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EFFICIENCY OF RIVERBANK FILTRATION IN REMOVING PATHOGENS TO IMPROVE WATER QUALITY IN MALAYSIA - A REVIEW

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ABSTRACT: In increase of pathogenic bacteria *Echrichia coli* in the surface water in the river, ground and lakes water is a concern as it is the main precursor to health hazard disinfection in conventional drinking water treatment systems. One possibility of growing interest in water utilities is the technology of riverbank filtration (RBF). RBF is a new method that could introduce non-chemical techniques and natural treatments in Malaysia. Although RBF systems are efficient in reducing or removing the concentrations of contaminants, they are mostly ineffective in the removal of pathogenic bacteria especially during flood and wet seasons. This literature focused on reports published at the last years including the pathogenic bacteria *i.e*. the total coliform, bacteria *E. coli*, *Giardia lamblia*, *Leptospira interrogans*, *Cryptosporidium* spp., *Enterococci*, *Cyanobacteria* as well as other baceria i.e. *Clostridium perfringens*. Using this method, the analysis provided an overview of the removal rates of pathogens as the main indicators of BF efficiency. In order to understand and develop further knowledge on RBF, at different locations in Malaysia. Three pilot projects of RBF facilities were constructed in the states of Selangor, Perak, and Kedah. The results from the proposed analytical model are well matched with the data collected from a RBF site in France. After this validation, the model was then applied to the first pilot project of a RBF system conducted in Malaysia. Sensitivity analysis results highlighted the importance of the degradation rates of contaminants on surface water (rivers, lakes and groundwater) quality after removal of pathogens, for which higher utilization rates led to the faster consumption of pollutants. The development perspective of RBF in Malaysia is promising. With the establishment of a management system, improvement of the monitoring system, reinforcement of legal protection, and promotion of civic awareness, Malaysia RBF will play an important role in development of the water resource industry.

Key words: Drinking water, coliform, bacteria, *E. coli*, RBF, banks filtration, Malaysia.

INTRODUCTION

Nations' Sustainable Development Goal 6 (SDG 6) aims to ensure the accessibility and management of water and sanitation for all, including an end to open defecation, by 2030. It is known that due to rapid advancement of industrialization will results in destruction of ecosystem and biodiversity loss. As mentioned by World Health Organization (**WHO, 2017**), it is expected that under supply of water will displace 700 million people by 2030, while desertification will put the livelihood of one billion people living in 100 countries across the world at risk by 2050 . To fulfill the objectives of the SDG 6, the High-Level Panel on Water has developed innovative approaches to solve global water scarcity since recent years traditional financing solutions and technologies have proven to be insufficient in addressing these challenges.

Malaysia is rich with groundwater as a freshwater source apart from surface water

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supply, and its demand has been projected to increase by 63% from 2000 to 2050 (**Manap *et al*., 2013**). In Malaysia, groundwater is in severe demand where surface water supply is non-existent and inadequate. However, groundwater has only become a highly-sought water source in the recent years because the quality of river water is continually deteriorating while water demand is expected to increase (**Shamsuddin *et al*., 2014**). Moreover, low surface water levels at the point of intake during the dry season could prevent water from being pumped to water treatment plants, and consequently stop the supply of clean water to millions of people. One of the groundwater abstraction techniques that has proven be effective in preserving groundwater and treating polluted river water for drinking purposes is the riverbank filtration (RBF) system (**Bauer *et al*., 2011**). RBF has long been recognised as a natural method for surface water treatment (**Shamrukh and Abdalla, 2010**). It is an efficient and low-cost alternative of water treatment for drinking water. During infiltration and underground transport, the processes of filtration, biodegradation, and sorption are significant to improve raw water quality (**Partinoudi and Collins, 2007**). The RBF system is interesting because it can control and remove contaminants from surface water using low-cost treatment technology (**Adlan *et al*., 2016 and Hu *et al*., 2016**). It is also an effective method of removing pathogenic bacteria and viruses during the infiltration of surface water (**Hu *et al*., 2016 and Wang *et al*., 2016**). Nonetheless, this method is sensitive to the surrounding activities on the ground, aquifer layer properties, and the physical characteristics of the river water (**Kuehn and Mueller, 2000**). As a result, the removal efficiency of microbial contaminants at different locations are varied, with less than 2.1 logs removal for *E. coli*, and more than 3.2 logs removal of viruses (**Weiss *et al*., 2005**). Nevertheless, *E. coli* and other bacteria were still observed in RBF or groundwater wells (**Cady *et al*., 2013 and Gutierrez *et al*., 2017**). Therefore, some improvements or enhancements with other treatment techniques can increase RBF efficiency.

