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TAP WATER PURIFICATION USING PITCHER FILTERS

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Abstract
Due to the high risk of exposure to various contaminants in drinking water, pitcher filtration is rapidly growing in popularity worldwide as a cheap and easy method to remove pollutants from drinking water. On the other hand, an evaluation of the real-time performance of pitchers is not possible for usual consumers. This study presents the performance of pitcher filtration in the removal of copper, chlorine, and chloroform from tap drinking water. Pitchers were packed with Aquaphor cartridges JS500, A5, and B25. Experiments were performed with model solutions, which were prepared from hard drinking water (7.5 mval/L, pH=7) spiked with copper, hypochlorite sodium, and chloroform. It was found that pitcher filtration is a very effective method for the removal of pollutants such as heavy metals, chlorine, and disinfectants by-products. The concentration of copper, chlorine, and chloroform in filtrates did not exceed the maximum admissible values. Cartridges JS500, A5, and B25 reduced chlorine at a comparable level – almost 100%. During the whole experimental period, removal of chloroform was slightly better for JS500 (100%) and A5 (100%) cartridges than for B25 (91.4–97.7%).

Keywords: **Chlorine; chloroform; Drinking water; Heavy metals; Pitcher filtration.**

1. INTRODUCTION

In recent years, the demand for high-quality drinking water has increased. It applies to both tap water supplied by the water supply network, but also bottled water. Consumers pay attention not only to the organoleptic characteristics of water, i.e., its taste and odor, as well as organic and inorganic micropollutants usually present in trace amounts [1].

Due to contamination of drinking water sources (e.g., groundwater, river water, lake water) by wastewater or agriculture runoff, tap water organic can contain organic micropollutants such as pesticides, pharmaceuticals, and personal care products [2].Organic micropollutants are not fully eliminated by water treatment facilities due to periodical higher contamination of drinking water sources, use of insufficient technology, or seasonal and climate changes [3]. Another organic harmful contamination of potable water are trihalomethanes, which are disinfection by-products, especially for drinking water source with a high content of natural organic matter (NOM), and chlorination is used as a disinfection method [4]. Chlorination is the most popular disinfection method due to its simplicity and low price [5]. Chaukura et al.[6] evidenced 700 disinfection by-products (DBPs) in drinking water. Among DBPs, trihalomethanes (THMs) are the largest group of DBPs, typically represent by chloroform ($ChCl_3$) [7]. Different worldwide reports showed that the concentration of THMs exceeded the maximum permissible value causing adverse effects on human health [8–10].

The origin of inorganic substances (e.g., heavy metals) in tap water can be similar to that of organic pollutants (wastewater discharge and agriculture runoff to drinking water source), in addition, some metals can be released from the pipes transporting water from the treatment plant to the tap [11, 12].

Even though the quality of drinking water is strictly controlled and the content of individual substances in it cannot exceed the values specified in the Regulation of

Table 1.
Characteristic of cartridges

Cartridge	Performance	Filling	Shape	Intended use
JS500	500 L	Fibrous sorption materials with activated carbon and a microfiltration membrane	One-chamber oblong	Removal of pollutants with size>0,1 μm, including chlorine, organic compounds, heavy metals, phenols, and bacteria
A5	350 L	Sorbent	One-chamber oblong	Elimination of chlorine, phenols, pesticides, heavy metals, and water softening
B25	200 L	Ion exchange resin and activated carbon, Aqualenfiber	Oval single-chamber	Improvement of taste, smell, and color of water, water softening

the Minister of Health on the quality of water intended for human consumption [13],violations of drinking water quality are widespread. They include exceedances of the maximum admissible concentration of pollutants, failure to perform regular monitoring of potable water quality, and failure to inform consumers about the insufficient quality of drinking water. The total number of violations in 2019 in the United States was 4650 [14]. Such a situation causes consumers to have doubts about the quality and safety of the supplied water. Even low concentrations of pesticides, pharmaceuticals, trihalomethanes, and heavy metals are of concern to people.

Exposure to these substances occurs not only through drinking contaminated water but also through skin contact or inhalation of aerosols, which occurs when using outdoor swimming pools or swimming pools [15, 16]. Therefore, in fact, total human exposure to pollutants occurring in the water environment (water supply, swimming pool, surface, and others) is intensified, and therefore the number of pollutants in individual elements should be minimized.

