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Preliminary communication

Study of water composition in the glass industry

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Abstract

The glass industry uses water in various production steps. Water is mainly used for washing produced glass after cutting, grinding, or after storage in intermediate steps, when the produced glass from one operation waits for a longer period before the next operation, and it can become contaminated. Water quality is key to effective glass washing. In particular, the number of dissolved ions affects the surface properties of glasses and therefore many ions in water are undesirable. Water is also used in steam generators, where the water evaporates and the steam heats, for example, heating cylinders. In this application, it is important that the water does not contain large amounts of dissolved ions that could cause scale formation. The aim of the work is to analyse the water quality from different production steps in an effort to be able to recommend which water is suitable for which production step.

Keywords:

water; glass; automotive

1. Introduction

The glass industry, especially the automotive industry, uses water in various parts of the production and water quality is crucial for maintaining high quality standards of the glass produced, such as windshields. Poor quality water, especially from the point of view of a high volume of ions, can leave marks on the glass and thus affect the usability of the glass in further production. If the water dries in a place where other materials are applied, it may adversely affect their adhesion to the glass. For example, the water may dry at the location where the paint is printed in the next process, additional parts may be applied to it, or it may adversely affect the adhesion between the polyvinyl butyral interlayer and the glass surface.

A windshield is produced in the first step on a float furnace by floating the glass in a tin bath (**Pilkington, 1969**). The glass is then sent to a cutting line, where the glass is cut to the desired shape corresponding to the shape of the windshield. The glass is then ground and washed. The washing may occur in a series of sections, with the beginning sections using recycled water to minimize cost. It is important that the final rinse water be fresh and of consistent water hardness and temperature. Air knives are used to dry the glass at the completion of the washing cycle.

Black print or silver is applied to the glass in the next step, which ensures both aesthetic functions, in the case of black, or heating of the glass in the case of printed silver. Glass with printing, and possibly with silver, is bent in pairs on the furnace in the next step, which is called the bending process where gravity bending technology uses antifriction $CaCO_3$ powder to prevent glass sheets from sticking to one another (**Xu et al., 2019**). Alternatively, if using a press, then it is called the mold bending process (**Moise et al., 1966**), with either one-sided or two-sided glass sheets in pairs, or one after the other. The bending process is chosen according to the design of the resulting windshield. More complex models require the use of the press bending process, where higher quality requirements are achieved. After the kiln, the glass is loaded onto a laminating line, where the inner glass is laminated with the outer glass and an intermediate layer, usually a polyvinyl butyral foil, is inserted between them (**Stas et al., 1993**).

Once the glass is bent, it enters the post process line. The glasses are washed again with water before the interlayer glasses are assembled. The purity of the water in

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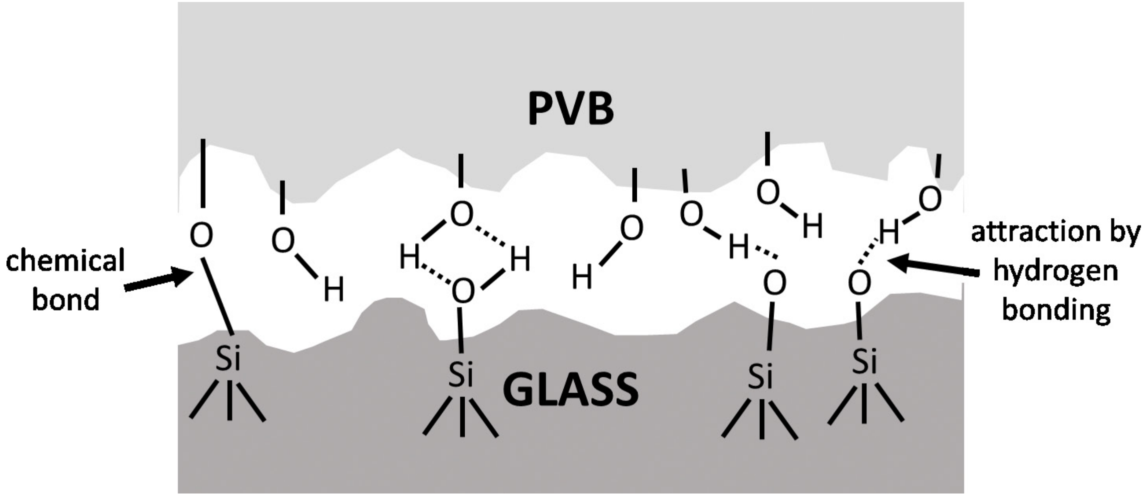

Figure 1: Adhesion mechanism among glass and PVB by hydrogen bonds.

this intermediate step plays a key role in achieving optimal adhesion between the inner glass, the polyvinyl butyral film and the outer glass. Adhesion is achieved by hydrogen bonds between the two materials. The presence of contaminants, say alkali ions, whether on the glass or in the PVB film leads to a deterioration in the adhesion between the glass and the polyvinyl butyral, which in turn can lead to delamination of the laminate. The manufacturer of polyvinyl butyral takes care of the amount of alkali ions so as to ensure perfect adhesion between the film and the glass (**Smith et al., 2009**). Glass manufacturers also pay attention to the purity of the glass, which is mainly affected by the washing process before the glass is folded with polyvinyl butyral foil. The high content of alkali ions leads to a reduction in the adhesion of the glass to the film. It is important that the final rinse water, that contacts the windshield, is fresh and of consistent hardness and temperature. Air knives are used to dry the glass at the completion of the wash cycle. In many cases, the washed glass goes directly from the drying area into the lay-up room conveyed by belt conveyor. Cut polyvinyl butyral sheets are assembled with glass sheets. It is, therefore, extremely important that the glass be completely dry. If residual moisture or water remains on the glass, it can possibly reduce adhesion, and in some cases lead to de-lamination type defects (see **Figure 1**).

