Chemical Engineering Journal 229 (2013) 585–594

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

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

Review

Botanical biofiltration of indoor gaseous pollutants – A mini-review

Gabriela Soreanu [a,*], Michael Dixon [b], Alan Darlington [c]

[a] Technical University "Gheorghe Asachi" of Iasi, Faculty of Chemical Engineering and Environmental Protection, Department of Environmental Engineering and Management, 73 D. Mangeron Blvd, Iasi 700050, Romania
[b] University of Guelph, School of Environmental Sciences, Controlled Environment Systems Research Facility, 50 Stone Road East, Guelph, ON N1G 2W1, Canada
[c] Nedlaw Living Walls, Breslau, ON N0B 1M0, Canada

HIGHLIGHTS

- Botanical biofiltration of indoor gases is demonstrated.
- Plant-assisted biotrickling filters are more effective than potted plants.
- Plant-assisted biotrickling filters were successful in VOCs removal.
- Plant-assisted biotrickling filters have not yet been tested on inorganic gases removal.

ARTICLE INFO

Article history:
Available online 27 June 2013

Keywords:
Biofiltration
Biotrickling filtration
Botany
Phytoremediation
Biotechnology
Indoor gaseous pollutants

ABSTRACT

In the last decade, indoor air pollution has been unanimously recognised as a public health hazard worldwide, both in developed and developing countries. Accumulation of indoor air pollutants appears to significantly contribute to "sick building syndrome" (SBS) and other reported diseases in affected spaces. Botanical biofiltration has received a great deal of attention in the past decade, likely due its economical, environmental and social benefits, including its potential in the near future to be incorporated in both traditional and the new trend of sustainable zero-emission green buildings. This paper focuses on the potential and challenges of using botanical biofiltration for reducing the impact of gaseous pollutants in indoor environments. It is aimed at reviewing the current state of the art and the future research needs.

Contents

* Corresponding author.
E-mail address: gsor10@yahoo.ca (G. Soreanu).

1385-8947/$ - see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.cej.2013.06.074

1. Introduction

Urban people spend about 85–90% of their time indoors (residential and public spaces), which can explain the direct relationship between indoor air quality and public health risk [1–3]. Indoor air quality (IAQ) was ranked by the US Environmental Protection Agency in the top five public health concerns [4]. Indoor air pollutants such as fine particles, bioaerosols and gaseous compounds appear to be important contributors to poor air quality in domestic and various industrial settings, having a negative impact toward human health i.e. causing discomfort, acute and chronic diseases. "Sick building syndrome" (SBS), manifested by ocular, nasal, cutaneous irritations, allergies, respiratory dysfunction, headache and fatigue is one of the most typical indicators of poor indoor air quality [5–7].

Indoor air pollutants are generated from various sources such as occupational activities, materials, household products, pets, underground garages, outdoor air sources, and chemical reactions in indoor air [1,8–12]. Particularly, hundreds of volatile organic compounds (VOCs), comprising aliphatic and aromatic hydrocarbons, alcohols, aldehydes and chlorinated compounds are emitted in indoor air from furniture, carpets and construction materials, sprays and recipients, cleaning and restoration activities, or are subject to surrounding industrial sources (organic industry, painting stations, and transport) [13–19]. Inorganic gaseous compounds (ICs) such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x) and sulphur dioxide (SO_2) are generated from various combustion processes such as combustion of fossil fuels in unvented gas space, kerosene heaters, gas-fired appliances (stoves and ovens), wood stoves and gas-fired hot water heaters as well as tobacco smoking, being also related to outdoor sources exposure (road transport, power stations, and refineries) [1,10,20–22]. Although the individual pollutant levels are usually below the permitted exposure limits regulated for workplaces by the Occupational Safety and Health Administration (OSHA PEL), the cumulative level of pollutants, their synergetic effect and the prolonged exposure appears to be a major cause of indoor air pollution-related diseases [7,15].

