calculating health risks from a deficit of biogenic (essential) elements

New terminology - new average daily dose are proposed

$$HQ_d = ADRD/ADAD$$

Average Daily Required Dose (ADRD)

Average Daily Accepted Dose (ADAD)

Average Daily Missing Dose (ADMD)

Minimum required concentration (MRC)

MRC – represent the minimum content of an element, at which there is no known health risk, crucial point of calculation

$$ADMD = (MRC - CW) \times IR \times ED \times EF/BW \times AT$$

CW – represent the average content of Ca, Mg in drinking water

We used the same scenarios and the same input data as US EPA method

(MRC – CW): is the value of how much of an essential element is missing

MRC: two calculation methods

1. On the basis of some standards (if they exist). For example, we used half the value of the recommended value of the Slovak standard for drinking water for Mg = 10–30 mg l⁻¹, **we used the value of 20 mg l⁻¹**

2. Based on calculations from real data on health indicators.

We used four main HIs:

Relative mortality for CVD, OD, GS, RS (represent 85% of causes of death),
which we weighted by the number of deaths

The calculations are quite complicated, there is no time for a detailed explanation.

The following are detailed in the work:

Rapant, S., Cvečková, V., Hiller, E., Jurkovičová, D., Kožišek, F., Stehlíková, B., 2020: Proposal of New Health Risk Assessment Method for Deficient Essential Elements in Drinking Water – Case Study of the Slovak Republic. Int. J. Environ. Res. Public Health 2020, 17, 5915; doi:10.3390/ijerph17165915.

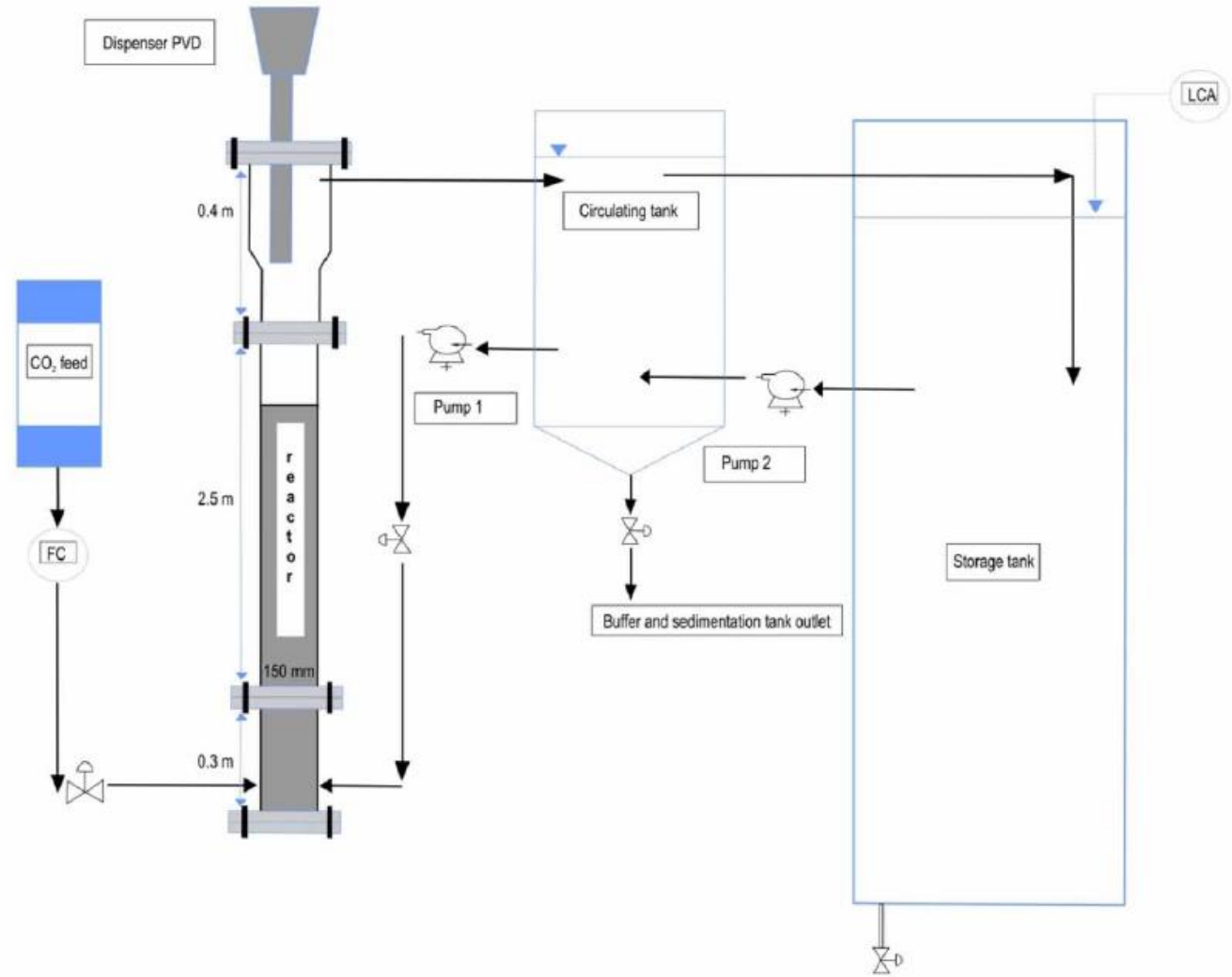
Target values for recarbonatization of drinking water in Devičie and Kokava nad Rimavicou municipalities