The inner and outer glass is pre-pressed with the polyvinyl butyral (PVB) interlayer in a press furnace. The vacuum prelamination process is primarily used for the effective de-airing of strongly complex windshields. The glass enters the autoclave in the next step. Autoclaving is required to dissolve any residual air in the prepress into the PVB. Air moves into the PVB by diffusion that occurs exponentially with temperature and linearly with time and pressure. During the autoclave cycle, the PVB relaxes and flows, filling minor gaps and flowing away from pinches. By the end of the autoclave cycle, the PVB comes in full contact with the glass (**Xu et al., 2019**). The glass is then checked for aspect defects and then it is sent to another operation, where the glass is washed again and additional parts are applied to it, most often by gluing to the glass, for example with polyurethane adhesives (**Agrawal et al., 1996**). Here again, the purity of the glass is key, so that the adhesion between the glass and the adhesive, and therefore the part, is perfect.

The so-called pummel test and the shear test are common approaches to check the adhesion behavior directly. An alternate test method is based on measuring the light transmission of the laminated safety glass. The pummel test is a basic test for evaluating the adhesion of polyvinyl butyral between glass and polyvinyl butyral film (**Xing et al., 2022**). A high value of the so-called pummel value parameter (**Omer, 2019**), means that the adhesion between the glass and the interlayer is too strong and there is a risk that the glass will not fulfill its function in the event of a collision. A low value is also critical from a safety point of view (pummel value 1-3), which means low adhesion between the polyvinyl butyral film and the glass. The low value is caused by a high alkali content on the glass surface or in polyvinyl butyral before the lamination process (**Hunstberger et al., 1981**).

Like the pummel test – the measurement of the adhesion to glass with the compressive shear strength method is not standardized in the glass industry, but in laminated glass this method allows a good linear correlation to the pummel test result in the specified PVB film moisture range. The optimal pummel value is between 3-4, which also means optimal adhesion of glass with PVB. A low pummel value of 0-1 indicates low adhesion between glass and PVB and a value of 6 and above indicates extreme adhesion between glass and PVB. The maximum shear force is measured (in Newtons) until the glass breaks (**Schneider et al., 2001**).

The automotive industry uses different types of glass washing water, which can be divided according to the conductivity given in micro-Siemens per centimeter.

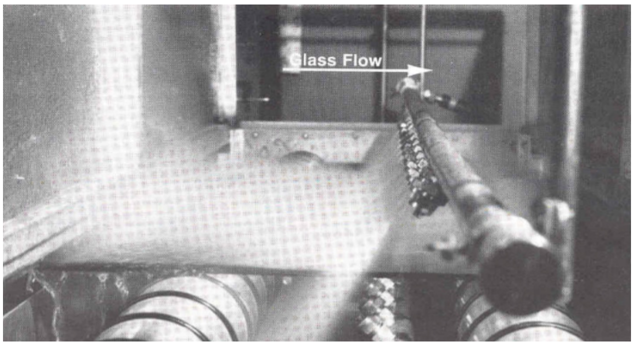

Figure 2: Glass sheet being washed in a washing machine.

Depending on the importance of the production step and the type of washing machine, demineralized water <0.05 µS / cm, distilled 0.3 - 5 µS / cm, drinking water > 50 µS / cm, or utility water > 200 µS / cm is used (**Mareška et al., 2022**). Glass processing plants often have their own water treatment plants using reverse osmosis, ion exchangers and are thus able to turn drinking water into distilled water, which they use to rinse the glass, especially in the washing machine before laminating the windshield. Such a washing machine initially uses a cascade overflow, in the first section the glass is washed by rinsing with water from the dirtiest section of the washing machine, while in the last section where the last glass rinse takes place the glass is washed with distilled water obtained at the station by treating drinking water. The rinse section water quality is extremely important because it is the last liquid to contact the glass before the drying process (see **Figure 2**). The use of water treatment systems such as reverse osmosis or mixed bed deionizer is recommended to provide water of high quality with low mineral content (**Zaidi et al., 2022**). The condition of the glass surface in the automotive industry is usually evaluated according to its surface tension (**Mujic et al., 2011**). Surface tension is measured in mN/m. The higher the surface tension of the material, the better the adhesion of anything mentioned above when fixed to the surface. On the other hand, surface contamination (grease, oil, fingerprints) can be the cause of low surface tension (**Douglas et al., 1964**).

An important parameter of water that affects its further processing is the so-called water hardness. Water hardness is a property that expresses the content of dissolved minerals (most often CaO and MgO) in water (**Khoshzaher et al., 2023**). Water hardness is important for its use as drinking and utility water. It is a source of water and scale formation and affects the taste properties of water. It can be permanent and temporary. Hard water leaves marks on the glass after washing, which can negatively affect the adhesion of materials that stick to the glass (**Pavlovič et al., 2021**).

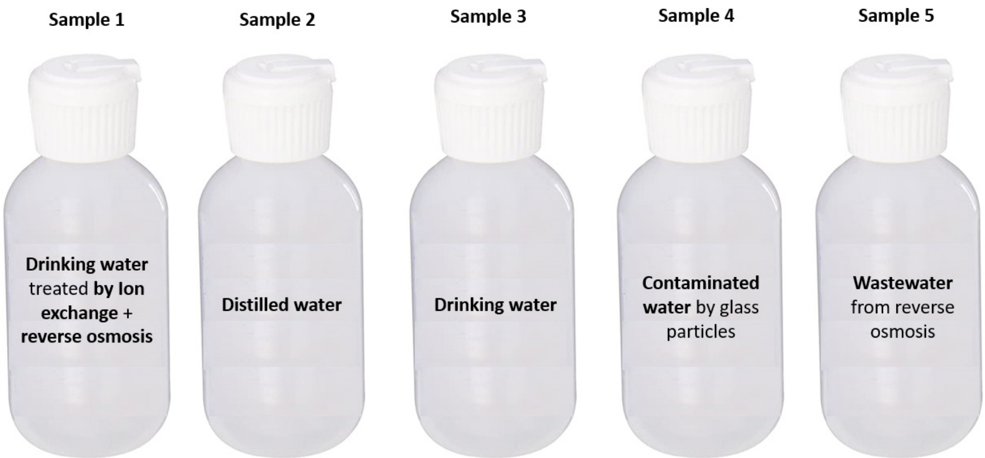

Figure 3: Collected samples for the analysis by atomic absorption spectroscopy.

