18th Newsletter of the UFZ Green Roof Research

04th May 2024

Extensive green roof in May 2024
(Photo: Lucie Moeller)

Diese Baumaßnahme wird mitfinanziert durch Steuermittel auf Grundlage des von den Abgeordneten des Sächsischen Landtags beschlossenen Haushalts.

Research partners:

Practice partners:

18th Newsletter of the UFZ Green Roof Research

After the 17th UFZ Green Roof Research Newsletter addressed the colonisation of green roofs by fungi and their establishment in the green roof habitat, this time the focus will be on the ability of such fungi to eliminate or render harmless organic environmental pollutants introduced by humans. Firstly, the general principles of the biocatalytic conversion of organic pollutants by fungi will be examined in more detail. Subsequently, organic environmental pollutants that are to be expected on green roofs (Fig. 1) are discussed. Finally, the potential of fungi on green roofs for the elimination or conversion of environmental pollutants is illustrated in more detail using examples.

Author of the Newsletter: **Dr. Dietmar Schlosser**, UFZ, Department Applied Microbial Ecology

Figure 1: The UFZ research green roof facility is also used for the quest for new biocatalysts (organisms, enzymes) for the circular bioeconomy .
(Photo: Johanna Sehrt)

Fungal degradation and biotransformation of organic environmental pollutants

Many fungi of different taxonomic groups and habitats have the ability to completely degrade organic pollutants in the environment such as, e.g. polycyclic aromatic hydrocarbons (PAHs), dioxins, explosives, dyes and also plastics, or to transform them into less toxic compounds [1-4]. Some environmental pollutants can be utilised by fungi as a nutritional source. However, a large number of organic pollutants are converted by fungi cometabolically, i.e. in the presence of a substrate that can be used for growth and energy production. The ability to completely degrade the natural and complex macromolecule lignin down to CO_2 and H_2O represents a special habitat adaptation of a number of higher fungi (basidiomycetes) and enables them to also completely degrade many organic pollutants. The unspecific extracellular enzymes (oxidases and peroxidases) of their so-called ligninolytic system are responsible for this. Frequently, the utilisation of a pollutant to generate energy and building blocks for the construction of biomass is also associated with a complete degradation to CO_2 and H_2O. In other cases, pollutants are not completely converted to CO_2, but various organic products are formed. The term "biotransformation" is often used here instead of "degradation". The degradation or biotransformation of organic pollutants by fungi is generally oxidative and requires the presence of oxygen. However, individual partial reactions can also involve partial reductions [3, 5, 6].

Urban environmental pollutants on green roofs

Typical urban environmental pollutants are relevant for green roofs as well as for other blue-green urban infrastructures (e.g. tree trenches, green spaces). Possible entry pathways are e.g. formed by the conceivable purification of domestic grey water with the aid of wetland roofs (for subsequent use for irrigation purposes), as well as by the atmospheric deposition of particulate pollutants and particle-bound (e.g. sorptive), dissolved or gaseous pollutants [7-9]. Corresponding compounds can originate from very different sources. Examples include urban traffic in the form of exhaust gas combustion residues (PAHs such as naphthalene) and tyre wear (rubber particles, microplastics, 2-mercaptobenzothiazole; the latter is used as a vulcanisation accelerator in tyre production), biocides (e.g. carbendazine, diuron, mecoprop, terbutryn in plasters and paints as anti-fouling and wood protection), as well as functional plastic surfaces (phthalic acid ester-based plasticisers such as diethylhexyl phthalate = DEHP, which is classified as toxic to reproduction) [7-9].