An effective solution for an improvement of the quality of water at home is the use of pitcher filtration [17–19]. Filter manufacturers declare that depending on the type of filter, the taste, and smell of water can be improved and some pollutants such as chlorine, pesticides and heavy metals can be removed. There are many types of filters on the market from brands such as Aquaphor, Brita and Dafi, and others. While pitcher filters are well-known, highly commercialized, and cost-effective, they offer little in the way of real-time performance monitoring. A number of studies related to the performance of pitcher filtration for drinking water treatment are also missing.

Therefore, the significance of this study was to evaluate the performance of pitcher filters in removal from tap drinking water the most serious and typical pollutants such as copper, chlorine, and chloroform Copper was selected as a representant of secondary contamination of drinking water by heavy metals (due to release from pipes), chloroform represents a group of disinfection by-products and chlorine as a very common compound whose concentration can be periodically exceeded for sanitation safe. All these compounds are toxic and can cause an adverse effects on human health. Additionally, filtration speed was also evaluated as this is an important factor influencing usability of pitchers.

Table 2.
Characteristics of feed solutions

Parameter	S1	S2	S3
Water hardness, mval/L	7.5	7.5	7.5
Colour, mg Pt/L	6.0	6.0	6.0
pH	7.0	7.0	7.0
Copper, mg/L	3.0	<LOD	<LOD
Free chlorine, mg/L	0.0	1.1	0.0
Chloroform, µg/L	<LOD	<LOD	100.0

2. MATERIALS AND METHODS

2.1. Pitcher filters

Three commercially available Aquaphor® filter cartridges (i.e., JS500, A5, and B25) were obtained from local merchants. Each filter cartridge was mounted in the dedicated for that cartridge's pitcher filters of Aquaphor. The characteristics of the filter cartridges are presented in Table 1.

2.2. Model feedsolutions

To evaluate the efficiency of pitcher filtration in the removal of copper, chlorine, and chloroform, three different feed solutions were prepared (i.e., S1, S2, and S3). S1, S2, and S3 solutions were prepared by adding to the tap water (Gliwice, Poland, hard water) the proper amount of copper standard solution, sodium hypochlorite and chloroform standard solution, respectively. Characteristics of model feed solutions are presented in Table 2.

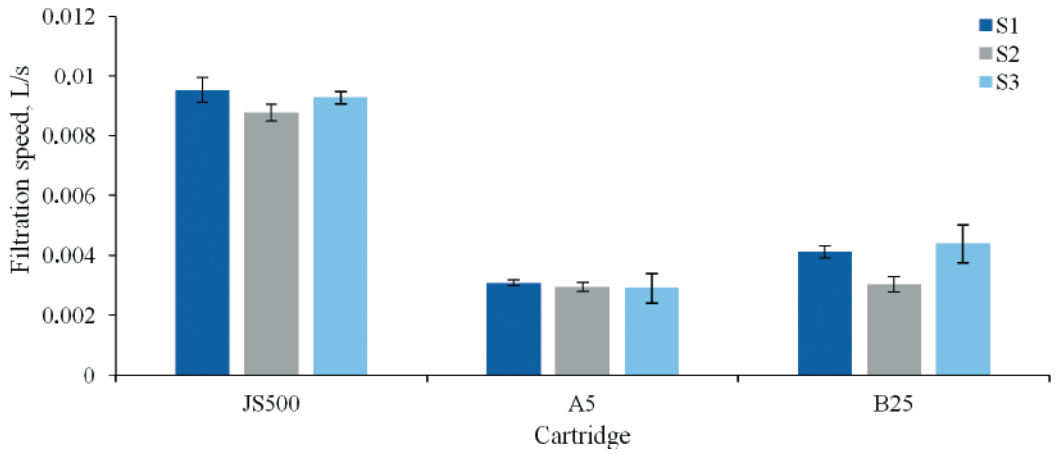

Figure 1.
Average filtration speed for studied cartridges during filtration of S1, S2, and S3 feed solutions

2.3. Filtration tests

Before starting the actual filtration tests, the pitchers were rinsed twice with deionized water. For each feed solution, a new cartridge was mounted. Then, 200 L of the model feed solution was passed through the filters. This was repeated with two lots of each cartridge type. The concentration of copper, chlorine, and $CHCl_3$ was monitored every 20 L increments.

