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Bank filtration: A sustainable water treatment technology for developing countries

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As good quality water sources become more scare, water quality standards become more stringent and the cost of water treatment is increasing, there is need for a sustainable and robust water treatment technology. Bank filtration has been used for surface water treatment in Europe and USA for many years. However, this technology has not been utilised fully in developing countries. Bank filtration is a natural process of water treatment which is simple, avoids the use of chemicals and when properly designed and operated produces water of acceptable quality and reduces the cost of water treatment. It utilises the physical, chemical and biological removal processes in the soil and aquifer for purification of surface water during its passage to production wells. Based on the results of two feasibility studies conducted in Malawi and Kenya, this paper elaborates on the potentials and constraints of promoting bank filtration technology for water treatment in developing countries.

Introduction

Good quality water sources are getting more scarce and pollution of the water sources is increasing due to overexploitation of water resources to meet the increasing water demand and insufficient sanitation services provision. On the other hand, water quality guidelines are getting more stringent due to the increasing number of emerging contaminants in water and consequently the cost of water treatment is increasing. In many developing countries, disinfection (very often chlorination) is the only treatment applied to public water supply. In this context, there is a need for a robust water treatment technology which is effective, low-cost and could be operated and maintained relatively easily in developing countries.

Bank filtration for water treatment

Bank filtration (BF) applied to a river or lake, is a reliable, natural and multi-objective treatment process which removes particles, biodegradable organic compounds, trace organics, microorganisms as well as ammonia and nitrate to some extent. Furthermore, it also dampens temperature peaks and concentration peaks associated with spills. BF could replace or support other treatment process, thus providing a robust barrier within a multi-barrier system and also decreases the costs of water treatment. BF is a traditional, efficient and well accepted method of surface water treatment in Europe. For more than 100 years, river bank filtration has been used in Europe for public and industrial water supply along Rhine, Elbe, and Danube rivers (Grischek et al., 2002). Several mechanisms are responsible for improvement of water quality during BF. During infiltration and travel through the soil and aquifer sediments, surface water is subjected to a combination of physical, chemical and biological processes such as (i) filtration, (ii) solution-precipitation. (iii) ion-exchange, (iv) sorption-desorption, (v) complexation, (vi) redox reactions. (vii) microbial biodegradation and (viii) dilution that significantly improve water quality. A schematic diagram of processes affecting water quality during bank filtration is presented in Figure 1.