DEVÍČIE			KOKAVA NAD RIMAVICOU		
Ca	Mg	(Ca+Mg)	Ca	Mg	(Ca+Mg)
mg l ⁻¹		mmol l ⁻¹	mg l ⁻¹		mmol l ⁻¹
<i>Target values</i>			<i>Target values</i>		
35-40	16-21	1.5-1.6	25-30	8-12	1.1-1.3
<i>Real concentration</i>			<i>Real concentration</i>		
30.00	10.00	1.15	19.10	3.50	0.62

The calculation shows that the Ca and Mg content must be increased by approximately 10 mg l⁻¹ in the water sources of Devičie and Kokava nad Rimavicou in order to achieve a low to negligible risk of developing chronic diseases from deficient Ca and Mg content in drinking water.

Re-carbonatization reactor for increasing Ca and Mg content in drinking water

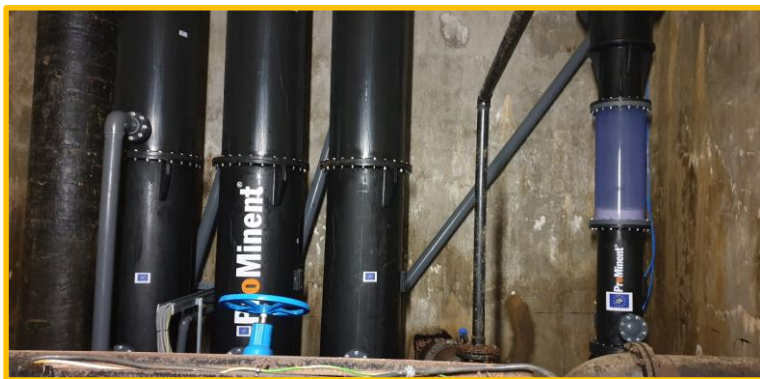
To enrich the drinking water, supplied to the inhabitants in the village of Devičie and KnR, with Ca and Mg, a prototype of a fluidized bed re-carbonatization reactor (RRF) was developed. In the RRF, a layer of solid particles of carbonate rock– half-burnt dolomite (HBD) – is kept in lift and in motion by the bottom-up flow of water, which intensifies the dissolution process of the carbonate rock.



Kokava nad Rimavicou

The recarbonatization reactor with a fluidized bed was introduced at the Kokava nad Rimavicou water source to:

- temporary operation July 12, 2021
- permanent operation on April 1, 2022



Devičie

The recarbonatization reactor with a fluidized bed was introduced at the Devičie water source to:

- temporary operation June 25, 2021
- permanent operation on April 1, 2022



In the reactors, water is circulated by pumps between the circulation tank and the reactor body, and after reaching the required concentration (approx. 100 mg l⁻¹ Mg), it is drained directly into the water reservoir, where it is diluted in a ratio of 1:10.

Carbonate rock – Half burned dolomit (HBD)

Oxidizing agent – food CO₂, to accelerate the dissolution of HBD

Result of rekarbonatization of drinking water at the Devičie

Basic conditions for the enrichment of drinking water:

- average daily water consumption is 30 m³,
- average daily dose of produced and added concentrate is 3 m³
- mixing ratio of concentrate and water drained from the reservoir is 1:10
- total volume of the reservoir is 90 m³ of water,
- average HBD consumption 300 kg year⁻¹
- average consumption of CO₂ – 400 kg year⁻¹

Operation time		Conductivity	Ca	Mg	Ca + Mg
		[μS cm ⁻¹]	[mg l ⁻¹]		[mmol l ⁻¹]
Initial state		298	30.1	10.2	1.16
1 day	after putting into operation	300	30.1	10.1	1.16
3 days		310	30.3	10.4	1.18
5 days		360	32.6	15.2	1.43
10 days		380	33.7	20.7	1.60
30 days		430	36.7	21.5	1.79
July 2021		444	37.4	21.2	1.80
August 2021		435	36.5	20.9	1.76
September 2021		440	37.2	20.1	1.74
October 2021		452	38.4	22.1	1.85
November 2021		425	36.5	21.8	1.80
December 2021		430	36.5	20.0	1.73
January 2022		405	36.2	21.1	1.77
April 2022		418	38.2	21.8	1.85
June 2022		405	37.8	21.2	1.81
September 2022		402	37.1	20.5	1.37
December 2022		435	39.1	22.2	1.89