Waterborne pathogens remain a major global health concern, causing significant morbidity and mortality in developing countries such as Iraq, where healthcare facilities and access to safe drinking water are frequently lacking. Waterborne pathogens are well known to be the primary agents of transmitted diseases such as diarrhea, cholera, dysentery, salmonellosis, shigellosis, and typhoid (**Wang *et al*., 2016**). It is also estimated that contaminated drinking water causes 502,000 deaths from diarrhea per year. Almost one-tenth of the global disease burden could be avoided by improving the water supply, sanitation, hygiene, and the management of water resources. By removing environmental contaminants, it has been possible to improve the quality of groundwater in different regions of the world. Since the amount of groundwater is not always enough to meet demand, surface water is used to supplement the groundwater reserves. Some countries obtain their drinking water from wells, which are located near riverbanks and lakes, such as Switzerland (80%), France (50%), Finland (48%), Hungary (40%), Germany (16%), and the Netherlands (7%). The RBF process is used widely in the world to sustain the quality of water supplies, which depend on the vertical and horizontal wells adjacent to the riverbanks and inter-mountain basins (**Hu *et al*., 2016**).

The hydrochemistry of river water and RBF water demonstrates that RBF water is safe to drink with barely minor treatment such as chlorination or ozonation. The RBF technique has caused a substantial reduction in pathogens concentration in water supply compared to the raw water sources.

To date, many treatment methods for the removal of *E. coli* have been introduced in treatment plants, such as membrane filtration (**Modified, 2002**), soil aquifer treatment (**Levantesi, 2010**), slow sand filtration (**Bauer *et al*., 2011**), granular activated carbon (GAC) adsorption (**Zietzschmann *et al*., 2016**), and advanced oxidation (**Tijani *et al*., 2014**). All these methods have long been used in water treatment, and proved effective for bacteria removal. However, there is no information about non-ionising radiation applications in water treatment plants in Malaysia. This method is a better option for new applications in RBF systems based on the requirements of packing materials around the well screen.

The current work aims to (a) explore the water quality of surface water; (b) compare findings with the literature on efficiency of river bank filtration in removal of pathogens from surface water in Malysia.

The calculation of water quality indexes (WQI) and analysis of each parameter are included in this study to evaluate the surface water categories and potential treatments according to identified pathogens. Moreover, this research aligns with Malaysian aspirations toward sustainable technologies and environmental-society governance (ESG) directives to reduce water pollution, which has become a major global problem that could have a devastating impact on human health, ecosystems, and the economy.

Literature Cited

This literature focused on reports published at the last years including the pathogenic bacteria i.e. the total coliform, bacteria *E. coli*, *Giardia lamblia*, *Leptospira interrogans*, *Cryptosporidium* spp., *Enterococci*, *Cyanobacteria* as well as other baceria *i.e. Clostridium perfringens*. Furthermore, studies surveyed the method, the analysis provided an overview of the removal rates of pathogens as the main indicators of BF efficiency.

