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30 FILTER MATERIALS - A POSSIBLE METHOD TO OPTIMISE THE REDUCTION AND RECYCLING OF PHOSPHORUS IN SMALL-SCALE WASTEWATER TREATMENT SYSTEMS?

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ABSTRACT

One of the environmental goals adopted by the Swedish Parliament concerns the reduction and extended recycling of nutrients, especially phosphorus (P). Phosphorus is discharged into the environment through poorly treated wastewater, especially in sparsely populated areas where few people are connected to the municipal sewer-system. In these areas, small-scale wastewater treatment systems such as constructed wetlands and infiltration systems have been used as treatment facilities. These systems have shortcomings and the recycling of phosphorus is very limited. New methods have therefore been searched for. One interesting method is the use of filter materials that efficiently sorb high amounts of phosphorus and, when P-saturation is achieved, could be used as soil conditioner or P-fertilisers. The criteria such materials have to fulfil are that they have a high P-sorption capacity, are available and that sorbed phosphorus is available for uptake by plants. Different filter materials, natural materials as well as anthropogenic ones have been tested in different kinds of investigations. Most materials have been tested in batch experiments, others have been selected for further studies in column experiments and a few materials have also been tested in field experiments. A few materials have also been investigated with regard to plant availability of sorbed phosphorus. The results from the different investigations are promising, even though the knowledge still is scarce. In order to learn more about these materials, further studies are suggested.

KEYWORDS

Constructed wetland, Filter material, Infiltration system, Phosphorus removal

1. INTRODUCTION

Excess nutrients, e.g. nitrogen (N) and phosphorus (P), in water bodies cause undesirable environmental effects such as eutrophication. In order to avoid this special problem, as well as others, the Swedish Parliament has adopted fifteen environmental goals. One of these goals concerns the reduction of nutrient discharges into the environment and an increase in the recycling of these nutrients back to the agriculture. One is especially concerned about phosphorus (P), since this nutrient is regarded as a limited resource (1).

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In Sweden, discharges of phosphorus occur through run-off from the agriculture and from a large number of countryside households discharging poorly treated wastewater. These households are not connected to the municipal sewer-system, and consequently have to rely upon other treatment facilities. In most cases, these facilities consist of simple septic tanks or infiltration into the ground. The treatment facilities are in many cases not adequate for a proper wastewater treatment, thus the discharges of phosphorus. Eco-technologically on-site treatment systems, such as constructed wetlands and soil infiltration systems have been regarded as favourable methods for removal of phosphorus not only in Sweden (2, 3) but also elsewhere (4, 5, 6, 7). With regard to the P-removal capacity, the systems have proved to remove phosphorus, but they still suffer from some shortcomings. Constructed wetlands for instance, require a large surface area that implies that the P-removal per-unit-area is low (6) while in soil infiltration systems, the P-removal has been reported to decline over time (8). In addition, the recycling of phosphorus from these systems is very limited.
With regard to the desire of a sustainable society with demands on phosphorus recycling, new ideas have to be developed for the small-scale wastewater treatment systems. Different treatment systems based on recycling have been developed and there has been a large interest for these systems, not only from municipalities, but also from house owners (9). One of these systems that have been pointed out as an attractive system is the filter bed technique. The technique is based on wastewater passing a special filter material that is incorporated into a constructed wetland, an infiltration system or a special filter box. The filter material efficiently sorbs phosphorus and separates it from the wastewater before it reaches the recipient. When P-saturation is achieved, the filter material could be transferred back to agricultural land as soil conditioner or P-fertiliser (10).
The interest for the filter bed technique is big, not only in Sweden, but also world wide, which has been manifested through a large number of scientific papers and reports on the testing of different potential filter materials suitable for use in constructed wetlands or in infiltration systems. The aim with this paper is therefore to present a short overview on the latest research within this field.

2. METHOD

The research on filter materials begun in the early 1990's and has been carried out since then. In the end of the 1990's, a number of PhD thesis on the topic were presented in different European countries. This paper is partly based on these thesis works, and partly on a recently conducted literature survey. The latter was carried out in order to include some of the latest research results.

3. RESULTS

From the literature survey, it can be concluded that a filter material intended for use in the small-scale wastewater treatment systems like those mentioned above must fulfil several criteria. These criteria include a high P-sorption capacity, availability of filter material, and availability of sorbed P for uptake by plants.

3.1 P-sorption capacity

The major P-removal processes in constructed wetlands and infiltration systems are different kinds of sorption processes (11) and therefore, the P-sorption capacity of the filter material is one of its most important characteristics (12, 13, 14, 15). Several factors affect the extent of P-sorption, for instance the content of aluminium (Al), iron (Fe) and calcium (Ca). From the literature survey, it can be concluded that the different materials tested are rich in one, or several of these constituents.
These constituents can be found in different types of materials. The materials that have been subject for research can roughly be divided into natural materials and anthropogenic materials. The natural materials consist of soils, rocks and marine sediments, while the anthropogenic ones can be further divided into industrial by-products and processed products. Examples of investigated materials are presented in table 1.