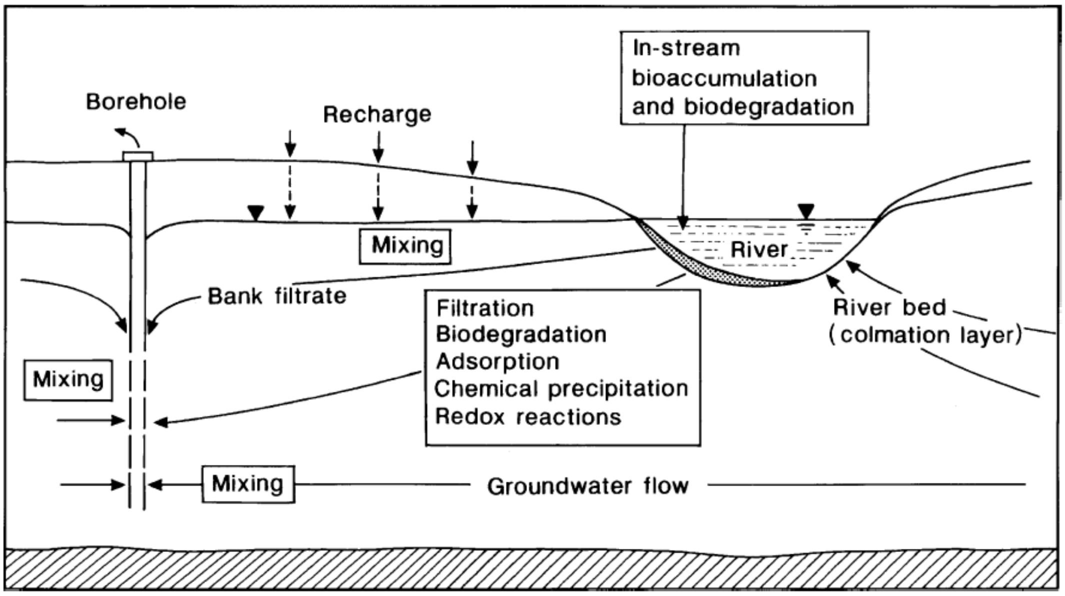

Figure 1. Schematic diagram of processes affecting water quality during bank filtration

Source: Hiscock and Grischek (2002)

Factors affecting performance of BF systems
The performance of BF with respect to water quality improvements depends on a number of variables; (i) hydrogeologic conditions including characteristics and composition of alluvial aquifer materials, (ii) river/lake water quality, (iii) groundwater dilution, (iv) filtration velocity and distance of the well(s) from river/lake, (v) temperature of the water, (vii) pumping rate, and (viii) soil/sediment characteristics at the river/lake-aquifer interface.

Attributes and Limitations of BF
The main attributes and limitations of bank filtration systems are listed below (Ray et al. 2002; IAH and IHP, 2005):

Attributes:
- BF is a natural treatment process, avoids or reduces the use of chemicals and produces biologically stable water.
- BF improves water quality by removing particles (suspended solids), organic pollutants, microorganisms, heavy metals and nitrogen.
- BF dampens concentration peaks associated with spills (in river/lake) and dampens temperature peaks.
- BF replaces or supports other treatment processes by providing a robust barrier and reduces the overall cost of water treatment.

Limitations:
- BF is site specific, and is feasible only when the local hydrogeological conditions are favorable.
- There can be leaching of the aquifer materials under reducing conditions, sometimes leading to increased concentration of iron and manganese in extracted water.
- One of the main problems is clogging of the aquifer due to accumulation of suspended matter that is filtered out when river/lake water enters the aquifer, especially when the system is not properly designed.
- BF and groundwater recharge may be only a limited barrier for certain contaminants.
- Influences of surface water and operation on quality are poorly known.

Bank filtration for water treatment in the developing countries

As bank filtration systems are simple to operate and robust, they have a high potential for application in developing countries. However, this technology has not been fully utilised in the developing countries. In some countries, wells have been constructed next to a river or pond by the local communities in order to improve water quality without adequate design considerations; however BF systems have not been used as water treatment step by water supply companies. In an attempt to promote this technology in developing countries feasibility studies for BF systems were conducted in Malawi and Kenya using a four step methodology developed at UNESCO-IHE for feasibility assessment of BF under given conditions.

Feasibility assessment for BF system

In the feasibility assessment methodology, a hydraulic model MODFLOW is firstly used to determine the travel time and pumping yield corresponding to given location of extraction wells. Furthermore, the number of the wells required for a given production capacity and their spacing is determined. Secondly, the NASRI Bank Filtration Simulator is used to compute the share of bank filtrate and local groundwater for each well location. Both of these hydraulic models can be used to assess different scenarios by changing variables such as number of wells, well spacing, and well distance from riverbank, hydraulic conductivities, and initial hydraulic head. Thirdly, water quality from the BF system is predicted using Water Quality Prediction Algorithms developed based on the literature review. Finally, the capital and O&M costs of the BF system are compared with that of existing conventional water treatment systems.

