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Guidelines and prediction tool for pharmaceuticals removal during bank filtration

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Abstract

Bank filtration (BF) is a well known method of water treatment which also has high potentails for removal of organic micropollutants including pharmaceuticals. Guidelines and prediction tools were developed to estimate the removal of different classes of organic micropollutants or single compound during BF. The guidelines include 7 different classes of organic micropollutants. The guidelines are part of a prediction tool which enables users to estimate the removal efficiencies based on either residence time or travel distance from a water source using zero or first-order kinetic models. The accuracy of the prediction tool was tested using data from a BF site and the reliability of the estimates was assesed. Output from the prediction tool is a range of removal efficiency of a selected compound. Residence times provided a better estimation of pharmaceutical removal compared to travel distance in the prediction tool. One of the limitations is that the tool can be used only within the specified influent concentration ranges. If the influent concentration at a given site is of the range, no preliminary estimate of removal can be made. However, having a prediction tool for BF systems will provide a preliminary assessment of removal or fate of specific compounds or different classes of compounds to users.

Keywords: bank filtration, organic micropollutants, pharmaceuticals

1 Introduction

Bank filtration (BF), involving soil/aquifer-based natural treatment processes, can potentially be included in a multi-barrier treatment for pharmaceutical removal in indirect potable reuse schemes. However, there are a number of considerations such as design and operational conditions that must be met for the barrier to be effective in attenuating a range of pharmaceuticals including non-steroidal anti-inflammatory drugs (NSAID), antibiotics, antiepileptic drugs, blood lipid regulators, beta-blockers and contrast media. Important design/operational factors include travel distances, residence (travel) times, and redox conditions (i.e., oxic and anoxic conditions). Soil/aquifer-based natural treatment processes can be classified into two types: (i) BF induces infiltration of the source water (e.g., river or lake) to abstraction wells which create a hydraulic gradient by pumping (ii) artificial recharge and recovery (ARR) in which river or lake water, or wastewater effluent (i.e., soil aquifer treatment (SAT)) is diverted to an infiltration/recharge basin and later abstracted by recovery wells. For the former, more anoxic conditions often dominate with transport through the saturated zone; residence time and travel distance are generally longer which can be controlled by pumping rates. For the latter, more oxic conditions dominate with transport through both the unsaturated (vadose) zone and saturated zone; generally, residence times and travel distances are generally shorter. Redox conditions also play an important role in removing some pharmaceuticals that are dependent to redox conditions (Schmidt et al., 2003). Moreover, depending on the physico-chemical properties of pharmaceuticals, their principal removal mechanisms during soil/aquifer passage include sorption and biodegradation.

2 Material and methods

A literature survey was carried out on the fate and transport of organic micropollutants in BF systems and column studies. A total number of previous studies and their types are summarized in Table 1. Guidelines and prediction tool for pharmaceutical removal during BF were compiled and showed in Fig. 1. Moreover, field database which comprised of measurements of physical and chemical parameters taken along the transects at BF and ARR sites were also used Organic micropollutants detected in these systems mainly comprised of not only for pharmaceutically active compounds (PhACs) but also flame retardants and pesticides. These datasets were analysed using SPSS 14.0 (SPSS Inc, Chicago, Illinois, USA) to establish generalised relationships between variables and selected organic micropollutants. The methods employed in the analysis were correlation analysis, multiple linear regression analysis, clustering of data, and factor analysis.

Table 1: Literature sources and study types used to compile database

Types of bank filtration studies	No. of Literature Sources
Batch	-
Column	15
Field Sites (20 No. sites)	27
Total	42

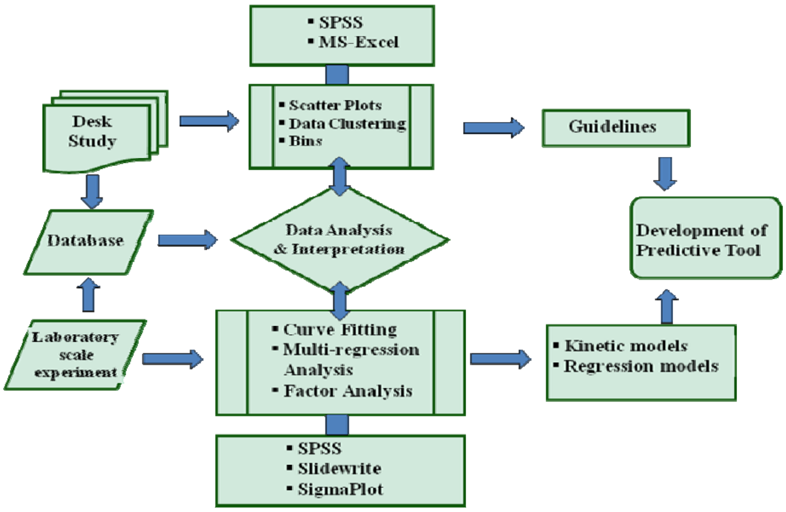

Figure 1: Methodology of a developing guidelines and prediction tool for predicting pharmaceutical removal during soil passage

3 Results and discussion

3.1 Guidelines

Guidelines were developed for seven groups of organic micropollutants. For each group, ranges of removal efficiencies corresponding to residence times and travel distances were proposed. These results are presented in scatter plots indicating the created bins and tables which summarize the bin computations and the proposed guidelines.

Pharmaceutically active compounds

PhACs comprises of various pharmaceuticals and their transformation products from 6 field studies/sites and 5 column studies. Scatter plots and the analysis of the removal efficiencies against residence time and travel distances are presented in Fig. 2, Fig.3, Table 2 and Table 3.