Natural materials		Anthropogenic materials	
Soils:	Marl gravel, shale	Industrial by-products:	Blast furnace slag
Bedrocks:	Opoka	Processed products:	LECA, LWA-products
Marine sediments:	Shell sand		

Table 1. Filter materials that have been investigated with regard to their P-sorption capacity

These materials have all been the subjects of initial P-sorption studies through batch experiments (16, 17, 10, 18, 19, 20 and 21). The materials tested in batch experiments have all been exposed to P-solutions, or in some cases natural wastewater, for a certain period of time. Some researchers (16) have exposed the filter materials to very high P-concentrations ranging from 10 to 1 000 mg/l or more, while others (10, 18) have tested P-concentrations more similar to P-concentrations in an ordinary wastewater.
Promising results from the batch experiments resulted in further studies in column experiments. Opoka (a marine deposit found and excavated in Poland), shell sand, blast furnace slag, burned shale (an argillaceous rock quarried as a raw material for brick making) and LECA (Light Expanded Clay Aggregates) were selected for such studies (10, 18, 20, 21). Marl gravel, burned shale and LECA proved to have a high P-sorption capacity also in the column experiments and were consequently tried in field investigations. Marl gravel was tested for a limited period of time (16), while the constructed wetland using LECA as filter material is still in operation. The results from these field experiments showed in the case of marl gravel that the material had limited potential to reduce phosphorus, and in the case of LECA that the removal of phosphorus still occurs.

3.2 Availability of filter materials

There are several reasons for testing new materials. One reason is that natural occurring materials are not available to the desired extent or are too expensive, which has made it necessary to investigate other materials that are available or cheaper (19).
Another reason for testing new materials has simply been the presence of a potentially suitable material at a certain location. Shale has been investigated due to its potential suitability as filter materials and due to the fact that it is a commonly available material in central Scotland (17). In Norway, shell sand is available along the Atlantic coast and it is mined as a fertiliser since it is rich in Ca. This property also made the material interesting for use in constructed wetlands (18).

3.3 Availability of sorbed phosphorus for plant uptake

The recycling of phosphorus sorbed to filter materials used in small-scale wastewater treatment systems has been the subject of a very limited number of studies, even though several researchers mention that the filter materials probably could be used as fertilisers when P-saturation is achieved (10, 17, 20).
The research available describes an extraction experiment and a pot experiment (22, 23, 24). In the extraction experiment (22), a number of filter materials, including different blast furnace slag materials, were initially exposed to P-solutions of varying concentrations. Thereafter, the sorbed phosphorus was extracted utilising ammonium-lactate as extractant. The results from this study indicated that some slag materials sorbed and desorbed phosphorus to a certain extent. The pot experiment (23) was based on the slag materials showing the best results in the preceding experiment. Materials were saturated with phosphorus, they were thereafter used as soil media in pots in which rye (*Hordeum vulgare L. c.v. Pernilla*) was sawn and cultivated in a greenhouse. After a month, the rye was harvested, dried and analysed for phosphorus. It was concluded that phosphorus sorbed to some slag materials was available for uptake by plants, indicating that these materials could have the potential to work well in a small-scale wastewater treatment system and thereafter be used as soil-conditioner or P-fertiliser.

4. DISCUSSION

There is no doubt that the interest for the filter bed technique is large all over the world. Several researchers have presented promising results from different types of studies, but the knowledge is still rather limited due to testing methods and variations in testing parameters. A large number of different filter materials have been tested in laboratory experiments, most of them in batch and column set-ups. This fact contributes to limitations in the knowledge of the materials capacity to remove phosphorus in field conditions, since these in general are much more complex than laboratory conditions. But the researchers who have tested materials in laboratory scale with promising results often suggest that the materials should be tested also in field experiments. The filter materials that have been subjects of field experiments have been in use for rather short periods making it difficult to draw any conclusions about the time-dependent sorption capacity.
Another shortcoming so far, is the limited knowledge of the possibilities to use the filter materials as soil-conditioners or P-fertilisers when P-saturation is achieved. Some researchers have mentioned the possibility to use the P-saturated materials within the agriculture, but only a few studies on the topic are available.
The use of small-scale wastewater treatment systems gives rise to risks of infections and, this could also be the case when using filter materials, even there are no studies presenting results on this specific application. It is however worth mentioning since the filter materials are supposed to be spread on agricultural land after P-saturation, and in this case it is important to know that no contaminants are attached to the filter material. Further research is therefore suggested in order to learn more about other substances than phosphorus that might be sorbed by the filter materials.

5. CONCLUSIONS

Many results on the P-sorption capacity of different filter materials presented in the literature are promising, but the knowledge of how the P-sorption capacity will work in the field is very limited. It is therefore suggested that this research should be made possible, not only in Sweden but also elsewhere since the problem of excess phosphorus in water bodies is a global environmental problem. Research should also continue of the availability of sorbed phosphorus for uptake by plants since this is an important step in obtaining an increased recycling of phosphorus. It is also suggested that further research should be carried out on potential risks of infection that the use of filter materials could give rise to if spread on agricultural land.

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