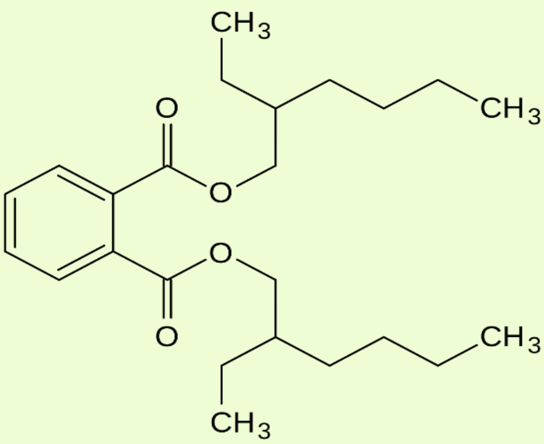

Figure 2: Structural formula of DEHP or bis(2-ethylhexyl) phthalate (= diethylhexyl phthalate) without information on stereochemistry (by user Dschanz - Own work using: BKchem, Public domain, https://commons.wikimedia.org/w/index.php?curid=2850227).

Transformation of organic environmental pollutants by fungi on green roofs

A large number of fungi of different taxonomic groups and lifestyles, including both symbiotic (mycorrhizal) and non-symbiotic fungi, have been identified on green roofs [10, 11]. A total of 19 fungi have been identified at species level on the three roofs of the UFZ research green roof facility in Leipzig, which differ in terms of substrate, vegetation, irrigation and maintenance requirements [12]. Together with plants, bacteria and archaea, fungi can be regarded as key players in the natural degradation and transformation processes of urban pollutants on green roofs and in other blue-green infrastructures [7]. In laboratory experiments, several fungal isolates obtained from the UFZ research green roof were able to effectively transform the phthalic acid esters DEHP (Fig. 2), dibutyl phthalate and diethyl phthalate, as well as the endocrine disruptor bisphenol A. Phthalate esterases detected in the fungal cultures are apparently responsible for the hydrolysis of the phthalic acid esters [12, 13]. In addition, biosorption processes involving the fungal biomass also contribute to varying degrees to the removal of the aforementioned compounds from the aqueous phase.

18th Newsletter of the UFZ Green Roof Research

As part of the five-year FINEST (Use and management of finest particulate anthropogenic material flows in a sustainable circular economy) research project funded by the Hermann von Helmholtz Association of German Research Centres, new biocatalysts are currently being sought in order to effectively recycle microplastic fractions of fine-particulate wastes currently almost lacking feasible recycling options (https://finest-project.de/project/finest-microplastics/). Among other things, fungal communities from the UFZ research green roof (Fig. 3) are being investigated as possible sources of such biocatalysts. A number of the fungal isolates tested are able to effectively depolymerise polyurethane and other synthetic polymers [14], which can be regarded as a prerequisite for the recycling of such materials.

Fungi on green roofs can thus not only make a potential contribution to the elimination of environmental pollutants on green roofs, but also serve as valuable bioresources in the search for new biocatalysts for a circular bioeconomy.

Figure 3: Agar plate culture of a fungal isolate from the UFZ research green roof facility. The fungus grows on an aliphatic polyester-polyurethane dispersion as its sole source of carbon and energy. The arrows indicate areas where the polyurethane was depolymerised and the turbidity of the culture medium was thus eliminated.
(Photo: Stefanie Clauß, UFZ)

References

[1] https://doi.org/10.1007/s12268-011-0120-5
[2] https://www.fluter.de/pilze-plastik-muell-nachhaltigkeit
[3] https://doi.org/10.1038/nrmicro2519
[4] https://doi.org/10.1007/s00253-015-6879-4
[5] https://www.taylorfrancis.com/chapters/mono/10.1201/9781315119496-45/fungal-community-organically-polluted-systems-john-dighton-james-white
[6] https://doi.org/10.1007/978-3-030-29541-7_2
[7] https://doi.org/10.1007/978-3-662-66916-7_11
[8] https://doi.org/10.1186/s12302-021-00547-2
[9] https://doi.org/10.3390/w13192609
[10] https://doi.org/10.1371/journal.pone.0058020
[11] https://doi.org/10.3389/fevo.2018.00005
[12] Sehrt, Johanna (2021): Bachelorarbeit, Universität Leipzig.
[13] Clauß, Stefanie (2021): Bericht zum Forschungsgruppen-praktikum, Martin-Luther-Universität Halle-Wittenberg.
[14] Clauß, Stefanie: Unveröffentlichte Ergebnisse.