Results of recarbonation of drinking water at the Kokava nad Rimavicou water source

Operation time	Conductivity	Ca	Mg	Ca + Mg
	[$\mu\text{S cm}^{-1}$]	[mg l^{-1}]		[mmol l^{-1}]
Initial state	111	19.1	3.40	0.61
August 2021	165	25.6	4.9	0.84
September 2021	202	33.7	10.2	1.26
October 2021	197	30.3	8.8	1.12
November 2021	202	33.7	10.2	1.26
December 2021	197	30.3	8.80	1.12
January 2022	202	32.9	14.0	1.39
February 2022	210	33.2	13.2	1.33
March 2022	225	35.6	12.8	1.41
April 2022	259	46.4	12.6	1.61
July 2022	242	44.8	13.2	1.64
October 2022	225	39.6	11.1	1.44
December 2022	229	40.2	12.8	1.53

Basic conditions for the enrichment of drinking water: average daily water consumption:

- 275-300 m³,
- average daily dose of produced and added concentrate: 25-30 m³ day⁻¹,
- mixing ratio of concentrate and water drained from the reservoir: 1 : 9 (1 : 10),
- circulation pump capacity: approximately 10 m³ hour⁻¹,
- average dose of added HBD: 50 kg per week,
- average amount of added CO₂: 230-240 kg per week,
- total volume of water reservoir: 1,300 m³.

During the first three months (July – September 2021), the reactor only operated at approximately 20% capacity due to a hydraulic failure.

- Both reactors work very reliably.
- No maintenance is required.
- HBD needs to be added once a week, CO₂ bottles need to be replaced once every two weeks.
- For economic reasons, the reactors only operate at approximately 40% capacity.
- At 100% capacity, we can increase the Mg content in drinking water in both reactors by 25-30 mg l⁻¹.
- The price for drinking water treatment is approximately €0.1 per m³ of drinking water (before COVID-19), currently the price would not exceed €0.2/m³ of water.
- Is it a lot?
- The price of 1 m³ of drinking water in the Slovak Republic is approximately €1.8.

Rapant, S., Čermák, P., Cvečková, V., Hajduk, I., Kožíšek, F., Stehlíková, B. (2024): The significance of calcium and magnesium content in drinking water for arterial stiffness among residents of the Slovak Republic. Journal of Water and Health Vol 22 No 10, 1874 doi: 10.2166/wh.2024.179

MEASUREMENT OF ARTERIAL STIFFNESS

(Monitoring the positive impact of increased content of Ca and Mg in drinking water on human health)

There are many ways to monitor the content of Ca and Mg in human tissues and fluids and monitor their effects on human health.

They are very demanding:

- collection of biological materials
- expensive analyses
- demanding clinical examinations

We therefore monitor the impact of different Ca and Mg contents on human health using

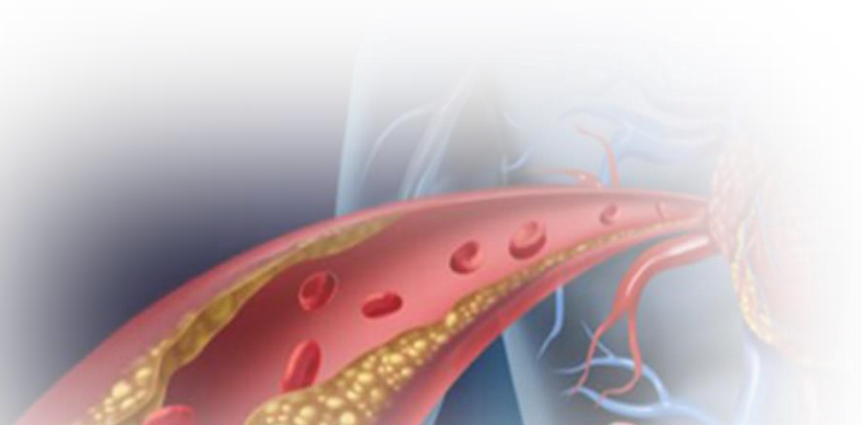
MEASUREMENTS OF ARTERIAL ELASTICITY so cold ARTERIAL STIFFNESS

very cheap and easy method (approx. €30)

Recently, it has been demonstrated in the world literature that AS, in addition to CVD, is also associated with other diagnoses, mainly OD and DM

MOTTO:

**HARD WATER – SOFT ARTERIES
SOFT WATER – HARD ARTERIES**



This compelling dictum was formulated by Schroeder, 1960

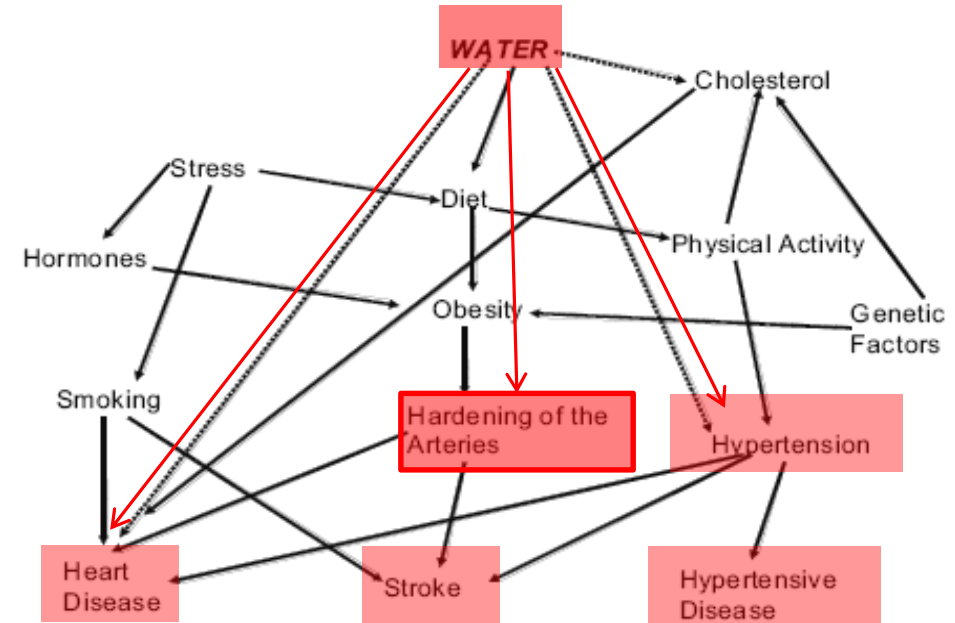
GOAL:

verifying this slogan, that is, whether people who drink soft water have hard (stiff) vessels and people who drink hard water have soft (elastic) vessels and whether there is an improvement in the elasticity of vessels in people who started drinking hard water

Introductory remarks

Main risk factors of CVD:

- Stress,
- Genetic factors,
- Obesity,
- Smoking,
- Unhealthy eating habits,
- **Environmental factors**
(water quality, air quality...)



SOFT WATER

deficit of Ca and Mg in drinking water



HARD VESSELS

sufficient Ca and Mg content in drinking water

Drinking water belongs among significant factors of CVDs, having beside other risk factors (lifestyle, genetic predisposition etc.) causal relationship with risk of **CVDs**.

A significant risk factor for the development of CVDs is the loss of elasticity in arteries, commonly referred to as arterial stiffness (AS). The measurement of AS, as a non-invasive method, has become an important part of the predictive determination of cardiovascular risk in preclinical medicine and diagnostics in the last 30-40 years.

Measurement of arterial stiffness

**Were performed with
arteriograph
developed in Hungary**

(Arteriograph, TensioMed Ltd, Budapest, Hungary)
and patented in over 30 countries.



complete information about measurement can be obtained on website: <https://youtu.be/JgLkLpozZOg>

Methodology of arterial stiffness measurement

- The most common is a direct measurement of aortic pulse wave velocity (PWVao) between 2 arterial sites. PWVao is a measure of the speed of arterial pressure waves travelling along the aortic pathway. It is calculated using mean time difference and the arterial path length between the two recording sites. **Higher arterial pulse wave velocity is indicative of stiffer arteries.**
- Equipment for arterial stiffness measurements: **ARTERIOGRAPH**
- Measurement duration is 15 minutes and is similar to multiple measurement of blood pressure
- Output: documentation of function and elasticity of central aorta and PWVao values

The measured PWVao values are then converted into arterial vascular age values.

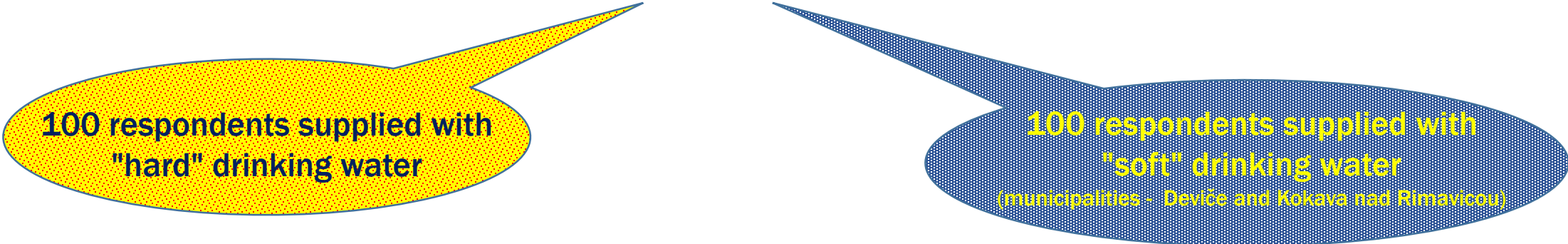
Average arterial age does not correspond to the actual age of an individual, but it reflects the status (age) of arteries. The arterial age can be higher or lower than the actual age of the respondent. The more flexible the walls of the arteries, the lower the PWVao, indicating healthier arteries with an age lower than the physical, i.e., actual age of the measured respondents. In consideration of the age of the measured respondents, we present the results also in terms of Δ age, which represents the difference between arterial and actual age.