Malaysia's Drinking Water Resources

Malaysia had abundant and rich water resources throughout the years. The main source of drinking water in Malaysia is groundwater and surface water. Approximately 99% of water for domestic uses in Malaysia are from surface water, while another 1% of the supply is from groundwater (**Azrina *et al*., 2011**). Malaysia's internal water sources are estimated to be about 580 km^3/year, with 30% of water production for municipal uses (**Naubi *et al*., 2016**). Water supply from surface water is widely used as drinking water, such as water withdrawn from Sungai Kinta, Sungai Langat, and Sungai Selangor (**Hafiza *et al*., 2016**). Water supply from groundwater intake from a few states in Malaysia such as Terengganu, Kelantan, Perlis, Kedah, Pahang, Sabah, and Sarawak are also used for drinking water (**Ong *et al*., 2007**). According to the data published by Suruhanjaya Perkhidmatan Air Negara (**Span, 2015**) only 1.5% of total groundwater supply is present in Malaysia, and there was an increase in groundwater usage by 3.3% from the year 2014 to 2015 (**Span , 2015**). Nonetheless, the key issue to be considered is the quality of the water sources for drinking water supply. Both surface and groundwater sources are easily affected by the surrounding changes, whether man-made or natural. Therefore, it is important to determine undesired constituents, and monitor the characteristics of the water sources to ensure the pollutants in the water do not exceed the standard limits for water supply stated by the National Water Quality Standards for Malaysia (NWQS), and the Ministry of Health.

Quality of Water

The Department of Environment (DOE) uses NWQS and Water Quality Index (WQI) to evaluate the status of the water source quality (**Naubi *et al*., 2016**). The WQI, introduced by the DOE, has been practiced in Malaysia for about 25 years, and serves as the basis for the assessment of environment water quality, while the NWQS classifies the beneficial uses of the watercourse based on WQI (**Yuk *et al*., 2015**). To design the drinking water quality management system, the assessment of water quality is an important step in determining the possible problems in the quality of the drinking water source. Basically, the characteristics of water quality are determined by physical, chemical, and biological factors to describe the overall condition of the water quality and its suitability for a specific use.

Water Quality Index

The water quality index (WQI) is a set of parameters that classify surface water quality for public use, including drinking water, fishing, recreational usage, and irrigation. It is made up of six water quality indicators: biochemical oxygen demand or BOD, dissolved oxygen (DO), Chemical Oxygen Demand (COD), suspended solids (SS), NH_3–N, and pH. WQI classification based on parameters is summarized in Table 1.

The WQI was calculated according to the Malaysian Department of Environment Water Quality Index (**DOE-WQI, DOE 2020**) and **Standard-Kualiti-Air-Sungai-Kebangsaan-Dan-Indeks (2020)** as shown in Equation (1),

Table 1. Water quality index classification for Malaysia Standard Kualiti-Air-Sungai-Kebangsaan-Dan-Indeks 2020

Parameters	Unit	Class				
		I	II	III	IV	V
pH	-	>7	6–7	5–6	<5	>5
dissolved oxygen (DO)	mg/L	>7	5–7	3–5	1–3	<1
biochemical oxygen demand or (BOD)	mg/L	<1	1–3	3–6	6–12	>12
Chemical Oxygen Demand (COD)	mg/L	<10	10–25	25–50	50–100	>100
suspended solids (SS)	mg/L	<25	25–50	50–150	150–300	>300
NH_3–N	mg/L	<0.1	0.1–0.3	0.3–0.9	0.9–2.7	>2.7
WQI	-	>92.7	76.5–92.7	51.9–76.5	31–51.9	<31

Source: Hanafiah *et al.* (2024)

where SIDO, SIBOD, SICOD, SIAN, SISS, and SI pH are subindexes for DO, BOD, COD, AN, SS, and pH, respectively.

WQI = (0.22 × SIDO) + (0.19 × SIBOD) + (0.16 × SICOD) + (0.15 × SIAN) + (0.16 × SISS) + (0.12 × SIpH) (1)

The general WQI classification, microbiological contents in the main lake water sample compared to National Lake Water Quality Standard (NLWQS) categories A and B and Water quality index of Main Lake are shown in Tables 2, 3 and 4 which can be classified into three categories: clean water (80–100), slightly polluted water (60–79) and polluted water (0–59).