This assessment method was applied for feasibility assessment of BF in five cities in Africa; three cities in Malawi; Blantyre, Lilongwe, and Mzuzu; and two cities in Kenya; Eldoret and Nakuru. In most of these water supply systems surface water (river) is the main source of water and conventional surface water treatment (sedimentation, chemical coagulation/flocculation, clarification and chlorination) is applied. For groundwater treatment in Nakuru, chlorination is the only treatment applied. Furthermore, excessive chemical sludge production and difficulty in water treatment plant operation due to variation in the turbidity of the surface water are common in water supply systems of these cities. Details of the feasibility analysis methodology, hydraulic calculations, existing water treatment plants, water quality predictions and cost calculations are presented in Chaweza (2006) and Bosuben (2007). Salient features of the water supply systems analysed are presented in Table 1.

Table 1. Salient features of the water supply systems analysed for bank filtration

	Blantyre	Lilongwe	Mzuzu	Eldoret	Nakuru
Population	700,000	670,000	135,000	217,000	285,000
Water sources	Surface water (Shire river, Mudi dam)	Surface water (Lilongwe river)	Surface water (Lunyangwa river)	Surface water (Ellegirini, Endoroto and Moiben rivers)	Surface water (31%); Groundwater (69%)
Existing water treatment plant capacity (m^3/day)	110,000	75,000	15,000	22,000	35,950
Operational costs of existing treatment system (US$/$m^3$)	0.120	0.030	0.009	0.043	0.029
Estimated operational costs of BF system (US$/$m^3$)	0.098	0.014	0.009	0.036	0.020

Feasibility studies revealed that in all the five cities, the hydrogeological conditions are favourable for BF and with the proper design of the production wells (number, spacing and location), existing water demand can be met with the BF systems. Analysis in Malawi showed that by switching to BF, savings of over 80% on existing annual treatment costs (chemical and energy only) are likely for Blantyre and Lilongwe cities, but for Mzuzu the annual costs of BF and existing conventional water treatment are comparable. Even when chlorination is applied after BF system, there is a potential savings of 20%, 53%, and 2% for Blantyre, Lilongwe, and Mzuzu, respectively, on total annual operations costs without reducing the existing O&M staff level (which may not be required for BF system). In Eldoret and Nakuru cities in Kenya, annual operational costs savings of about 16% and 32%, respectively, could be achieved by switching from conventional surface water treatment to BF system. For both cities in Kenya, the total cost of water (per m3) from BF system is about half that of water produced from conventional water treatment systems. In terms of capital costs BF system is expected to be seven and four times cheaper than conventional water treatment systems for Eldoret and Nakuru, respectively.

Promotion of bank filtration in the developing countries

Despite the high potential BF technology is not being practised by water utilities in developing countries mainly because the BF system design is site specific and until now designs are based on local experiences. There is lack of knowledge about the mechanisms and processes involved and there are no tools, frameworks or design guidelines available to apply this technology under given local hydrogeological conditions or to transfer the experience from one region to another. The following activities should be implemented to help in promotion of BF technology for water treatment in developing countries.

- Development of design guidelines, nomographs, software, and a decision support system for application of BF technologies in the developing countries
- Including and officially recognizing BF as a viable technology for water treatment
- Information dissemination: making design engineers, planners and educators aware of the potentials of BF technology (training and capacity building; demonstration projects)
- Networking among the professionals involved in BF (at international, regional and national level) for information sharing and collaborative research.

Conclusions

- BF is a proven, cost effective and environmentally friendly technology that can reduce stresses on existing groundwater resources and reduce the incidences of diseases caused by use of untreated surface water.
- There is an enormous potential for application of BF technologies for water treatment in developing countries.
- BF could be an attractive alternative or supplement to conventional water treatment technologies.
- Switching from conventional chemical-based surface water treatment to BF, where it is feasible from hydrogeological considerations, will reduce the cost of water treatment and avoid or minimise the problem of chemical sludge treatment and disposal.
- BF technology needs to be adapted to suit the local hydrogelogical conditions and water quality requirements.
- Guidelines, tools and manuals should be developed to facilitate design and implementation of BF systems for water treatment in the developing countries.

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