INNOVATIVE GEOTEXTILE CONTAMINANT BARRIERS IN INFRASTRUCTURE APPLICATIONS – ENVIRONMENTAL PROTECTION WITHOUT SURFACE SEALING

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Abstract

Our road and railroad infrastructure contributes to a considerable extent to the sealing of urban areas. Due to the intensive and still growing use of these traffic routes, pollutants, such as microplastics, hydrocarbons, heavy metals, and others accumulate on sealed asphalt or concrete surfaces. With each rain event, these contaminants are flushed into the sewer system (present best case) or just enter the surrounding soil and the groundwater untreated (present worst case). Innovative, large-area, permeable contaminant barriers made of geotextiles overcome the concept of piping runoff water and centralized treatment in wastewater treatment plants. By treating the water directly at the source of the contamination, surface sealing and thus interference with natural flow paths are significantly reduced. The groundwater protection measurement is therefore called "passive in-situ treatment" or "passive in-situ decontamination". Geotextiles mechanically stabilize sorbents such as activated carbon or oil binders in a sandwich fabric. HUESKERs active geocomposites place the sorbents directly where pollutants enter the environment. The use of active geocomposites lead to a highly effective ground protection in which only a barrier against pollutants is build, but not for the carrier medium –the runoff or seepage water. Thus, no further sealing is necessary. The presentation will explain different application for large-scale permeable contaminant barriers in infrastructure based on three case studies: Field trails with filter trenches along roads in Germany, Construction of a filtration basin for road runoff in Finland, Earth structures with contaminated soils – valuable construction material instead of waste.

Keywords: contaminant barrier, geocomposite, groundwater protection, innovative material, infrastructure

1 Introduction

More than ever before, environmental protection is being taken into account in the planning of transport routes, industrial, commercial, storage and handling areas. An important goal is to prevent the spread of pollutants generated using the areas into the underground. Nowadays, surfaces with potentially significant contamination are sealed with impermeable concrete or asphalt layers in order to collect the carrier medium of the substances of concern – the runoff. The collected water is discharged and treated centrally in wastewater treatment plants. This scenario describes the desirable case for subsoil protection according to today's standards. In many places, however, traffic routes and other sealed areas are not connected to the sewer infrastructure, and consequently pollutants enter the subsoil and ultimately also the groundwater untreated. Better protection of this finite resource should therefore be sought. New construction materials provide smart and cost-effective options for subsurface

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protection. In this paper innovative permeable contaminant barriers made of geotextiles will be introduced. Large-size, so-called active geocomposites made of two layers of geotextiles that sandwich a sorbent, enable effective, decentralised treatment in different applications. The use of a range of different sorbents, such as activated carbon, oil binder or heavy metal binder (Figure 1), enables manufacturing of customized systems for site-specific pollutant situations. As large-area, permeable filters, these products prevent the flow of pollutants, but not the flow of the carrier medium. The interference with the natural flow paths of the water is therefore significantly reduced and a connection to an existing sewer network is not required. Equipping or retrofitting our infrastructure with geotextile contaminant barriers can be realised in many places without great expense. There are many areas of application for this newly developed pollutant filters. With regard to infrastructure, this paper deals with groundwater protection at roads with the help of filter trenches or retention ponds. Moreover, the concept of building with contaminated soils as valuable construction material for earth structures, such as noise barriers or infrastructure dams, is introduced.

Figure 1 Different types of active geocomposites

2 Active geocomposites for in-situ water purification

The designation "active geocomposite" refers to a group of products, shown in Figure 1, that consists of at least two layers of geotextiles that sandwich a granular or powder amendment material. The latter has the ability to remove contaminants from water or gas.

2.1 Geotextiles (Carrier and cover layer)

Either woven or nonwoven geotextiles are used as carrier and cover layer of an active geocomposites. These two layers are joined by mechanical bonding techniques, such as needle-punching or sewing. Depending on the selection of different geotextiles and binder techniques, different properties result for the final product, e.g., tensile strength, elongation, water permeability, etc. In this way, optimal active geocomposites can be customized for different applications. Permeability is of utmost importance for the system and the overall approach of decentralized water purification. In contrast to sealing systems, such as geomembranes or geosynthetic clay liners, active geocomposites have a high permeability. The coefficient of permeability is $k \geq 1,0E\text{-}5$ m/s [1]. The high permeability ensures that the natural water flow path remains unaffected, while the exposure path of the contaminant is interrupted with the help of the sorbents.
Another important aspect is the high durability of the materials. Oxidation tests can be used to simulate the ageing of the geotextile components in order to make statements about their service life in situ. A life expectancy of 100 years can be considered normal for quality manufactured geotextiles which have been correctly installed and exposed to natural conditions with soil pH values of $4 \leq pH \leq 9$ and soil temperatures of ≤ 25 °C.