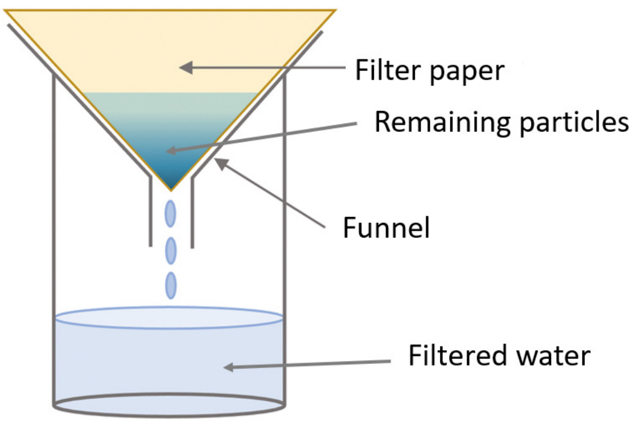

Figure 4: Filtration of water samples.

2. Methods

Water samples are taken from a specific glass treatment process, and they are collected in polypropylene bottles. Sample 1 is drinking water that has been treated with ion exchangers and reverse osmosis. Sample 2 is distilled water, sample 3 is drinking water, sample 4 is contaminated with glass particles, it is wastewater from the glass washing process, sample 5 is wastewater from reverse osmosis (see **Figure 3**).

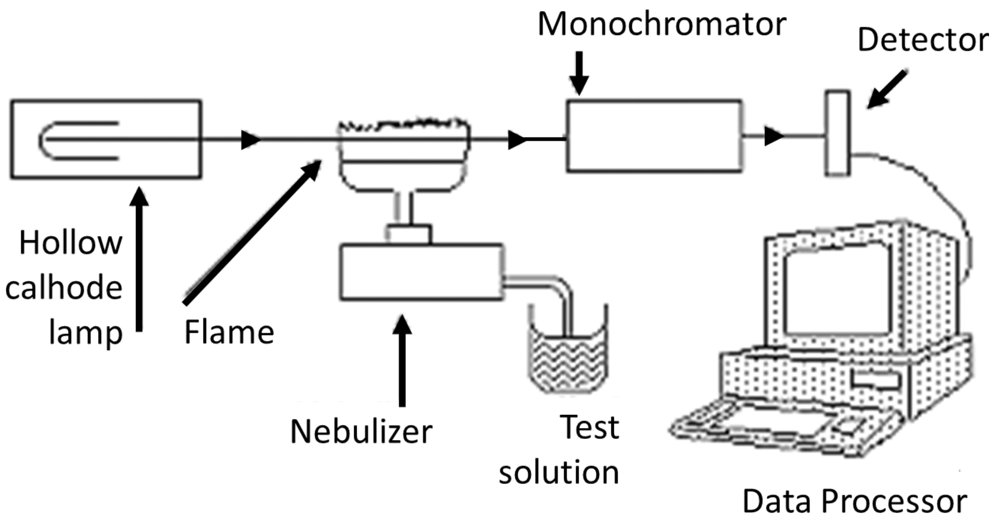

Figure 5: Scheme of atomic absorption spectroscopy.

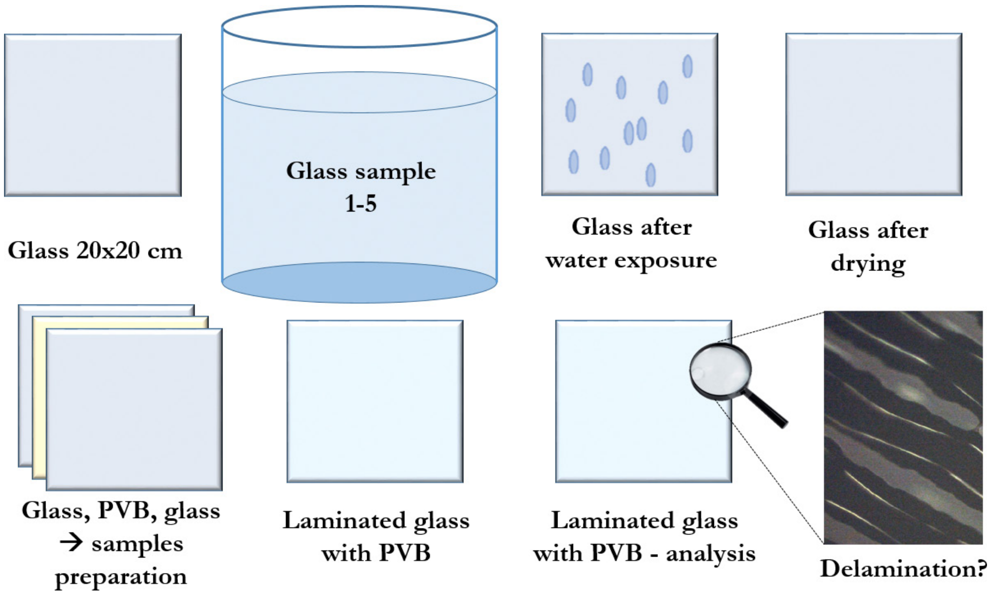

Figure 6: Scheme of the analysis – glass exposed by water samples.

The water samples are then filtered using a funnel, beaker, and filter paper (see **Figure 4**) (**Medved et al., 2023**).

The filtered water is analysed by atomic absorption spectroscopy (AAS). The AAS method follows Beer's law, which defines a direct proportionality between absorbance and element concentration (**Wurts, 1993**). AAS consists of a light source, cuvette, monochromator, and detector (see **Figure 5**). AAS is a method suitable for the detection of metal ions present in water samples. After the sample is sucked into a flame that contains atoms of the given element, the sample is atomized. In this process, the elements are atomized with the help of a flame (**Clesceri et al., 1998**). Atoms absorb radiation of a specific wavelength produced by a source, which is a hollow cathode lamp of a given specific metal. The wavelength of the radiation emitted by the source is like the wavelength absorbed by the atoms in the flame (**Christian, 2007**).

The results from the atomic absorption analysis are compared and the recommended water for each process is determined. Glass samples of 20x20 cm are prepared in the next step by cutting float glass. The glass samples are washed only from samples 1 to 5 and then dried in an oven at 100°C for 10 minutes. Cut samples of float glass measuring 20x20 cm are laminated with polyvinyl butyral foil using a Termolis REA 23x30 cm laminating machine. The samples are laminated for 15 minutes at 130°C for 5 minutes. The resulting samples are compared in terms of the occurrence of lamination defects (see **Figure 6**).