2.4. Analytical measurements

The concentration of copper and free chlorine was measured with spectrophotometric Merck test kits and spectrophotometer Prove 100 (Merck). μ was measured using the Head & space GC-ECD method(Agilent Technologies 7890B with Agilent Technologies 7697A autosampler). The water sample was capped in a septum vial, then it is annealed in an autosampler chamber and the gas phase, from above the water phase, is injected into the chromatograph dispenser. Volatile compounds (i.e., chloroform) during annealing of the sample are released from the water sample into the gaseous headspace phase and it is this phase that is analysed by chromatography.

3. RESULTS

Filtration speed is an important factor from the point of view of the usability of the pitcher filters. Figure 1 shows an average filtration speed (from two repetitions) for studied cartridges during the filtration of S1, S2, and S3 feed solutions. It was found that the solution type did not affect greatly the filtration speed, since the difference in the filtration speed observed for one cartridge type was not significant. On the contrary, the filtration speed was highly dependent on the type of cartridge. The filtration speed obtained for JS500 was more than twice higher compared to A5 and B25 for all studied feed solutions. For any of the tested cartridges, no statistically significant decrease in the filtration speed over time was observed.

3.1. Removal of copper via pitcher filters

Fig. 2 presents a change of concentration of copper during filtration of 200 L of feed solution S1. For cartridge B25, the concertation of copper increased from 0.095mg/L (20 L) to 1.05 mg/L (200 L). For the cartridges, JS500 and A5, a slight increase in the concentration of copper during filtration experiments was observed. More specifically, for JS500, Cu^{2+} concentration was at relatively the same level i.e. (from 0.05 to 0.06 mg/L) while for A5, the concentration of copper increased from 0.025 mg/L (20 L) to 0.1 mg/L (200 L). The increase in the concentration of copper during filtration can be explained by the successive breakthrough of the filtration bed. In other words, sorption and ion exchange capacities of filtration materials filling cartridges were successively exhausted [20]. Importantly, the concentration of copper in filtrates from the whole experiment did not exceed

a permissible value indicated in the Regulation of the Minister of Health on the quality of water intended for human consumption [13].

For better evaluation of the performance of studied cartridges in the removal of copper, the removal efficiency was also calculated (Fig. 3). It is clear that, for cartridges JS500 and A5, the removal of copper was

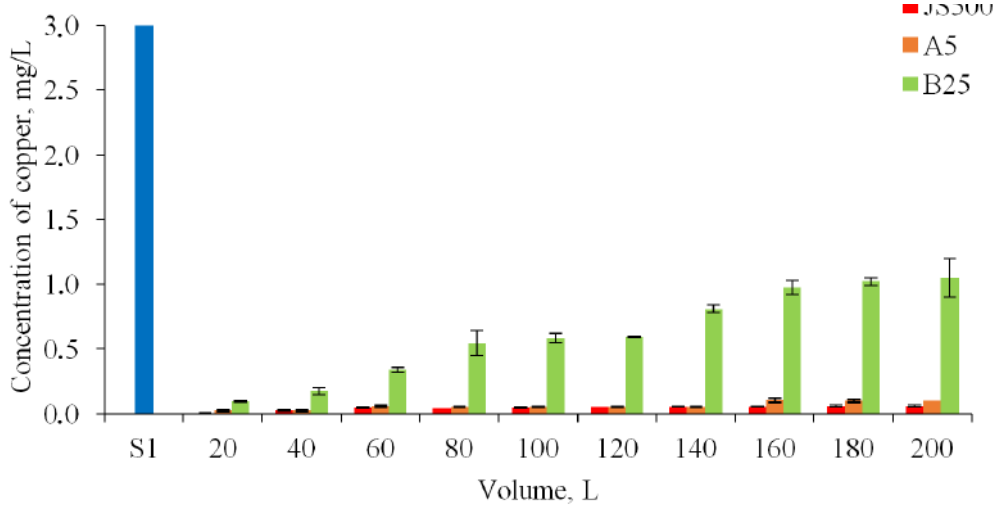

Figure 2.
The concentration of copper during filtration of 200 L of S1 feed solution

