Remove the pharmaceuticals from water using selected adsorbents

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Abstract. As part of the project of specific university research at the Institute of Municipal Water Management of the Faculty of Civil Engineering, Brno University of Technology, a laboratory test was carried out to try and remove to pharmaceuticals from water using selected sorption materials. The goal of the laboratory test was to compare two selected adsorbents as Filtrasorb F100 and Bayoxide E33 in terms of pharmaceutical removal effectiveness from water. Salicylic acid was selected as a pharmaceutical; which is a colourless organic acid, which is of great importance in the field of dermatology and is a proven tool for various dermatological problems including acne. This is a pharmaceutical that is obtained from the bark of a willow white. Sorbent Filtrasorb F100 is in practice commonly used for the removal of micropollutants, as opposed to the sorbent Bayoxide E33, which is used to remove metals from water. In order to remove pharmaceutical from water, two glass columns were used with internal diameter 4.4 cm filled with said sorption materials. Height of sorbent was elected as recommended by the producer of filter material at least 75 cm. Model water was prepared in laboratories by mixing liquid pharmaceutical into drinking water. Samples of filtered water were taken after 0.5 minute and after or 1, 2, and 4 minutes respective. Totally 9 samples including model water were taken. The analysis of water samples after filtration from individual columns with said sorption materials showed found that Filtrasorb F100 reliably removed to concentration of salicylic acid after half a minute, while Bayoxide E33 started remove the acid but from one minute higher concentrations were onwards measured again. This means that the latter material was oversaturated, and therefore gradually ceased to remove the acid.

1. Introduction

In the context of a specific academic research project the Institute of Municipal Water Management, Faculty of Civil Engineering, Brno University of Technology, performed laboratory tests of drug removal from water with the help of selected sorption materials. The purpose of the experiment was to compare two sorption materials – charcoal Filtrasorb F100 and Bayoxide E33, with regard to their efficiency in removal of salicylic acid from water.

2. Properties of Tested Sorption Materials

The sorption material Filtrasorb F100 was selected for the experiment because of its widespread use for removal of micro pollutants. The adsorption properties of carbon-reach materials have been known...
for millennia, but only since the beginning of the twentieth century has this material been improved by special activation processes. Activated carbons can be produced from different carbon-containing raw materials and by different activation processes [1]. As the sorption material Bayoxide E33 appeared very effective in removal of metals (such as As, Cu, Pb), it was selected as the second tested sorbent for use in drug removal from water.

Granulated charcoal Filtrasorb F100 is known for its widespread use in treatment of drinking and service water (Table 1). Filtrasorb F100 is made from selected sorts of black coal by activation with vapour pursuant to the relevant quality standards. In addition to capturing of mechanical impurities charcoal shows sorption and chemisorptions properties of its large surface area. It is able to capture substances, mainly of organic nature, dissolved in water [2].

Table 1. Properties of Filtrasorb F100 [2]

| Parameter                          | Value          |
|------------------------------------|----------------|
| Iodine number min.                 | 850 mg/l       |
| Methylene number min.              | 200 mg/l       |
| Effective size                     | 0.8 – 1.0 mm   |
| Abrasion resistance                | 75 %           |
| Surface area                       | 900 m²/g       |
| Apparent density after wash        | 500 g/l        |
| Particle density in water          | 1.25 g/ml      |
| Homogeneity coefficient            | 1.8            |
| De-chlorination half-value         | 2.9 cm         |
| Load capacity for atrazine 1mg/L   | 20 mg/g        |
| Load capacity for trichloroethylene 1mg/L | 80 mg/g    |
| Recommended flow rate              | 5 to 20 m/h    |
| Minimum pour height                | 75 cm          |
| Minimum free level                 | 20 % of pour height |
| Package size – paper bags with PE lining | 50 l         |

Bayoxide E33 is a dry crystalline medium developed by Severn Trent and designed for removal of arsenic, antimony and other metals, such as iron and manganese, from water (Table 2). The material service life depends on the quality of the treated water. The filtration material is marketed in two forms, Bayoxide E33 in granules and Bayoxide E33P in tablet form [3, 4].

Table 2. Properties of Bayoxide E33 [3, 5]

| Parameter                          | Value          |
|------------------------------------|----------------|
| Fe2O₃ level                        | > 70%          |
| Specific adsorption surface        | 120-200 m²/g   |
| Porosity                           | 85%            |
| Sieve analysis                     |                |
| > 0.5 mm                           | max. 20%       |
| > 2.0 mm                           | max. 5%        |
| Particle density                   | 3.6 g/cm³      |
| Bulk density                       | 0.45 g/cm³     |
| Working pH                         | 6-8            |

3. Progress of Experiment

The adsorption was performed in two glass columns with 4.4 cm inner diameter, with a grit drainage layer on the bottom, particle size 1 – 2 cm, followed with a layer of glass beads, size 4 mm, and another bead layer, size 2 mm. The bead and grit layers prevented escape of the bulk sorption material
from the column. The height of the adsorption fill followed recommendations of the sorption material manufacturer, recommending at least 75 cm. The whole system consisted of a 30 l barrel with the test water (drinking water with salicylic acid), a pump, a flow meter, a pipeline with stop valves and vessels for the filtered water.