Delaminated samples are measured by Raman spectroscopy to determine if there are any visible impurities at the delamination site. The Raman dispersion spectro-

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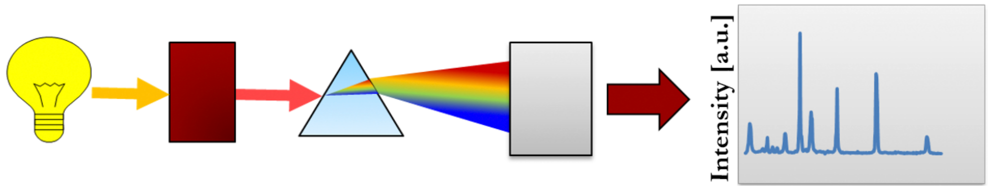

Figure 7: Scheme of the analysis – Raman spectroscopy.

photometer measures Raman spectra using confocal microscopy. An Nd: YAG laser with a wavelength of 532 nm with a power input of 10 mW is used as the radiation source. A grid with 900 scratches per mm is used for measurement. A thermoelectrically cooled CCD camera serves as a detector. The samples are focused 5x-100x with a measuring path of 1 μm^2. The samples using a 50 μm scratch are measured. Thermal degradation is eliminated with the use of 8 mW of power. It is measured for 30 s with 20 accumulations of spectrum (see **Figure 7**).

3. Results and discussion

The various effluents from the glass process are freed of solids by filtration and subsequently analysed by atomic absorption spectroscopy. The aim of the discussion is to design suitable water for different parts of the process (see **Figure 3**). **Table 1** shows the results of atomic absorption spectroscopy for 5 different water samples.

According to **Table 1** and **Figure** 8, the largest number of dissolved ions is contained in sample 5 - reverse osmosis waste. A total of 127.96 mg/l of dissolved ions is detected in sample 5 by atomic absorption spectroscopy. The second largest proportion of ions is detected in sample 4, which is wastewater from the washing machine, the number of solutes 66.21 mg/l. Less ions 40.19 mg/l are contained in sample 3, which is drinking water. The type of the lowest proportion of ions is analysed in a sample of distilled water, namely 4.71 mg/l. The smallest number of ions is detected in the case of a sample of 2.31 mg/l of solutes, which is a sample of drinking water, which is purified by means of ion exchangers and reverse osmosis. The more ions the water contains, the more dissolved substances there are in the water. A high content of dissolved ions then has a negative effect on the adhesion between glass and PVB. Dissolved ions in the water interact with the surface of the glass and PVB, occupying OH- groups that serve to ensure adhesion between the PVB and the glass (**Tupý et al., 2012**).

Table 1: Chemical analysis by atomic absorption spectroscopy for water samples 1-5

	Concentration of element [mg/l]										
Number of sample	**Na**	**Zn**	**Cu**	**Si**	**K**	**Mg**	**Li**	**Bi**	**Sn**	**Ca**	**Sum**
1	1.25	0.03	< 0.01	< 0.70	0.27	0.06	< 0.01	< 0.10	< 0.40	0.7	2.31
2	1.28	0.02	< 0.01	< 0.80	0.19	0.09	< 0.01	< 0.10	< 0.40	3.13	4.71
3	4.59	0.05	< 0.01	1.6	1.52	3.31	1.52	< 0.10	< 0.40	27.6	40.19
4	2.03	0.02	< 0.01	0.9	0.26	0.3	< 0.01	< 0.10	< 0.40	62.7	66.21
5	13.8	0.02	< 0.01	4.5	4.42	11.7	4.42	< 0.10	< 0.40	89.1	127.96

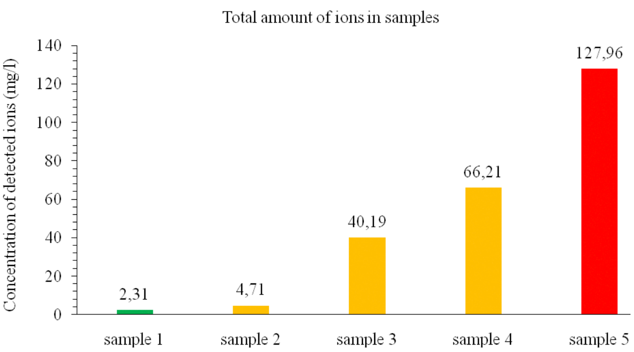

Figure 8: Total amount of detected ions in samples 1-5.

In **Figure 9** the total amount of dissolved inorganic ions is compared in different samples. It is observed that the highest number of dissolved ions in water, specifically 89.10 mg/l, is Ca^{2+}, followed by Na^{+} (13.80 mg/l) and Mg^{2+} ions (11.70 mg/l). There is also a significant amount of K^{+} (4.42 mg/l), SiO_4^{4-} (4.50 mg/l) and Li^{+} (4.42 mg/l) ions in the water. Calcium ions are found in water due to the dissolution of calcium carbonate. Calcium carbonate is used as an antifriction powder to dust the glass before the bending process in the gravity furnace. The glasses do not tend to slide on each other and will not be damaged. Calcium carbonate dissolves poor-

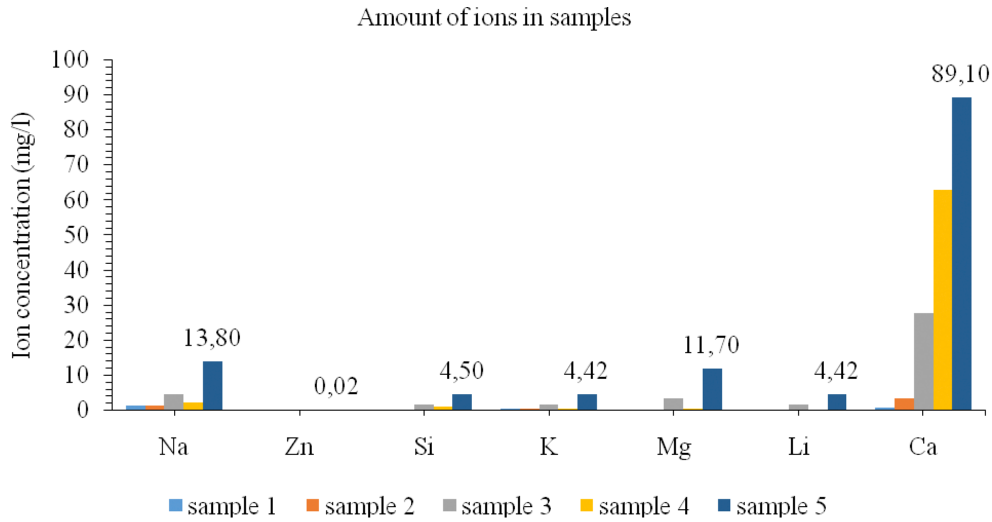

Figure 9: Types of ions in different samples 1-5.