Measurement of vascular elasticity was performed in 4 stages

Measurement of arterial stiffness

The project is based on 4 stages of measuring the arterial stiffness

I. STAGE



100 respondents supplied with
"hard" drinking water

100 respondents supplied with
"soft" drinking water
(municipalities - Deviče and Kokava nad Rimavicou)

Goal:

To determine the difference in vascular elasticity between residents who are supplied with "soft" and "hard" drinking water.

Measurement of arterial stiffness

II., III., IV. STAGE

The stages were always implemented at approximately six-month intervals.

100 respondents originally supplied with **"soft" drinking water** in the municipality Devičie and in the municipality Kokava nad Rimavicou, where the drinking water is enriched with Ca and Mg

Goal:

To find out whether the elasticity of arterial stiffness improves in residents who started drinking water enriched with Ca and Mg.

I. Stage measurement of arterial stiffness

Basic characteristics of drinking water in municipalities

„HARD“ WATER (100 respondents)

Municipality	District	Conductivity	Ca	Mg	(Ca + Mg)
		$\mu\text{S cm}^{-1}$	mg l^{-1}	mg l^{-1}	mmol l^{-1}
Dolné Vestenice	Prievidza	598	88.1	27.6	3.33
Trenčianska Turná	Trenčín	429,5	62.4	23.7	2.54
Nenince	Veľký Krtíš	996	82.6	37,5	3.60



Measurement of vascular elasticity only once.

„SOFT“ WATER (100 respondents)

Municipality	District	Conductivity	Ca	Mg	(Ca + Mg)
		$\mu\text{S cm}^{-1}$	mg l^{-1}	mg l^{-1}	mmol l^{-1}
Devičie	Krupina	280	30	10.2	1.15
Kokava nad Rimavicou	Poltár	140	19.1	3.5	0.62



Measurement of vascular elasticity four times.

- the first time before the recarbonization of the drinking water
- three times after the recarbonization (always approximately at six-monthly intervals)

We will expect an improvement in vascular elasticity and arterial age in respondents who drink recarbonized water.

I. STAGE

„Hard“ water

Municipality	Number of respondents	Actual age	Arterial age	PWVao [m s ⁻¹]	Difference arterial – actual age
Nenince	20	42.15	44	8.04	1.85
Dolné Vestenice	20	36.95	38.05	7.65	1.1
Trenčianska Turná	60	39.91	42.65	8.03	2.73
	100	Ø 39.67	Ø 41.56	Ø 7.91	Ø 1,89