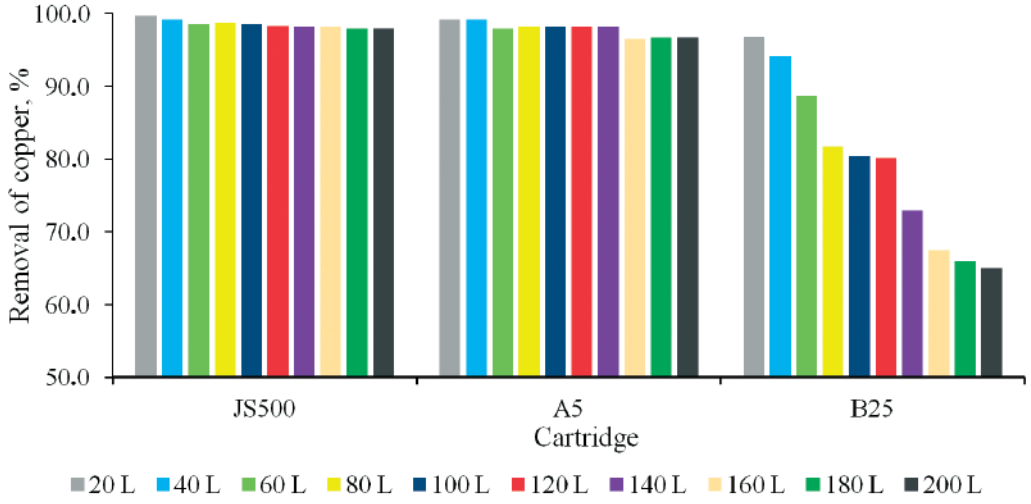

Figure 3.
The removal efficiency of copper during filtration of 200 L of S1 feed solution

very high (96.7–99.8%) during the whole period of the experiment. In that case, the removal degree exceeded 96% after filtration of 200 L of S1 solution. In case of cartridge B25, the removal of copper was slightly lower i.e., from 96.7% (a beginning of filtration = 20 L) to 65% (the end of filtration = 200 L). This difference in the efficiency of copper removal can be related to a few factors such as the shape and length of cartridges and the material filling the cartridge. Cartridges JS500 and A5 had a longitudinal shape and the biggest height, this could positively affect the removal of copper. Barkouchet al. [21] showed an increase in the removal of heavy metals (copper, cadmium, lead, and zinc) with an increase in the length of the filtration bed. This was attributed to a higher amount of adsorption sites bonding the heavy metals. In another report where pitcher filters were used to remove lead from drinking water, the removal efficiency was in the range of 10.9% to 92.9% [22].

Considering the material filling cartridges, JS500 and A5 were filled with sorbent (activated carbon) and microfiltration membrane (JS500), while B25 was packed with resin and activated carbon. Thus, JS500 and A5 cartridges have probably more sorption sites not only due to the almost twice bigger size of these cartridges compared to B25 but also due to domination of sorbent as filling material.