2.2 Sorbents (Active layer)

To purify water, different kinds of sorbents are used in pump & treat systems or in wastewater treatment plants since a long period of time. Depending on the molecular structure of the pollutant, the most suitable sorbent must be selected. In general, a distinction is usually made between organic and inorganic pollutants. For infrastructure applications the group of petrochemicals must also be considered environmentally harmful.
Organic pollutants consist of hydrocarbon compounds which form chains or aromatics. Those frequently encountered in conjunction with infrastructure are for example polycyclic aromatic hydrocarbons (PAH) and petroleum derived hydrocarbons (TPH). This group of contaminants can be sorbed by activated carbon. Because of their mesoporous structure, granular activated carbon has a very large surface area. For example, 10 g of this sorbent has a surface area like a football field. Basically, the larger the surface area is, the more pollutants can adhere.
Inorganic pollutants are for example, metals and metalloids, such as chromium, copper, and lead. Even at low concentrations, some of metals pose a risk to the environment and to human health. This group of pollutants are only slightly adsorbed by organic sorbents, such as activated carbon. For the removal of metals, for water streams cationic sorbents are more effective. A natural molecular sieve for heavy metals is, for example, the mineral zeolite.
It is generally assumed that one drop of oil can contaminate approximately 600 to 1000 litres of water. A barrier for oil is therefore crucial, especially on traffic areas. For oil, gasoline and diesel (petrochemicals), the use of oleophilic and at the same time hydrophobic nonwovens is suitable. This is not a granulate, but a textile that serves as a barrier to pollutants. Since it has poor properties in terms of tensile strength or UV resistance, it should also be sandwiched by other protective geotextiles.
In the following chapters different designs with active geocomposites in infrastructure applications will be shown.

3 Filter trenches along roads

Due to the intensive use of transport routes, pollutants such as microplastics, petroleum derived hydrocarbons and heavy metals accumulate on and next to the sealed asphalt surfaces. This occurs not only in the event of accidents, but also on a daily basis through normal tyre and brake wear as well as fluid losses from vehicles. Active geocomposites in the shoulder area of the road enable filtration of the substances on roads and areas without a sewage system. So-called filter trenches consisting of the active geocomposite under a 30-50 cm thick layer of topsoil significantly reduce the pollutant load. The pollutants and suspended solids are demonstrably retained, as can be seen in Figure 2. Since the active geocomposites remain permeable for a long time, the functionality and life expectancy of these filter trenches are comparable to that of the cover asphalt layer. Extensive field trails and pilot studies confirm the good properties of the geotextile pollutant filters for use in road construction.
In the field tests on a road in a German city, it was found that HUESKER's geocomposite with the absorbent nonwoven (product is shown on the left in Fig. 1) and a 20 cm topsoil removed the suspended soil from the runoff with an average efficiency of 95 %. The specification for decentralised precipitation treatment on roads in Germany according to the German Institute for Structural Engineering (DIBt) is 92 %. The system of a thin soil layer and an active geocomposite thus clearly complies with the requirements.

Figure 2 Generic design of a filter trench (top), test fields (bottom left) and unfiltered vs. filtered runoff from test fields (bottom right)

Metal retention is also a requirement for decentralized treatment systems in Germany. Due to the generally known fact that metals, such as copper, lead and chromium, adhere to these particles, a very high treatment of these metals also took place. The retention of metals is shown in Table 1. Despite the mix of different pollutants, however, the use of an active geocomposite is purposeful. More values, such as retention of petroleum derived hydrocarbon, or clogging of the geocomposite was analysed but will not be addressed in this paper.