Recent efforts are worldwide being made for indoor air pollution prevention at source (i.e. implementation of IAQ standards and emission regulations, population education) and for the development of sustainable air cleaning systems. The typical indoor air cleaning systems are mainly designed for particle removal (i.e. mechanical filters, electrostatic precipitators) rather than for gaseous compounds. The removal of gaseous compounds using present technologies (i.e. adsorption filters, photocatalytic oxidation cleaners, and ozone generators) represents an expensive and inefficient option. Gas-phase filters have a short life time and are not efficient for removal of multiple gases, actual catalysts are inefficient and ozone generators are potentially not safe [1,23–24]. In contrast, biological filtration using plant based systems appears to be a promising alternative to the conventional methods, due to its potential to remove most of the indoor pollutants (dust, inorganic and organic gaseous compounds) [15,25–28]. A combination and optimisation of different technologies could overcome the drawbacks of the air cleaning systems [1].

This paper presents the botanical biofiltration of indoor air, with emphasis on gaseous pollutants removal, as a tool of indoor air pollution mitigation. An overview of biosystem configuration, process performance, pollutant pathways, technology limits, challenges and relevance in practice, as well the future research needs, is presented.

2. Botanical biofiltration progress in environmental protection perspective

For the purposes of this discussion, botanical biofiltration is a hybrid of biofiltration and phytoremediation. Biofilters are bioreactors where a contaminated air or water stream is actively passed through a region with high biological activity where the contaminants are neutralized by biological processes. Plants have frequently been used for cleaning large contaminated areas of soil and water in the outdoor environment, especially with heavy metals, fertilisers (nitrate and ammonium), oil spills and solvents [26,29]. Phytoremediation is considered a non-invasive and cost-effective alternative for environmental cleaning, being up to tenfold more economical than the conventional technologies (i.e. soil excavation, washing or burning) [26]. Historically, field applications date from the 1990s, mainly on sites in the United States [26,29]. In the United States, phytoremediation was included in the list of emerging technical developments and was included in tests under US EPA's Superfund Innovative Technology Evaluation (SITE) program [30]. One of the first pilot scale applications began in 1996 at the J-Field Site at Aberdeen Proving Ground, United States, where poplar trees where used for the removal of chlorinated VOCs from groundwaters [29]. Currently, the phytoremediation market for restoration of soils and waters in the United States is estimated at about $100–150 million per year (i.e. 0.5% of the total remediation market, where bioremediation comprises 2%) [26]. Phytoremediation is poorly represented in Europe, but the interest in this research field is rapidly increasing within governmental agencies and industry, mainly for solving pollution issues of the new European Union countries [26]. Botanical biofilters are biofilters with green plants integrated right into their structure making it an environmental-friendly technology that uses plants and their rhizosphere microorganisms (natural microorganisms living near, on or inside the roots of plants) for pollutant removal from a moving contaminant stream.

During the 1980s, scientists from NASA (National Aeronautics and Space Administration, US) demonstrated the ability of several potted plants to remove VOCs (volatile organic compounds) from indoor air under static conditions [31]. Despite this discovery, the progress in air phytoremediation has been slow and few publications in this field are available at this time. Later in the 1990s and early 2000s, teams from University of Guelph, Ontario, Canada, the University of Sydney, Australia and the University of Georgia, United States launched several large research programs in the field of indoor air treatment using plants and associated rhizosphere microorganisms. These programs were focused on VOCs, but none on ICs (inorganic gaseous compounds) removal so far. Removal of indoor VOCs in specifically designed botanical biofilters was successfully demonstrated [14,18,28] and similar results are expected for indoor inorganic gaseous compounds as well, as indicated in the next section.

Many industrial biofilters pass contaminated air through a packing material that has limited life expectancy because of the exhaustion of its organic content which acts as a supplemental or alternative food source for the beneficial microbes [32, p42].