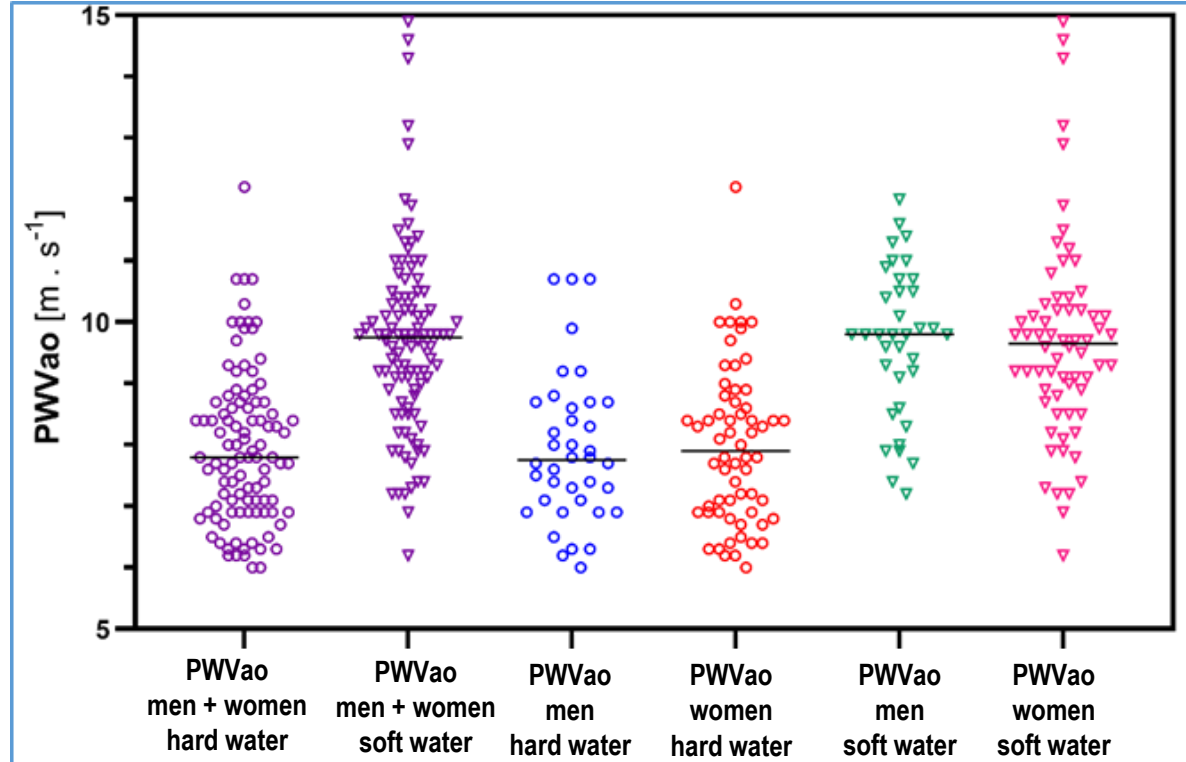
„Soft“ water

Municipality	Number of respondents	Actual age	Arterial age	PWVao [m s ⁻¹]	Difference arterial – actual age
Devičie	49	40.74	65.54	9.81	24.80
Kokava nad Rimavicou	57	52.87	64,60	9,68	9.71
	107	Ø 46.80	Ø 65,17	Ø 9,78	Ø 16,68

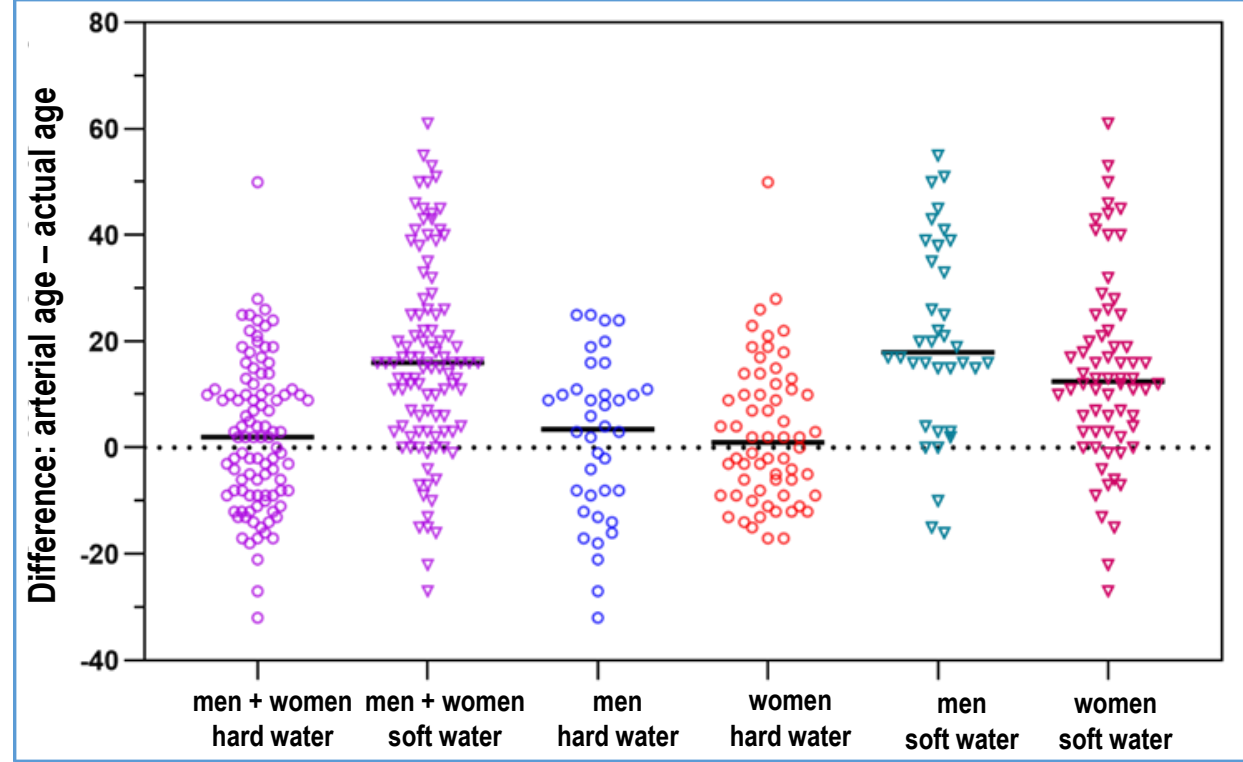
Note: PWVao - the speed of the pulse wave

PWVao comparison and difference (arterial - actual age) between "**soft**" and "**hard**" drinking water

	HARD WATER	SOFT WATER	DIFFERENCES
arterial – actual age	1.89	16,68	14,79
PWVao > 10 m s ⁻¹	7.91	9,78	1,87



PWVao velocity values of residents who live in areas with different Ca and Mg content in drinking water.
The horizontal continuous lines are the mean values



The difference between the arterial age and the actual age of residents who live in areas with different Ca and Mg contents in drinking water.
The horizontal continuous lines are the mean values.