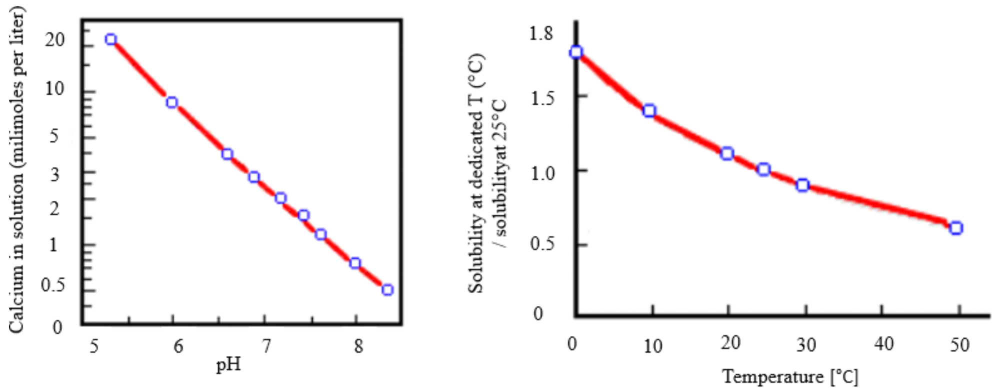

Figure 10: The solubility of calcium carbonate with pH and with temperature.

ly in water. Its solubility in water is temperature and pH dependent. It dissolves according to the equation: $CaCO_3$ (s) + CO_2 (g) + H_2O ↔ Ca^{2+} (aq) + 2 HCO_3^- (aq). As for the magnesium ions, they come from the glass from where they diffuse into the aqueous solution. Ca^{2+} and Mg^{2+} ions are referred to as low mobility ions. These ions are added to the glass in the form of compounds, namely limestone ($CaCO_3$) or dolomite ($(Ca(Mg)CO_3)_2$). The main purpose of these substances is to reduce the viscosity of the enamel and thereby facilitate the workability of the glass, the so-called flux. However, the positive influence of alkaline earths has not yet been proven, and in several works it is discussed that Ca^{2+} and Mg^{2+} ions are similarly mobile as alkali in the hydrated layer in atmospheric conditions. SiO_2 is the primary network-forming oxide. Alkaline oxides such as Na_2O, K_2O, Li_2O are so-called silica network modifiers and are responsible for breaking Si-O-Si bonds. Ions diffuse from the glass into the aqueous medium, thereby increasing the concentration of the substances in the aqueous solution (**Zanini et al., 2023**).

The solubility of calcium carbonate decreases with an increase in pH and decreases with an increase in temperature that is visible in **Figure 10** (**Hart et al., 2012**).

Figure 11 summarizes and compares the occurrence of calcium ions (Ca^{2+}) in individual samples. Calcium ions, Ca^{2+}, which come mainly from antifriction powder, which is used in bending glass in a furnace are the most common ions in the analysed samples. These ions are also found in the surface of the glass, from which they can be leached by ion exchange. A comparison of the amount of Ca^{2+} ions in individual water samples is described in **Figure 12**. In samples that did not meet glass, there is a small amount of Ca^{2+} ions (samples 1, 2, <3.13 mg/l). Sample 3 is untreated drinking water, which already contains a higher amount of Ca^{2+} ions, 27.6 ml/g. Samples 4 and 5 that met the glass contain more than 62.70 mg/l of dissolved Ca^{2+} ions. Sample number 4 contains 62.70 mg/l and sample number 5 contains 89.10 mg/l of Ca^{2+} ions. Samples 4 and 5 were in intensive contact with glass that was washed after the bending process. For this reason, there was a large amount of anti-friction powder in the water, which partially dissolved at a given temperature of 50°C and at a given pH=7. The water thus became saturated with Ca^{2+} ions. The water therefore becomes more saturated with ions, and it is debatable whether it can be reused in any glass processing step (**Mannina et al., 2022**).

In terms of Na^+ content (see **Figure 12**), the highest amount is in sample 5 (13.80 mg/l) followed by the sample 3 (4.59 mg/ml). Sodium is found in water by leaching from the glass surface. The smallest amount of Na^+ is found in sample 1 (1.25 mg/ml), which was treated with an ion exchanger and reverse osmosis. Sodium ions are leached from the glass into the water by an interdiffusion mechanism, where Na^+ ions diffuse from the glass and H_3O^+ ions from the water diffuse into the glass. This is one of the mechanisms of glass corrosion. The leached sodium ions from the glass are subsequently found in the aqueous solution, which increases the amount of sodium ions in the aqueous solution and saturates the water with ions, reducing the probability of possible water reuse in the glass processing process. Sample 5, which is reverse osmosis waste, contains the most sodium ions. The second highest sodium ion content is contained in the drinking water sample number 4. The composition of drinking water varies from place to place, and it can be determined by the efficiency of the water purification process, the condition of the pipes, etc. (**Naseem et al., 2022**).

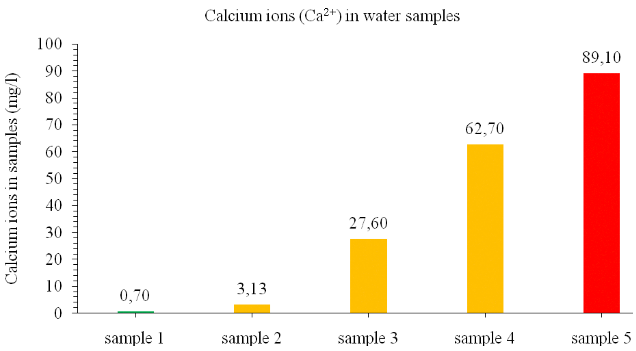

Figure 11: Calcium ions (Ca^{2+}) in different samples 1-5.