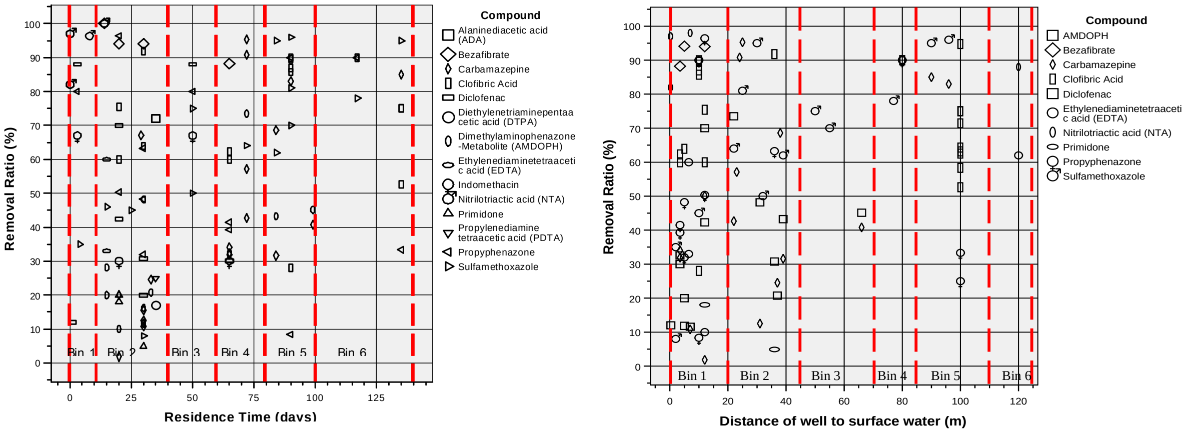

Figure 2: Plot of removal efficiencies of PhACs with (a) travel times and (b) travel distances

The proposed predictive removal efficiencies for PhACs are summarized in Table 2 and Table 3. For example, the scatter plots show residence times and travel distances to attain removal efficiencies above 30% (75 days of residence times or 60 m travel distances). In fact, various physical/chemical processes are responsible for the removal of PhACs.

Table 2. Analysis of scatter plot of PhAC removal with well distances

Influent range (µg/l)	Effluent range (µg/l)	Distance (meters)	Removal Ratios (%)	No. Of Cases	Average (µg/l)	Standard deviation (µg/l)	Predictive removals (%)
0.015 - 520	0.0 - 290	0-20	2-98	44	55	31	23-54
		20-45	5 -95	20	54	28	54-58
		45-70	41-75	4	58	17	58-75
		70-85	78-90	4	87	6	75-87
		85-110	25-96	14	68	22	87-89
		110-125	62-88	2	75	18	89-93
			Total No.	88			

Table 3. Analysis of scatter plot of pharmaceutically active compound removal with travel times

Influent Range (µg/l)	Effluent Range (µg/l)	Residence Time (days)	Removal ratios (%)	No. Of Cases	Average (µg/l)	Standard Deviation (µg/l)	Predictive Removals (%)
0.015 - 520	0.0 – 290	0-10	12-100	10	74	29	12-45
		10-40	2-100	38	45	29	45-58
		40-60	50-88	5	72	14	58-72
		60-80	30-95	14	58	23	72-80
		80-100	8-96	17	65	27	80-93
		100-140	33-95	10	76	19	93-96
			Total No.	94			

3.2 Prediction tool

Main page and typical computation windows of prediction tool are shown in Figure 3 and Figure 4. On each computation sheet for the removal of groups of organic micropollutants or single pharmaceutical, the limits of the guidelines are clearly indicated. Also, a hyperlink is also provided to the full display of the guidelines and references used in their compilation. Output from the prediction tool is given as a range of removal efficiency of a selected compound and compared data obtained from field sites. Residence times showed a better estimation of pharmaceutical removal compared to travel distances in the prediction tool. The tool can be used within specified influent ranges. However, validation of this prediction tool needs to be carried out.

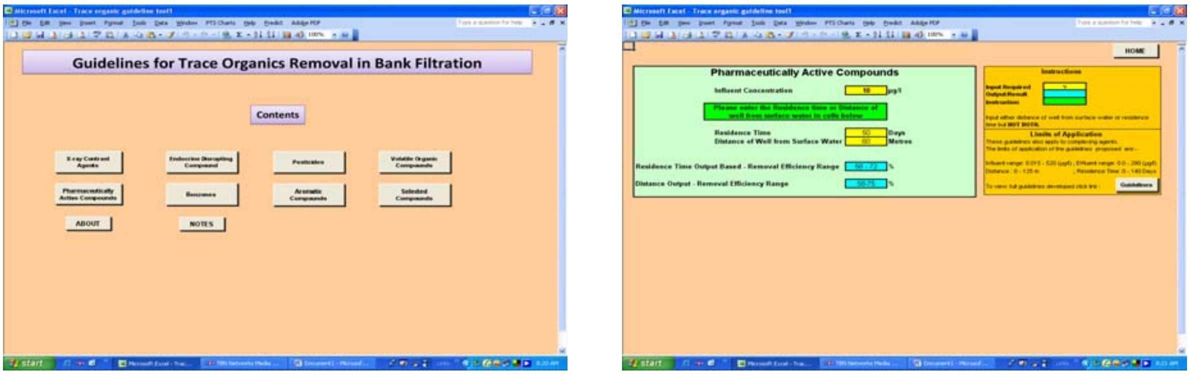

Figure 3: Screen capture of a prediction tool for BF system: (a) main menu and (b) computation windows

References

Schmidt, C.K., Lange, F.T., Brauch, H.J., W., K., 2003. Experiences with riverbank filtration and infiltration in Germany. International symposium on artificial recharge of groundwater. K-WATER, Daejon, Korea, pp. 117–131.