Before commencement of the adsorption process the sorption material was prepared according to the manufacturer’s instruction. The sorption fill was wetted and washed in the direction opposite to the filtration direction until clear water was flowing from the column. The washing water was drained to sewerage during the material preparation. Samples were taken after 0.5, 1, 2 and 4 minutes. The total number of samples taken was 9, including the test water. Turbidity was specified by means of a portable turbidity meter HACH 2100Q, and pH was measured with a digital pH meter. As the Institute of Municipal Water Management is unable to specify drug concentrations the samples were evaluated by the laboratory of ALS Czech Republic, s.r.o.

![Figure 1. The diagram of the filter device](image)

4. Results and Discussion
The concentration of salicylic acid in water was 659 mg/l. The sorption material Filtrasorb F100 reliably removed the acid concentration after mere half a minute – see Table 3. The sorption material Bayoxide E33 removed most of the acid after half a minute, but a higher concentration was measured again after one minute. That means that the material was oversaturated and ceased to remove the acid after a time. The progress of the drug removal is shown in Figure 1. The pH of the test water was 7.59 due to the added salicylic acid, and then the pH slowly decreased in the case of both sorption materials to reach the final 7.38 (Figure 2). The mean temperature of the samples taken was 19.6 °C. The water turbidity after filtration through the charcoal decreased from 1.16 ZF to 0.54 ZF, or, in the case of the second material, down to 0.42 ZF. In the case of Filtrasorb F100 higher turbidity was measured after 0.5 minute, which was probably caused by infiltration of the filtration material into the sample. Apart from the singular fluctuation of the turbidity value in the sample taken after 0.5 minute of filtration through charcoal the sorption materials easily removed turbidity form the test water. The quantity of the passing water was regulated on the flow meter with a throttle nozzle with the maximum flow rate defined at 30 l/h.
Table 3. Results of adsorption through Filtrasorb F100

| Time | pH F100 | pH E33 | Temperature F100 | Temperature E33 | Turbidity F100 | Turbidity E33 | c(C7H6O3) F100 | c(C7H6O3) E33 |
|------|---------|--------|------------------|------------------|----------------|---------------|----------------|----------------|
| Min  | -       | -      | -                | -                | -              | -             | -              | -              |
| 0    | 7.59    | 7.59   | 20.90            | 20.90            | 1.16           | 1.16          | 659            | 659            |
| 0.5  | 7.59    | 7.45   | 20.90            | 20.60            | 2.85           | 0.93          | < 0.1          | 117            |
| 1    | 7.54    | 7.43   | 20.20            | 20.70            | 0.80           | 0.68          | < 0.1          | 233            |
| 2    | 7.48    | 7.41   | 18.60            | 18.70            | 0.73           | 0.48          | < 0.1          | 450            |
| 4    | 7.38    | 7.38   | 17.80            | 17.40            | 0.54           | 0.42          | < 0.1          | 494            |

Figure 2. Progress of salicylic acid removal by the tested adsorption materials

5. Conclusion

The results of the experiment showed that charcoal reliably removed salicylic acid from water in a short time. That is why this sorption material is widely used in mater management practice for removal of micro-pollutants. The measured values of salicylic acid concentrations after filtration through Bayoxide E33 showed that the process going on in the sample was dynamic adsorption. In the case of dynamic adsorption the adsorbate flows through the immobile layer of the granulated adsorbent in the column, the substance adsorbs in the top section of the column and the remaining sections are flown through with a pure liquid phase. After a certain operation time the adsorbent in the top section of the column is absolutely exhausted. Adsorption does not happen anymore and the substance concentration in the water in this section is nearly identical with the concentration in the incoming water. The boundary between the exhausted and the fresh layer of the adsorbent is not sharp but is characterised by the adsorption wave. The point of transition to the fresh adsorbent zone is called zone face and the time dependence of the substance concentration on the outlet from the column is called penetration curve [6, 7]. Bayoxide E33 is a reliable metal adsorbent used for metal removal.
from water but is probably not absolutely ideal for drug removal from water. After a short time the sorption material got saturated and stopped filtering the water. However, possibly in the case of a lower concentration of salicylic acid in the test water the second filtration material might be expected to better cope with the drug removal from water. This result invites to consider further investigation of drug removal from water with the help of various sorption materials.

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