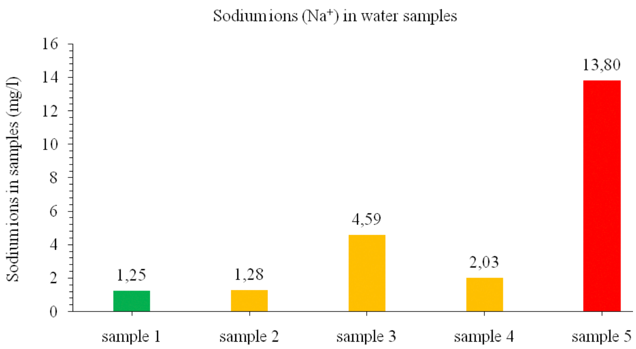

Figure 12: Sodium ions (Na^+) in different samples 1-5.

The amount of dissolved SiO_4^{4-} (see **Figure 13**) in water shows similar results, which confirms the theory of the leaching of Na^+ ions from the glass. The largest amount of these ions is again in sample 5 (4.5 mg/l) and sample 3 (1.60 mg/l). The smallest amount occurs in samples 1 and 2, which did not encounter the glass. It has been investigated that when using glass, flakes of different composition are formed. The composition of the flakes is determined by the composition of the glass. The formation of flakes is influenced not only by the temperature, but also by the pH of the leaching solution (**Lee et al., 2023**).

Water samples are prepared and analyzed according to the procedure described in a previous section (see **Table 2**) and in **Figure 6**. Samples 1-4 are without visible delamination. Delamination is observed for sample 5. Sample 5 is further analyzed by Raman spectroscopy analysis.

Sample 5, which is washed in reverse osmosis wastewater, was analyzed after lamination using Raman spectroscopy at the defect site and outside the defect area to confirm the cause of the contamination. No foreign particles or clearly visible impurities are detected at the site of the contamination. The probable cause of delamination is imperfect adhesion between the PVB and the glass due to the presence of ions from the water in which the glass was washed before analysis (see **Figure 14**).

In **Figures 15** and **16** different areas are compared with clear delamination and without delamination. The

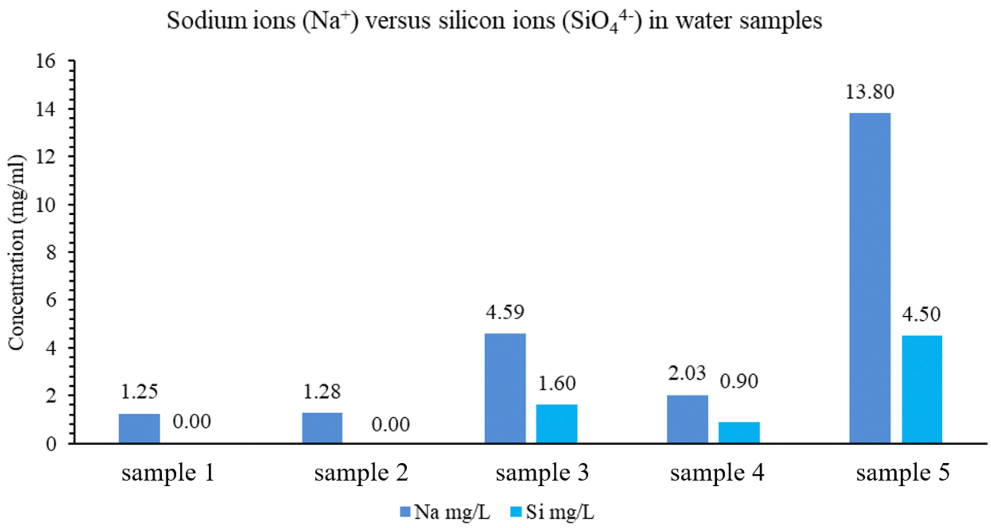

Figure 13: Silicon ions (SiO_4^{4-}) in different samples 1-5.

Table 2: Results of glass laminated samples from a delamination point of view

Water sample	Delamination
1	NO
2	NO
3	NO
4	NO
5	YES

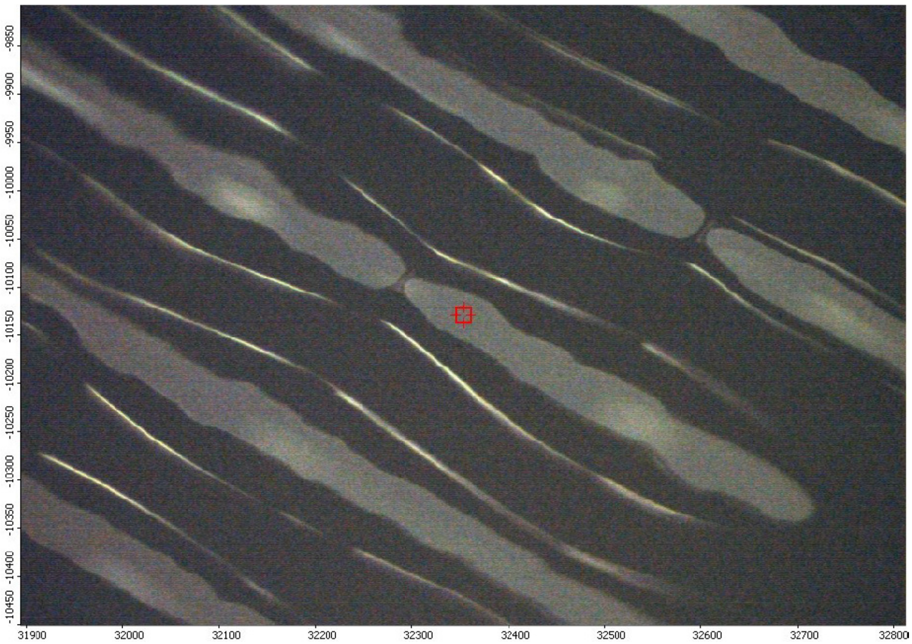

Figure 14: Picture from Raman Spectroscopy of sample 5 – area of delamination.

aim is to compare the chemical composition to confirm that the delamination is due to imperfect adhesion between the PVB interlayer and the glass due to exposure to water containing high ions. The red line corresponds to the delamination point between the PVB and the glass. The blue line corresponds to the place of perfect adhesion of PVB with glass. Both figures come from the same glass – sample 5.