II. – IV. Stage measurement of arterial stiffness

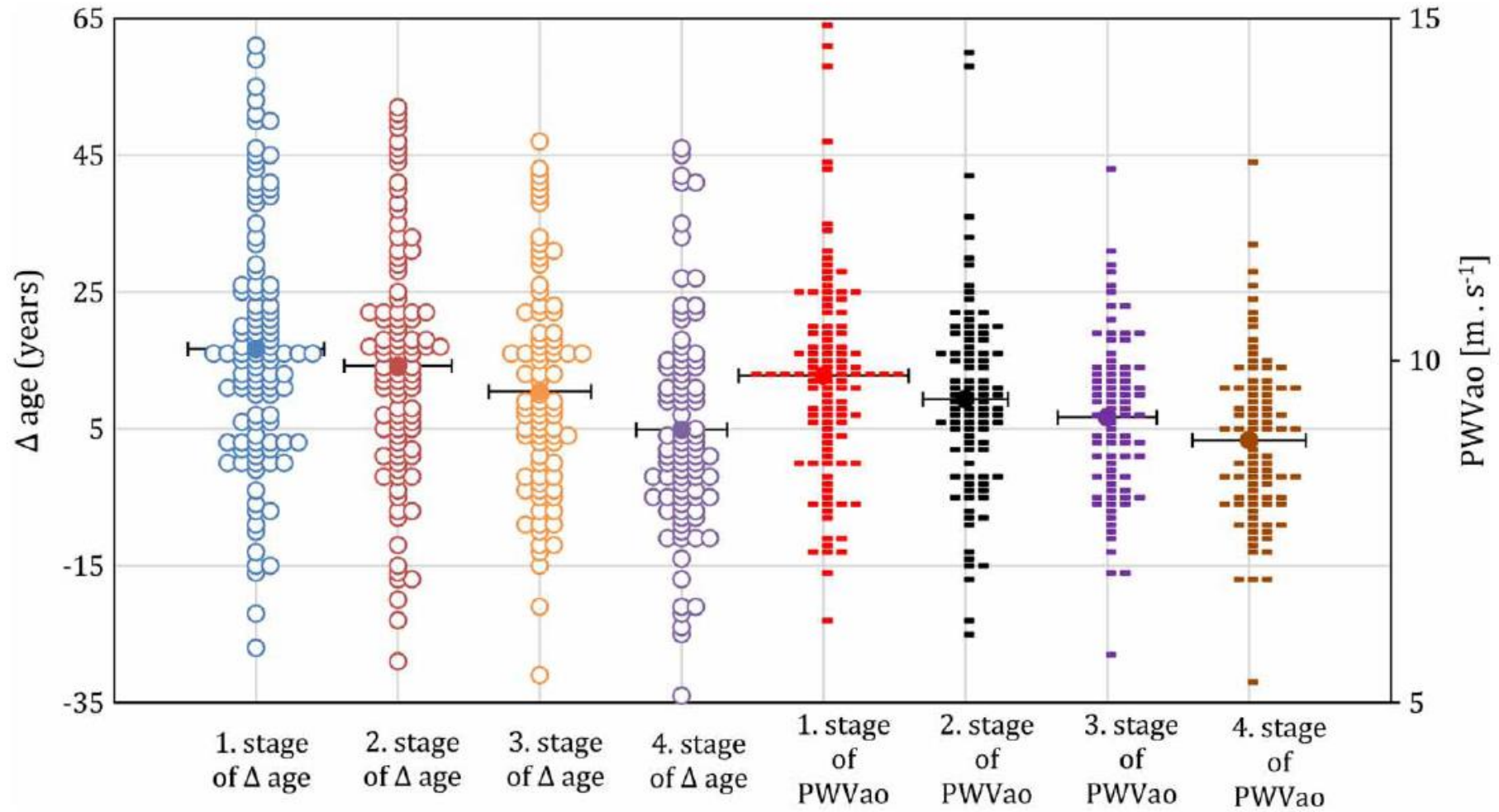
These stages were/will be implemented at approximately six-month intervals after the start of the enrichment of drinking water with Ca and Mg in the villages of Devičie and Kokava nad Rimavicou.

- ☐ It was not always possible to secure the same (original) respondents
- ☐ We present the results in two forms:
 - all respondents (original and replacement)
 - without alternate respondents

Results of the measurement of the AS in four stages of measurement Devičie and Kokava nad Rimavicou

Stages	Without substitute study subjects				With substitute study subjects			
	<i>n</i>	PWVao	Arterial age	Δ age	<i>n</i>	PWVao	Arterial age	Δ age
I stage (May 2021)	107	9.78	65.17	16.68	107	9.78	65.17	16.68
II stage (December 2021)	93	9.44	61.69	14.24	100	9.50	62.47	14.60
III stage (June 2022)	88	9.19	58.91	10.48	98	9.23	59.15	11.35
IV stage (December 2022)	100	8.85	54.75	4.89	114	8.94	55.70	5.13

Note: *n* is the number of respondents, data representing arithmetical mean.



