Journal of Chromatography A, 1218 (2011) 5964–5974

Contents lists available at ScienceDirect

Journal of Chromatography A

journal homepage: www.elsevier.com/locate/chroma

Review

Application of hydrophilic interaction chromatography for the analysis of polar contaminants in food and environmental samples

Alexander L.N. van Nuijs, Isabela Tarcomnicu, Adrian Covaci*

Toxicological Center, University of Antwerp, Universiteitsplein 1,B-2610 Antwerp, Belgium

ARTICLE INFO

Article history:
Received 21 May 2010
Received in revised form 22 January 2011
Accepted 25 January 2011
Available online 31 January 2011

Keywords:
HILIC
Pharmaceuticals
Pesticides
Polar compounds
Environmental samples
Food
Review

ABSTRACT

For the analysis of highly hydrophilic and polar compounds, Hydrophilic Interaction Chromatography (HILIC) has been established as a valuable complementary approach to reversed-phase liquid chromatography (RPLC). Moreover, the use of mobile phases with a high percentage of organic solvent in HILIC separation is beneficial for mass spectrometric (MS) detection, because of enhanced ionization which results in an increased sensitivity. In this review, various applications of HILIC are described for a number of environmental and food contaminants together with detailed methodological descriptions and the advantages or drawbacks of HILIC compared to other LC methods are critically discussed. In the first part of the review, an overview is given of the work that has been carried out with HILIC for the analysis of pharmaceuticals and pesticides in environmental samples. HILIC has shown its applicability for polar pharmaceuticals, such as antibiotics, estrogens and their metabolites, drugs of abuse, cytostatics, metformin and contrast agents. In the pesticide group, HILIC chromatography was helpful for polar phenylurea and organophosphorus pesticides. The second part of the review focuses on the analysis of antibiotic residues in food and feed with HILIC, while in the pesticide group, HILIC experiments have been reported for dithiocarbamates and quaternary ammonium compounds. The last chapter gives an overview of the analysis by HILIC of miscellaneous analytes in aquatic and food/feed samples.

Contents

---

* Corresponding author. Tel.: +32 3 265 2498; fax: +32 3 265 2722.
E-mail address: adrian.covaci@ua.ac.be (A. Covaci).

0021-9673/$ – see front matter © 2011 Elsevier B.V. All rights reserved.
doi:10.1016/j.chroma.2011.01.075

1. Introduction

Reversed-phase liquid chromatography (RPLC) has been the alternative method of choice for the analysis of various classes of compounds difficult to analyze by gas chromatography (GC). A large number of compounds have been measured by RPLC using C_{18}-based silica stationary phases. However, highly polar compounds undergo early elution on traditional RP stationary phases, leading to lower sensitivity of the mass spectrometric (MS) detection due to (1) high matrix effects and (2) high water percentage in the mobile phase at the beginning of the run resulting in lower ionization efficiency in the MS interface. The analysis of highly hydrophilic and polar compounds by hydrophilic interaction chromatography (HILIC) coupled to MS has been demonstrated as a valuable complementary approach to RPLC [1]. The use of a low aqueous and high organic mobile phase in HILIC separation is almost ideal for electrospray ionization in many cases, leading to increased sensitivity [1]. In this review, the analysis of environmental and food contaminants, such as pharmaceuticals, drugs of abuse and pesticides, by HILIC coupled to different detectors (e.g. MS or UV) is discussed.

2. Pharmaceuticals in environmental samples

Several studies have pointed out that excreted human or veterinary pharmaceuticals or drugs of abuse (DOA) end up in the environment through insufficient elimination during treatment of wastewater in wastewater treatment plants (WWTPs) [2–5]. Since these compounds can cause negative effects on the aquatic environment, considerable interest has been focused nowadays on their detection and quantification in waste- and surface water. Table 1 shows an overview of the analytical methods based on HILIC for the determination of pharmaceuticals in environmental samples.

2.1. Estrogens

Estrogens have been found in the environment resulting from natural sources (human and animal excretion, plants, or fungi) or as by-products of synthetic chemicals. Estrogens pose a risk as they act as endocrine disruptors which can lead to fish feminization [19] and can influence plant growth or human health. Their monitoring has become therefore important. The analysis of estrogens (e.g. estrone) and their glucuronide and sulfate conjugates at low ng/L levels in the aquatic environment can be done by immunoassays, GC–MS or LC–MS. Immunoassay methods are sensitive and specific, but only few antibodies are available and cross-reactions remain a problem. GC–MS methods require derivatization and hydrolysis of the estrogen conjugates, so the substitution group is lost before analysis. LC–MS/MS is the most advantageous technique and it is widely used today.