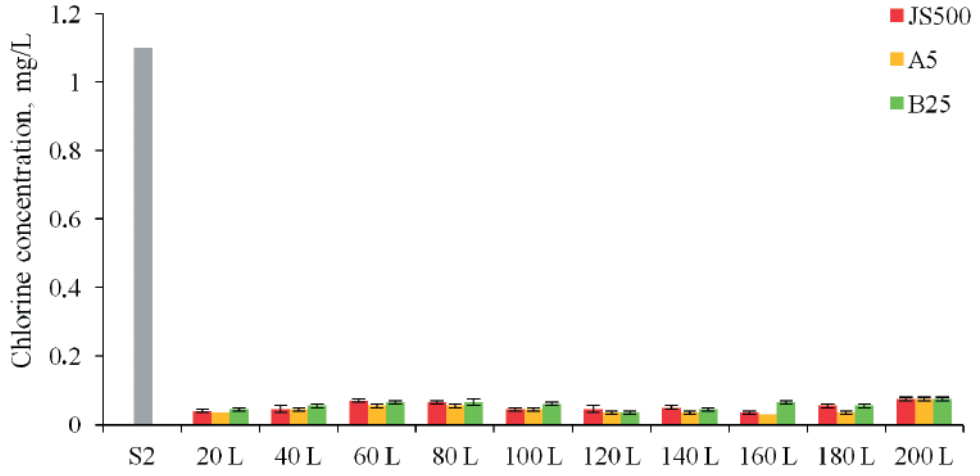

Figure 4.
The concentration of chlorine during filtration of 200 L of S2 feed solution

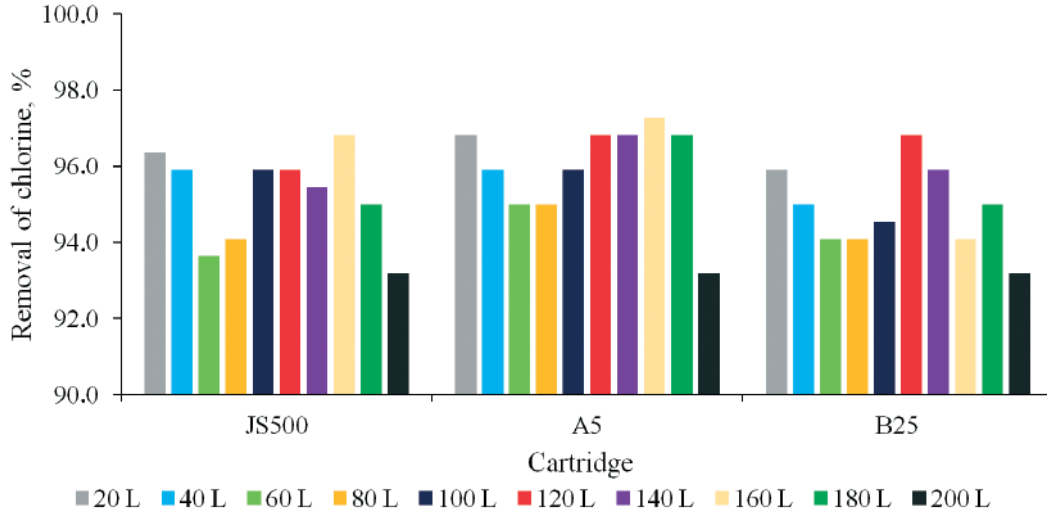

Figure 5.
The removal efficiency of chlorine during filtration of 200 L of feed solution S2

3.2. Removal of chlorine via pitcher filters

Figure 4 shows a change in free chlorine concentration during the filtration of 200 L of S2 feed solution. It is clear that the concentration of free chlorine during the entire experiment was very low, i.e., it did not exceed the level of 0.075 mg/L. Thus, despite the high initial content of chlorine in the S2 solution, the concentration of chlorine in the filtrates (20–200 L) did not exceed the admissible value, i.e., 0.3 mg/L [13]. Moreover, for all studied cartridges, the chlorine concentration in the filtrates remained relatively similar throughout the entire experiment. This is important for maintaining the water quality throughout the life of the filter cartridge.

For obtained data, the removal efficiency of chlorine was calculated (Fig. 5). For all studied cartridges, chlorine was reduced by more than 93% during the whole experimental period. No significant difference in the removal of chlorine between cartridges JS500, A5, and B25 was noted.

3.3. Removal of chloroform via pitcher filters

For filters JS500 and A5, during the whole experimental period a concentration of chloroform in filtrates was below the LOD (i.e., 0.1 µg/L), while for cartridge B25, it was in the range of 2.35–8.6 µg/L (Table 3). Importantly, using cartridges JS500, A5 and B25, the concentration of chloroform during the

Table 3.
The concentration of chloroform during filtration of 200 L of S3 feed solution

Cartridge	JS500	A5	B25
The concentration of chloroform, μg/L			
S3	100		
20 L	<0.1	<0.1	2.35
40 L	<0.1	<0.1	3.5
60 L	<0.1	<0.1	4.35
80 L	<0.1	<0.1	4.55
100 L	<0.1	<0.1	5.6
120 L	<0.1	<0.1	5.95
140 L	<0.1	<0.1	5.55
160 L	<0.1	<0.1	5.7
180 L	<0.1	<0.1	7.1
200 L	<0.1	<0.1	8.6

entire experiment did not exceed the standard value specified in the Regulation of the Minister of Health on the quality of water intended for human consumption, i.e., 0.03 mg/L (30 μg/L).