The distribution of $\Delta \text{ age}$ and PWVao among residents for four stages was measured without substitute study subjects.

Statistical analysis between AS parameters and factors that may influence AS

The values of Spearman correlation coefficients (R) indicating statistical dependence (p)

	PWVao	Arterial age	Δ age	BMI	Smoking	Alcohol	Gender	Ca	Mg
PWVao	1	0.99***	0.77***	0.23*	0.03	0.31***	0.00	-0.51***	-0.51***
Arterial age	0.99***	1	0.78***	0.23***	0.03	0.30***	0.00	-0.52***	-0.51***
Δ age	0.77***	0.78***	1	0.06	0.11	0.24***	0.04	-0.28***	-0.28***
BMI	0.23***	0.23***	0.06	1	-0.03	0.09	0.15*	-0.18*	-0.18*
Smoking	0.03	0.03	0.11	-0.03	1	0.33***	-0.02	-0.03	-0.03
Alcohol	0.31	0.03***	0.24***	0.09	0.33***	1	0.02	-0.29***	-0.29***
Gender	0.00	0.00	0.04	0.15	-0.02	0.02	1	0.08	0.08
Ca	-0.51***	-0.52***	-0.28***	-0.18*	-0.03	-0.29***	0.08	1	0.99***
Mg	-0.51***	-0.51***	-0.28***	-0.18*	-0.03	-0.29***	0.08	0.99***	1

Note: * $p < 0.05$ statistically significant, ** $p < 0.01$ highly statistically significant, *** $p < 0.001$ very highly statistically significant.

Based on statistical analysis, the closest relationship ($R = 0.77$ to 0.99 , with $p < 0.001$) was observed between AS parameters (PWVao, arterial age, and Δ age) and the content of Ca and Mg in drinking water ($R = 0.99$, $p < 0.001$). Among AS risk factors, besides the content of Ca and Mg in water, body mass index (BMI), alcohol consumption, and smoking were ascertained through the questionnaire. The highest dependency ($R = -0.51$, $p < 0.001$) was observed between the content of Ca and Mg and PWVao. Similarly, a significant negative correlation was observed between the content of Ca and Mg in drinking water and arterial age ($R = -0.52$, $p < 0.001$) and Δ age ($R = -0.28$, $p < 0.001$), indicating a high statistical dependency between the content of Ca and Mg in drinking water and AS parameters. Among other AS risk factors, a dependency of PWVao, arterial age, and Δ age on alcohol consumption was observed ($R = 0.24$ to 0.31 , $p < 0.001$). A lower dependency was observed between BMI and arterial age ($R = 0.23$, $p < 0.001$) and BMI and PWVao ($R = 0.23$, $p < 0.05$). No statistically significant dependency between AS and smoking was recorded. From the above, it is evident that PWVao, arterial age, and Δ age are most influenced by the content of Ca and Mg in drinking water. No statistically significant relationship according to gender was demonstrated.

Statistical analysis confirmed that the Ca and Mg content in drinking water has a much greater influence on the AS parameters than BMI, smoking and alcohol consumption.

We confirmed the improvement in AS of residents who started drinking water enriched with Ca and Mg by measuring vascular elasticity.

Rapant, Cvečková, V., Fajčíková, K., Igor Hajdúk, I., Hiller, E., Stehlíková, B. (2019): Hard Water, More Elastic Arteries: A Case Study from Krupina District, Slovakia. Int. J. Environ. Res. Public Health, 16, 1521

Rapant, S., Čermák, P., Cvečková, V., Hajduk, I., Kožíšek, F., Stehlíková, B. (2024): The significance of calcium and magnesium content in drinking water for arterial stiffness among residents of the Slovak Republic. Journal of Water and Health Vol 22 No 10, 1874 doi: 10.2166/wh.2024.179

CONCLUSIONS

- Drinking water with low Ca and Mg content is unfavorable for human health
- Drinking water with increased Ca and Mg content is favorable for human health

P.S.

- The impact of Mg on human health is much higher than Ca.
- WHO should include Ca and Mg among the mandatory regulated parameters of drinking water.
- Residents living in silicate geological environments should be informed by local authorities about the increased health risk.
- They should be advised to regularly consume small amounts of mineral water or nutritional supplements.

Thank you for your attention

This work was supported by the project
„Improvement of the health status of the population of the Slovak Republic through drinking water recarbonization“
LIFE – Water and Health (LIFE17 ENV/SK/000036),
and by student grant Comenius University UK/1041/2025.