To detect estrogens (e.g. estrone, estriol, estradiol) and their glucuronide and sulfate conjugates in surface water in a single run, Qin et al. [6] used a column-switching method involving a C_{18} and a HILIC stationary phase. The analytes were isolated and pre-concentrated from 500 mL surface water with solid-phase extraction (SPE) on Oasis HLB cartridges. Free estrogens were eluted with ethyl acetate, while estrogen conjugates were eluted with methanol (MeOH) containing 2% ammonium hydroxide. After elution of the SPE cartridge, the estrogen fraction was further derivatized with dansyl chloride and the reaction mixture was further purified on an Oasis HLB cartridge. The last methanolic eluate was mixed with the estrogen conjugates fraction and the solvent was evaporated. Analytes were reconstituted in mobile phase and injected in the LC–MS system.

RPLC–MS was optimal for the separation and detection of the hydrophobic dansyl derivatives of free estrogens, while HILIC–MS showed good performance for the highly hydrophilic estrogen con-

Table 1
Pharmaceuticals, drugs of abuse and pesticides analyzed in HILIC mode from environmental samples. A brief review of employed columns, mobile phases and type of samples.

Compound/class of compounds	Matrix	Column	Mobile phase	Refs.
Pharmaceuticals				
Estrogen conjugates	River water	SeQuant ZIC–pHILIC (100 mm × 2.1 mm, 5 μm)	AcN/ammonium acetate 5 mM in water; gradient	[6]
Cytostatics	Wastewater	SeQuant ZIC–HILIC (150 mm × 2.1 mm, 3.5 μm)	AcN/ammonium acetate 30 mM in water; gradient	[7]
Spectinomycin, lincomycin	Liquid manure Rainfall run-off	Alltech Alltima HP HILIC (150 mm × 2.1 mm, 3 μm)	AcN/formic acid 0.1% in water; isocratic	[8]
Metformin	Wastewater Surface water	SeQuant ZIC–HILIC (150 mm × 2.1 mm, 3.5 μm)	AcN/ammonium formate 10 mM in water (pH 3 with formic acid); gradient	[9]
Albuterol, cimetidine, ranitidine, metformin	Water, sludge	Waters Atlantis HILIC Silica (100 mm × 2.1 mm, 3 μm) Agilent Zorbax HILIC Plus (100 mm × 2.1 mm, 3.5 μm)	AcN/0.1% acetic acid/ammonium acetate; gradient AcN/ammonium acetate 10 mM in water; gradient	[10] [11]
13 pharmaceuticals	Wastewater	Phenomenex Luna HILIC (150 mm × 3 mm, 5 μm)	AcN/MeOH (87.5/12.5, v/v)/ammonium acetate 5 mM in water; gradient	[12]
Gd chelates	Wastewater	SeQuant ZIC–HILIC (150 mm × 2.1 mm, 3.5 μm)	12.5 mM ammonium formate and 12.5 mM formic acid in AcN/water (76/24, v/v, pH 3.75)	[13]
Drugs of abuse				
Cocaine and metabolites	Wastewater	Agilent Zorbax RX-Sil (150 mm × 2.1 mm, 5 μm)	AcN/ammonium acetate 2 mM in water (pH 4.5 with acetic acid); gradient	[14]
9 drugs of abuse	Wastewater	Phenomenex Luna HILIC (150 mm × 3 mm, 5 μm)	AcN/ammonium acetate 5 mM in water; gradient	[15]
Pesticides				
Organophosphorus pesticides	Water	Waters Atlantis HILIC Silica (150 mm × 2 mm, 5 μm)	AcN/isopropanol/ammonium formate 200 mM (pH 3); isocratic	[16]
Diquat, paraquat	Drinking water	Waters Atlantis HILIC Silica (150 mm × 2.1 mm, 3 μm) Waters Atlantis HILIC Silica (150 mm × 2.1 mm, 3.5 μm)	AcN/ammonium formate 10 mM, pH 3.7; isocratic AcN/ammonium acetate 250 mM, pH 3; isocratic	[17] [18]