Our proposal is to use water sample 1 or sample 2 only for the last rinse in the washing machines. Sample 1, which is water that is purified using ion exchange and reverse osmosis, contains the lowest number of ions and is suitable for rinsing the glass just before it comes into direct contact with the PVB film.

Drinking water, which is sample number 3, is proposed to be used in all parts of the process, thus saving energy costs associated with water production using reverse osmosis or ion exchange. In addition, waste from these processes can have a negative effect on the ecosystem. However, it is important to monitor the quality of the drinking water to confirm that it is stable, and we were able to establish the level of the amount of ions in the water for which the composition of the water does not yet have a negative effect on lamination. Therefore, it is necessary to carry out lamination tests and verify in time the satisfactory result of the lamination tests.

Sample number 4, which is the wastewater from the washing machine before laminating the glass with PVB, is recommended to be cycled in the washing machine for a longer period. This will reduce water consumption in the washing machine, as the glass producer will not have to add water to the washing machine as often. We recommend determining the concentration of ions in the water that do not have a negative effect on the lamination and until then cycle the water in the washing machine, which will drastically reduce water consumption.

The waste product of reverse osmosis is the so-called brine, which is extremely salty water (in our case, sample 5). For every litre of desalinated water, there is about 1.5 litres of brine. It is most often discharged back into the sea, as it has no industrial use. The resulting salty solution is the biggest problem with reverse osmosis. Every day, approximately 142 billion litres of this salty solution are returned to the seas, which can also contain other harmful substances, such as heavy metals and various chemicals after the entire process. There are already several studies showing the negative effect of the mixture on the ecosystem and on organisms in the oceans and seas. Another problem is that the brine is generated unevenly, with around 70 % being discharged into the seas from North Africa and the Middle East (**Missimer et al., 2018**). We suggest using reverse osmosis wastewater (such as the water used in sample 5) in washing machines that wash glass after lamination. This water is not suitable in the washing machine before lamination,

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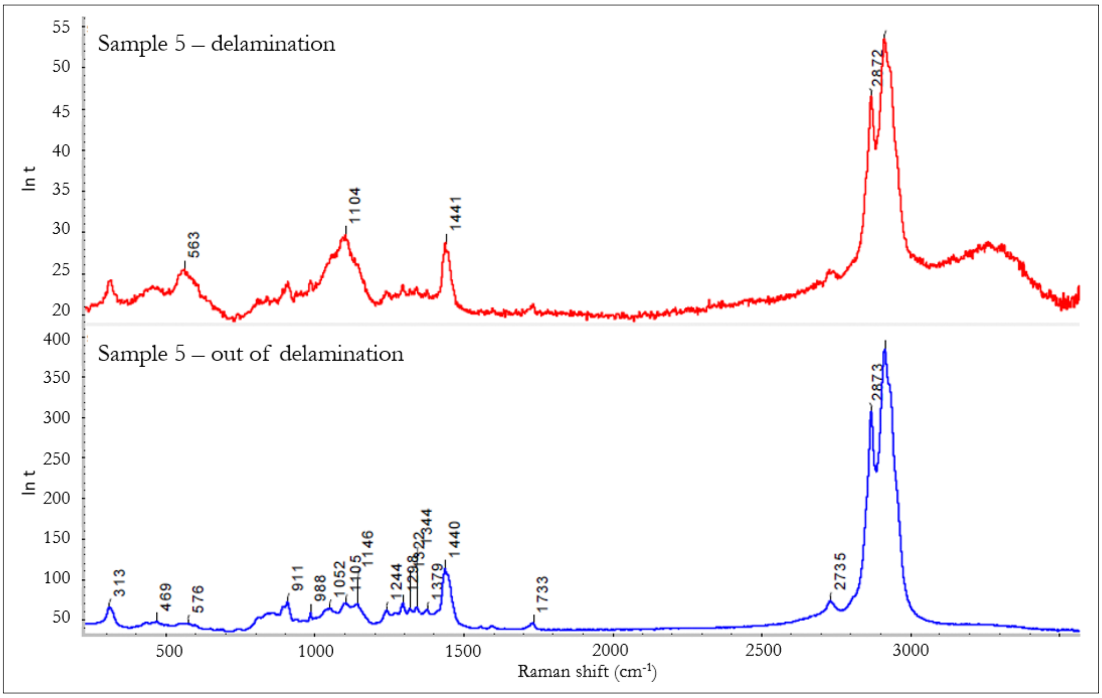

Figure 15: Difference in spectras in delaminated area and non-delaminated area.

