Removal efficiency of pharmaceuticals from municipal wastewater by advanced treatment methods †

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Supplementary Materials

Table S1. GAC Carbosorb40

Specifications	
Appearance	Granular Activated Carbon (produced from bituminous coal)
Iodine number	≥ 950 $mg.g^{-1}$
Hardness number	≥ 90
Moisture (as packed)	≤ 2%
Particle size	12x40 mesh
- ≤ 4% passing	0.425 mm
- ≤ 5% retained on	1.70 mm
Typical characteristics	
Bed density	450 $kg.m^{-3}$
Methylene blue adsorption	250 $mg.g^{-1}$
Specific surface area (BET)	950 $m^2.g^{-1}$
Effective particle size (EPS)	0.6 mm
Uniformity coefficient	1.8
Average particle size	1.1 mm
Dechlorination half-value layer	2.4 cm

Formulas for calculating indicators in GAC column filtration are outlined below:

$A = \frac{\pi d^2}{4}$ *where A is the flow area (m^2), π is the Ludolf number (3.141592) and d is the column diameter (m)*

$Q = \frac{V}{t}$ *where Q is the flow rate in the column (m^3/s^{-1}), V is the volume of wastewater (mL) and t is the measurement time (min)*

$v = \frac{Q}{A}$ *where v is the linear velocity (m/h^{-1}), Q is the flow rate in the column (m^3/s^{-1}) and A is the flow area (m^2)*



Figure S1. GAC filtration apparatus

Chromatographic Method Specifics

The analytes were initially separated using a Shimadzu Nexera X2 HPLC and subsequently analyzed on a SCIEX QTRAP 6500+ tandem mass spectrometer. The measurements were executed in MRM mode (Multiple Reaction Monitoring), wherein the target compounds were identified based on their MRM transitions and retention times. The analysis was conducted using an electrospray ionization source, employing both positive and negative ionization modes. The spectrometer analysis was conducted under the following conditions:

- Ionization mode ESI + ESI -
- Ion Spray voltage 4.5 kV -4.5 kV
- Capillary temperature 450 °C 450 °C
- Ion Source Gas 1 (GS1) 3.45 bar 3.45 bar
- Ion Source Gas 2 (GS2) 4.14 bar 4.14 bar

The gradient program is outlined as follows: The initial five-percent biogas (B) was reached within the first minute of the process, followed by a rapid increase to 75 percent B between the first and sixth minutes. Subsequently, a steady rise to 98 percent B was observed between the sixth and ninth minutes, followed by a decline to 5 percent B between the ninth and 10.5 minutes. Finally, a decrease to 5 percent B was noted between the 10.5 and 11 minutes, and again between the 11 and 15 minutes. The total analysis time was 15 minutes. The analytical method employed was linear within the range of 0.05–200 $\mu g \cdot L^{-1}$. The analysis and evaluation were carried out in accordance with established protocols, employing internal standards and the incorporation of quality control samples at concentrations of 10 and 100 micrograms per liter. These samples were included in each measurement series to ensure the accuracy and reliability of the results.

The separation process was executed in gradient mode, with a linear mobile phase flow rate of 0.350 $mL \cdot min^{-1}$ and a temperature of 30°C. The composition of the mobile phase was as follows:

- The mobile phase A (MP A) consists of 0.1% formic acid dissolved in ultrapure water.
- The mobile phase B (MP B) consists of formic acid at a concentration of 0.1% in a mixture of methanol and acetonitrile at a volume ratio of 1:1.

The quantification of analytes using HPLC is contingent upon the establishment of strict detection limits. However, in certain instances, peaks with intensities falling below these established limits were detected. These peaks were characterized by distinctiveness, enabling reliable quantification. In the context of this study, the efficacy of various methodologies in the elimination of specific analytes is being examined, and the temporal dynamics of analyte concentrations under each method are being investigated. It should be noted that the reported results occasionally include values below the formal detection limits, as these were reliably detected.