Table 1 Average retention of metals in filter trench

Metals relevant on roads	**Average retention with topsoil and HUESKER's active geocomposite with absorbent nonwoven**
Lead (Pb)	92 %
Copper (Cu)	88 %
Zinc (Zn)	84 %

4 Filtration basin for road runoff

Trenches are not the only way to remove substances of concern from surface runoff. Stormwater retention basins consisting of a floor lined with the permeable contaminant filter also allow for water purification. In the City of Tampere in Finland there is a stormwater pond which collects water from the surrounding roads. During ground water monitoring increased values of petroleum derived hydrocarbons and PAH have been noticed. The aim was to stop the influx of these contaminations into the groundwater. The first idea was to filter out contaminants before entering the pond, but it was impossible to identify the main influx location. The decision was made to renew the pond and to equip the floor with two layers of active geocomposites, as shown in Figure 3. First, the active geocomposite filled with activated carbon was installed. On top, the product with the oil-absorbent nonwoven was placed. In this way, a highly effective treatment train was built to remove the pollutants of concern and consequently protect the downstream drinking water reservoirs (i.e., the groundwater) of the city. The estimated minimum functionality for the pollutant filter system is 30 years. In order to protect the nonwoven filter layer from UV radiation a sand/gravel drainage layer was installed on top of the treatment system. In this project not only the most suitable sorbents were chosen but also the thickness of the absorbent nonwoven and the amount of activated carbon was adapted to the project's needs.

Figure 3 Basic functional principle (right) and construction of the ponds floor (left) [2]

5 Earth structures with contaminated soils

Basically, active geocomposites can be used whenever contaminated water or gas seeps or diffuses through the fabric. With regard to infrastructure projects, another application besides the runoff purification is the construction of earthworks, e.g., as noise barriers or railroad embankments. Some countries allow the use of substitute construction materials, such as reclaimed concrete, slag, ash, or slightly contaminated soil, if the distance to the groundwater table is large enough. This restriction is made in order to avoid the accumulation of leached cations (metals) in the groundwater with the help of the natural retention of the soil. If, however, the substitute building material is classified as too highly contaminated, additional encapsulation with a waterproofing geomembrane is required. Active geocomposites offer the option of omitting the sealing of the earth structure. Instead of placing a geomembrane over the earthwork, the permeable contaminant filter can be placed underneath. Leaching is then not critical since the underlying subsoil is effectively and permanently protected. The products are designed in such a way that the capacity limit of the sorbents is not reached with a defined degree of certainty. Even a theoretical leaching of all contained pollutants from the soil matrix can thus be bound by the filter. There is then no danger to the subsoil and strict adherence to a defined distance from the groundwater table is not necessary.

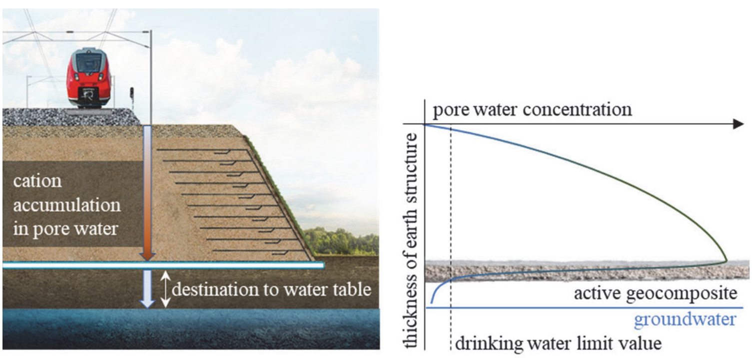

Figure 4 Schematic leaching of contaminants through earth structure (left) and pore water contaminant concentration over the thickness of the structure (right)

6 Conclusion

The use of large-area, permeable geotextile contaminant barriers offer new possibilities for soil and groundwater protection as well as for reuse of contaminated soil as valuable building material. Sealing of the underground and building of sewer networks, as it is necessary for centralised water treatment, is overcome by this innovative treatment approach. The geotextiles mechanically stabilize the sorbents and thus allow an incorporation of these purification agents in-situ over large areas in new and existing infrastructure. This allows for installation or retrofitting in a wide range of applications, such as roads, railroads, retention ponds, earthworks, and many more. New designs can be created technically and economically effective. Exposure pathways of contaminants can be interrupted without changing the natural flow path of the water. The latter is more important than ever before also in regard to climate change. Decision makers need to reduce land sealing to protect cities against flood events as a consequence of heavy rainfalls. The term of blue-green infrastructure refers to a more resilient fitting of our build environment to changing climate conditions. Active geocomposites can become one puzzle piece in this regard.

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