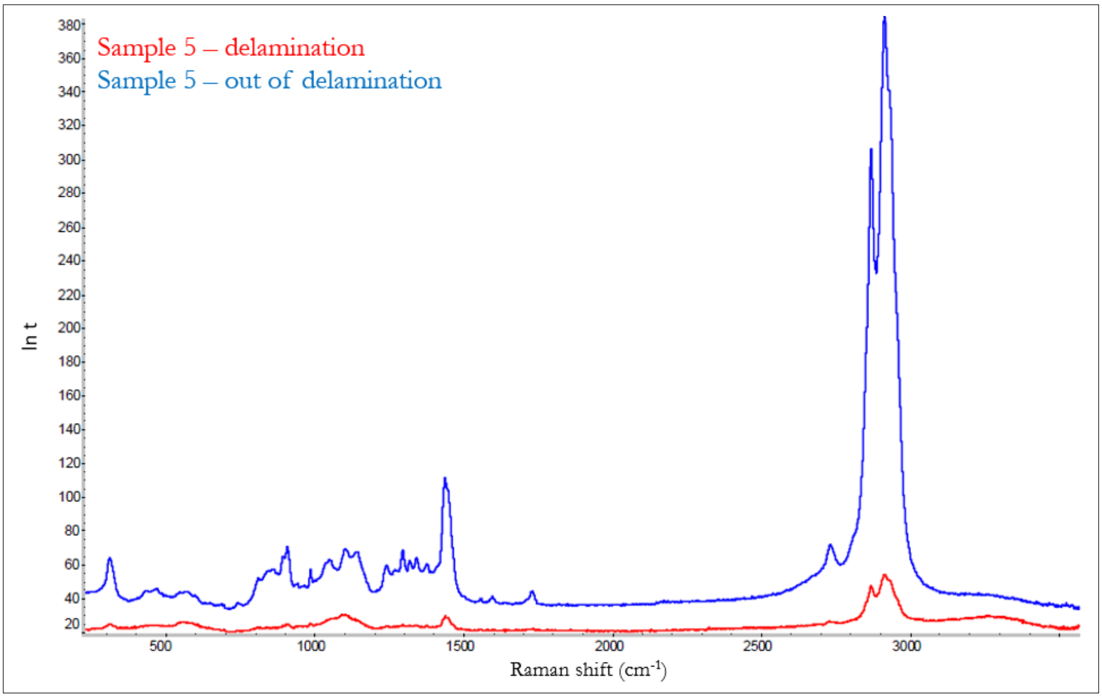

Figure 16: Difference in spectras in delaminated area and non-delaminated area (scope 1:1).

as it causes delamination of the samples. After lamination, however, the water can be used for washing laminated glass.

4. Conclusions

Various water samples from industrial glass processing were analysed to reuse these waters to save process costs and the environment. Possible usable waters are discussed. Samples of treated drinking water and commercially distilled treated water meet all quality requirements for glass washing. The untreated drinking water sample contains a higher number of ions in comparison with distilled water and treated water, but it can still be a usable water source to clean the glass. If drinking water contains a low number of dissolved ions, this water can be used for the last rinsing in the washing machine. If drinking water contain a high number of dissolved ions, this water can be used in the prewashing part of the machine in the first sections of the washing machines in case distilled or treated drinking water is used in the following sections of the washing machine. Reverse osmosis wastewater is unusable for glass rinsing because it contains a high proportion of dissolved ions. Our assumption is confirmed by glass lamination trials, when glass is exposed directly to different water samples and then they are laminated and analysed. The water that was removed from the washing machine before lamination is also useful for washing glass. This is proved by a lamination test. The article presents theoretical possibilities for saving water in the automotive industry dealing with the production of glass for cars. This is an option to reduce water consumption in washing machines.

Climate change, together with an increasing demand due to population growth, emphasizes how scarce freshwater resources are worldwide and how important it is to conserve water (**Salehi et al., 2022**). The problem is the lack of water in many regions. Water companies must constantly deal with water shortages. They address this in several ways, including by providing an alternative source of water, augmenting the water supply during periods of drought, and providing bulk water supplies (**Rudolph, 2020**). The ever-increasing demand for water, combined with deteriorating water supply infrastructure and overexploited water resources, threatens water security worldwide. A promising approach to mitigating this threat is the wider implementation of water reuse (**Leverenz et al., 2011**). However, water reuse is often a demanding engineering job requiring sophisticated solutions and thorough analyses adapted to local conditions (**Jiménez-Cisneros et al., 2011**). Water reuse provides a unique opportunity to augment traditional water supplies (**Giakoumis et al., 2020**). The literature mentions the reuse of wastewater from various industries, but not so much on the reuse of water from the glass industry. There can be several reasons, on the one hand, the glass industry is not the main polluter of water in the world (**Babuji et al., 2023**), and on the other hand, the reuse of this water without further purification of the water in wastewater treatment plants is perceived negatively due to concerns about the remaining glass particles in the given water (**Sun et al., 2011**).

We recommend using sample 5, the sample with the highest number of dissolved ions, in the washing machine after lamination with PVB glass. This water sample evidently reduces the adhesion between glass and PVB and causes delamination of the laminate, therefore this water cannot be used in the dishwasher before laminating PVB with glass. Water can be used, and we recommend using it in a certain ratio with water, which is mainly represented by samples 1, 2 and 3. We expect a reduction in water consumption and a reduction in energy consumption, and we can also reuse a waste product that would otherwise end up in the sea, for example.

We recommend reusing sample 4 water in the washing machine before laminating PVB with glass. We recommend determining the maximum concentration of dissolved substances in the water in the washing machine before layering so that delamination of PVB and glass does not occur. Subsequently, we recommend recycling the water in the washing machine through the pipe system and using the water several times before the industrial engineer finally leads it into the waste. The number of cycles must be determined depending on the maximum permissible concentration due to the quality of the laminate. We expect a reduction in water consumption and a reduction in energy consumption. The resulting energy and water consumption depends on how many times the industrialist can recycle the water in the washing machine.

Sample 3, which is drinking water, is recommended to be used in all washing machines during the glass processing process and thus replace the more expensive and energy-intensive production of distilled water or water treated by reverse osmosis.

Samples 1 and 2, which are treated water samples, are recommended to be used only for the last rinse of the glass in the washing machine.

The article confirms the initial hypothesis, namely that water can be reused in production. Out of the five tested samples, four samples met the required quality, which was proven by lamination of the samples and their subsequent analysis using Raman spectroscopy. Meanwhile we also tried to suggest a use for sample number 5, which did not meet the standards of the lamination tests.

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SAŽETAK

Proučavanje sastava vode u industriji stakla

Industrija stakla iskorištava vodu u različitim fazama proizvodnje. Voda se uglavnom koristi za pranje proizvedenoga stakla nakon rezanja, brušenja ili nakon skladištenja u međukoracima, kada proizvedeno staklo iz jedne operacije čeka duže vrijeme za sljedeću operaciju te se može onečistiti. Kvaliteta vode ključna je za učinkovito pranje stakla. Konkretno, broj otopljenih iona utječe na površinska svojstva stakla i stoga su mnogi ioni u vodi nepoželjni. Voda se također koristi u generatorima pare, gdje voda isparava, a para zagrijava, primjerice, cilindre za grijanje. U ovoj primjeni važno je da voda ne sadržava velike količine otopljenih iona koji bi mogli uzrokovati stvaranje kamenca. U radu se analizira kvaliteta vode iz različitih koraka proizvodnje kako bi se mogla preporučiti koja je voda prikladna za koji korak proizvodnje.

Ključne riječi:
voda, staklo, automobili

Authors' contribution

Aleš Mareška performed basic research and drafted the article. **Tereza Kordová** performed the measurements in the laboratory. **Martin Havlík Míka** reviewed the article and verified the data.