Water Quality Index Classification

The water quality index provides a detailed picture of a lake's conditions. The WQI is a rating system that measures the acceptability of water for consumption by combining the effects of numerous water quality criteria. The Main Lake water quality index was between 54.59 and 57.44, with an average value of 56.45; thus, the investigated water was categorized as Class III (Table 4). The respective sub-indexes of each parameter place DO in Class III, BOD in Class IV, COD in Class V, AN in Class III, TSS in Class I, and pH in Class III. Meanwhile, the water quality of the former mining lake was also analyzed based on its suitability for recreational activities, as recommended by the **DOE (2020)**. The WQI values of the study, categorized under Class III, require intensive treatment before they can be used for recreational purposes that involve water–human contact.

Microorganism Pollution

The occurrences of pollution and indicator pathogenic bacteria in potable water depend on a number of factors, including the intrinsic and chemical characteristics of the catchment area, and the range of human activities and animal sources that release pathogenic bacteria to the environment. Sources of pathogenic bacteria in potable water are numerous and, for operational efficiency, are typically assessed by faecal indicator bacteria investigation. In terms of biological characteristics for safe drinking water supply and drinking water distribution systems, water is one of the transmission routes for pathogenic microorganisms (**Guidelines for Drinking-water Quality, 2011**). In spite of having enhanced water management and sanitation, waterborne-diseases and outbreaks may continue to occur (**Mwabi *et al.*, 2013**). Drinking water polluted by microorganisms of faecal origin is a current worldwide health concern because of epidemic occurrences globally in relation to microbial-contaminated water. In drinking water, these microorganisms of interest include protozoa, bacteria, viruses, algae, and helminths. An overview of these microorganisms is given in Table 5.

Table 2.General rating scale for water quality index (WQI).

Percentage of WQI (%)	Water Quality Status
80–100	Clean water
60–79	Slightly polluted water
0–59	Polluted water

Source: Hanafiah *et al.* (2024)

Table 3. Microbiological contents in the Main Lake water sample compared to National Lake Water Quality Standard (NLWQS) categories A and B (text with bold and underline indicates reading exceeding NLWQS)

Microbiological	Unit	Water sample	NLWQS	
			Category A	Category B
Chlorophylla	µg/L	16.7	10	15
Clostridium perfringens	Count/mL	<1	nd	nd
Total coliform	Count/100 mL	176	5000	5000
Total *E. coli*	Count/100 mL	<1	100	600
Giardia lamblia	Absent/present	Absent	nd	nd
Leptospira interrogans	Absent/present	Absent	nd	nd
***Cryptosporidium* sp.**	Absent/present	Absent	nd	nd
Enterococci	Count/100 mL	<1	33	230
Cyanobacteria	Cells/mL	3230	15,000	15,000

nd: not detected.

***Source*: Hanafiah** *et al*. **(2024)**

Table 4. Water quality index of Main Lake.

	Water Quality Index (WQI)						WQI	WQI quality status: Polluted water
	SIDO	SIBOD	SICOD	SIAN	SISS	SIpH		
Main Lake	35.64	67.25	9.18	68.29	95.23	74.06	56.45	
Class	III	IV	V	III	I	III	III	

Source: Hanafiah *et al*. (2024)

