Marine Pollution Bulletin 78 (2014) 26–42

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

Review

Historical records of organic pollutants in sediment cores

Paulina Bigus *, Marek Tobiszewski, Jacek Namieśnik

Department of Analytical Chemistry, Chemical Faculty, Gdańsk University of Technology (GUT), ul. Narutowicza 11/12, 80-233 Gdańsk, Poland

ARTICLE INFO

Keywords:
Sediment cores
Historical trends of pollution
Polycyclic aromatic hydrocarbons (PAHs)
Polychlorinated biphenyls (PCBs)
Organochlorine pesticides (OCPs)

ABSTRACT

Analyses of sediment core samples are primary sources of historical pollution trends in aquatic systems. Determining organic compounds, such as POPs, in the dated sediments enables the estimation of their temporal concentration changes and the identification of the contaminant origin in local regions. Wars, large-scale fires, economical transitions, and bans on certain chemicals are reflected in the sediment organic compound concentrations. The high POP concentrations in surficial sediments suggest that these chemicals, even after being banned, remain in the environment. Furthermore, vertical profiles can help in understanding the sedimentation process and in estimating effective countermeasures against pollution. Moreover, studies published during the period 1991–2013 on PAHs, PCBs, OCPs, dioxins and dioxin-like compound concentrations in sediment core samples are reviewed.

Contents

1. Introduction

Sediment cores are one of the most easily accessed natural archives used to evaluate and reconstruct historical pollution trends in aquatic environments (Moon et al., 2009; Minh et al., 2007; Liu et al., 2012). The cores provide data to characterize sediment physical properties and their geochemistry and composition (Rothwell and Rack, 2010). Vertical profiles of particular contaminants can reflect sedimentation rate and diagenetic process changes (Ra et al., 2011; Heim and Schwarzbauer, 2013) and the effect of human interventions, e.g., river regulations, construction of reservoirs and hydroelectric dams and contaminant bans (Thevenon et al., 2013).

Compounds released into aquatic systems undergo various processes, such as adsorption, photolysis, chemical oxidation and microbial degradation (Lors et al., 2012). In addition to the contaminant physicochemical properties, sedimentation largely depends on the sediment physical properties, their adsorption capabilities and the partitioning constant at the water–sediment interface (Fei et al., 2011). Trace contaminants removed from the water column are adsorbed on particulate matter and eventually deposited on bottom sediments (Santschi et al., 2001).

Sediments or soils are an important reservoir for toxic and hydrophobic persistent organic pollutants (POPs), such as organochlorine pesticides (OCPs), polycyclic aromatic hydrocarbons (PAHs) (Zhang et al., 2009; Tobiszewski and Namieśnik, 2012), polychlorinated biphenyls (PCBs) (Wan et al., 2011), dioxins and dioxin-like compounds. These organic pollutants may have a petrogenic, pyrogenic, biogenic or diagenetic origin (Yim et al., 2007; Denis et al., 2012; Silva et al., 2012). The historical organic contaminant trends can be used to identify their sources (Gong et al., 2007). Moreover, the ecotoxicological risk assessment for anthropogenic pollutants reported using dated sediments could

* Corresponding author. Tel.: +48 583471897.
E-mail address: bigus.paulina@gmail.com (P. Bigus).

0025-326X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpolbul.2013.11.008

improve management strategies (Barakat et al., 2012a,b; Frignani et al., 2005).

The main goal of this review is to summarize information on sediment cores used for the reconstruction of historical trends of organic pollutants released into aquatic systems from different sources. The applicability of sediment cores for tracking changes in pollution emission sources that affect sediment quality is emphasized.

2. Sedimentation process

Various processes in aquatic systems (e.g., physical, biological and chemical) affect sediments before being accumulated. These processes are determined by environmental factors and human influences. To reconstruct the anthropogenic pollutant levels using samples of sediment cores, the processes controlling sediment deposition require further examination. However, many studies on sediment deposition have been published over the last two decades (Dearning, 1991; Salonen et al., 1995; Håkanson et al., 2004; Johannessen and Macdonald, 2012; Heim and Schwarzbauer, 2013).

The aquatic environment includes three main components: water, sediments and suspended particulate matter, which is also called suspended organic matter (SOM). Processes occurring between the water column–sediment interface and particulate organic matter (e.g., sorption and partition) may determine the environmental fate of organic pollutants. Adsorption of organic contaminants onto sediments strongly depends on the properties of both the pollutants (adsorbate) and sediments (adsorbent), the contaminant concentration, sediment organic matter content, pressure and temperature. In addition to adsorption, hydrophobic pollutants are also affected by physical and chemical processes, including vaporization, oxidation and reduction, and the biological processes, e.g., biodegradation and bioconcentration, that contribute to their transformations. The pollutants present in the bottom sediments undergo a combination of these and other processes, e.g., resuspension and redeposition.

Organic pollutant concentrations in dated sediments primarily depend on their sources, physicochemical properties (e.g., lipophilicity, solubility) and geochemical sediment construction (e.g., grain size, porosity, sorbing capacity and organic matter content). Sediments consist of two parts: inorganic (e.g., clay, silt and mud) and organic (Mechlińska et al., 2009). Organic matter consists of lipids, carbohydrates, proteins, and other biochemicals contained in the tissues of living benthic microorganisms and contributed by detritus from organisms living in aquatic environments. Humic substances are the major fraction of organic materials (Meyers and Ishiwatari, 1993; Fei et al., 2011). The sediment particle sizes and mineralogical compositions are determined by their origin conditions, e.g., temperature, pressure, pH and Eh, and are regulated by meteorological, geological and hydrological factors in various

Table 1
Factors influencing a sediment composition and process sedimentation as well as a estimation of the sediment dating.

Factor	Aquatic sedimentary system Estuary/Coastal/Sea	River	Lake	References
Geological	• A geological structure of the sea-, lake- and riverbed and sculpture geomorphology formed during the activities of glaciers and processes such as erosion and weathering of sediments • A formation of minerals • A depth of the basin/channel, and coastline shape			Eschard (2001)
Hydrological and hydrodynamic phenomena	• A vertical profile of salinity and the oxygenation in the water determined by: – a supply of the fresh and salt waters from the surrounding rivers and seas; – a water circulation; – a seasonal variability in the ocean currents; • The thermohaline structure of water depended on the seasonal variability in the water temperature and salinity; • A vertical profile of the seasonal variability in density determined by the water temperature and hydrostatic pressure; • A seasonal variability in sediment rates related to the wave action and storm surges (e.g., the occurrence of surface and internal waves, seiche, tsunami and the upweling phenomana) depended on the meteorological conditions	• A vertical profile of the oxygenation in the water determined by: – a supply of the fresh waters from the surrounding rivers • A water level; • A velocity and flow rate;	• A vertical profile of the oxygenation and the thermohaline structure of water determined by: – a water circulation; – inflow to the lake by river water and groundwater or flood events and storm waters; – in some cases, a presence of the ice cove at surface of water;	Borówka (2007), Dearning (1991), and Zonta et al. (2005)
Biological	• Sediment mixing by bioturbation and bioresuspension as well as vegetation patters	• Strong influence of biomixing by benthic microorganisms	• The plant cover at the bottom as well as around the lake; • Amount of microorganisms and their activities (e.g., microbiological degradation, bioresuspenion);	Johannessen and Macdonald, 2012
Meteorological	• Energy balance, annual temperature of air and pressure • Clouds and wind • Climate water-balance (i.e., balance between precipitation and evapotranspiration)			Zhu et al., 2012