Fig. 6 presents the removal efficiency of chloroform. For JS500 and A5 cartridges, chloroform was reduced by 100% during the whole experimental period. Very good results were also obtained for the B25 cartridge with the removal of chloroform ranging from 91.4 to 97.7%. Similarly, Levesque et al. reported 92% removal of THMs using pitcher filtration [23].

4. CONCLUSIONS

Overall, this study shows that tap water purification with Aquaphor pitcher filters guarantees almost total removal of different toxic pollutants such as heavy metals, chlorine, and THMs. Despite

a high concentration of copper, chlorine, and chloroform in initial feed solutions, the concentration of these substances in filtrates (20–200 L) did not exceed the maximum admissible values specified by the Regulation of the Minister of Health on the quality of water intended for human consumption. More detailed conclusions are as follows:

1. Cartridge JS500 revealed the highest filtration speed compared to A5 and B25.
2. Removal of copper was very high i.e., from 65 to 99.8% during the whole filtration experiment. Slightly better removal of copper by JS500 and A5 can be related totheir bigger size and thus more amount of sorbent in cartridges providing more adsorption sites.
3. Using Aquaphor JS500, A5, and B25 cartridges, copper was reduced to a concentration not exceeding the permissible value for drinking water.
4. Removal of chlorine was at a very high level for all cartridges i.e., 93.2–97.3% during the whole experimental period. Despite the high initial content of chlorine in the S2 solution, the concentration of chlorine in the filtrates did not exceed 0.075 mg./L. This means also that the concentration of chlorine in filtrates from the whole experiment did not exceed the permissible value.
5. Chloroform was reduced by 100% using filters

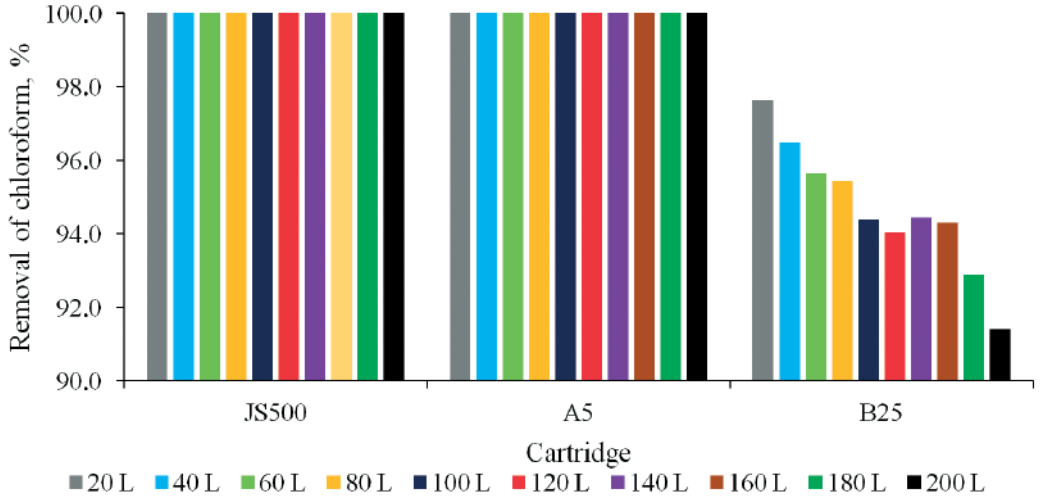

Figure 6.
The removal efficiency of chloroform during filtration of 200 L of S3 feed solution

JS500 and A5. The concentration of chloroform in filtrates afterJS500 and A5 was below the limit of its detection (LOD). i.e., 0.1 μg/L.

6. Concentration of chloroform in filtrates did not exceed the permissible value after the use of all studied cartridges.

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