Table 5. Microorganism in drinking water sources

Types	Description	Remarks
Bacteria *Vibrio cholerae* *Escherichia coli* Legionella *Shigella* spp. *Samonella* spp.	• Single cell organism with size ranging from 0.1 to 10 µm. • Negatively charge surface • Aerobic, anaerobic, facultative • Motile and non-motile	• The most reported water-borne plaque are involve of bacteria
Protozoa *Cryptosporidium parvum* *Giardia lamblia* *Entamoeba dispar* *Entamoeba histolytica*	• Group of unicellular and non-photosynthetic organism with diameter size between 1 and 102 µm. • Negatively charge surface aerobic and anaerobic motile and non-motile	• Under water-borne disease standpoints, the four listed Protozoa are consider as the greatest risk in water supply
Virus T-4 coliphage Adenovirus Enterovirus Rotavirus MS-2 coliphage	• Smallest of waterborne agents with diameter size of 0.02–0.2 µm Negatively charge surface	• Poliovirus and Hepatitis A are the only known virus that have been documented to be associated with water-borne transmission
Algae *Volvox* *Euglena* *Cyclotella* *Synedra* *Chlorella* *Anabaena*	• Diameter size: 1–102 µm Negatively charge surface aerobic motile and non-motile	• Algae are common living organism in water supply and play important part in nutrient cycle. But a few algae are pathogenic to human because it produce endotoxins that can cause gastroenteritis
Helminths	• Diameter size: 1–102 µm Negatively charge surface aerobic motile	• Effective treatment and disposal of sewage water can control the parasitic worm in water supply

Source: Salamat *et al*. (2019)

Faecal coliforms are bacteria which fulfill all the criteria used to define total coliforms, with the additional requirement that they grow and ferment lactose with the production of acid at a scientifically accurate 44.5°C (**Kostyla *et al*., 2015**). This bacteria of the coliform subgroup has been found to have a positive correlation with faecal contamination of warm-blooded animals (**Ishii *et al.*, 2006**). However, several thermotolerant coliform bacteria, by definition by the genus *Klebsiella* bacteria, have been isolated from environmental samples with the apparent absence of faecal pollution (**José Figueras and Borrego, 2010).** Similarly, Revetta et al. reported that other members of the thermotolerant coliform group and *E. coli* have been detected in clean areas, and were associated with regrowth events in the water distribution systems (**Revetta *et al*., 2016**). Faecal coliforms demonstrate a survival of the bacteria form similar to pathogenic bacteria, and also have usefulness as indicators of bacteria, tended to be replaced by *E. coli*.

Recently, the faecal coliform group has been extended to include other characteristics, such as β-D-*galactosidase* positive reactions (**Public and Association, 2005**). *E. coli* is a specific indicator for the presence of the faecal coliform group, and is the most reliable indicator of enteric pathogens (**Shoaib, 2016**). Several studies have indicated that *E. coli* is an indicator of choice to indicate the occurrence of recent faecal coliform in drinking water. Currently, *E. coli* appears to provide the best bacterial indication of faecal coliform, and only several strains of *E. coli* in drinking water can cause diseases (**WHO, 2006**). In several countries, this organism has been included in their regulations as a primary indicator of faecal contamination in drinking water (**Saxena *et al*., 2015**). Therefore, *E. coli* is the best faecal indicator to inform public-health risks associated with the consumption of contaminated drinking water.

Microorganisms with a range of 1 to 10 μm in particle size are harder to remove by conventional treatment systems, and unfortunately, most of the microorganisms of concern in drinking water fall within this diameter range. These microbiological particles have a consequence on surface effect, which is sediments, and this causes the anionic filter media to become ineffective in removing the particles without repulsion by means of coagulation (**Ibrahim, 2018**). Additionally, motile microorganisms are harder to remove without prior deactivation by disinfectants. As a measure of the degree of contamination in samples of water, or the degree of the infection in humans and animals, the term colony-forming units (CFU) is used, referring to the number of living bacterial cells.

Escherichia coli

Escherichia coli or *E. coli* is also known as a facultative anaerobic bacterium that is gram-negative. Cells of *E. coli* are typically rod-shaped with a cell volume of 0.6 to 0.7 μm3, 2 μm long, and 0.5 μm in diameter (**Odonkor and Ampofo, 2013**). Generally, *E. coli* is found in the faces of healthy cattle, and is transmitted in the lower intestinal tracts of warm-blooded organisms, including humans and animals (**Ishii *et al*., 2006**). In 1885, this microorganism was discovered by Theodor Escherich, and was first classified as a human pathogen in 1982 (**Lim *et al*., 2010 and Mead and Griffin, 2010**). Most of the *E. coli* strains harmlessly colonize the gastrointestinal tracts of humans and animals as normal flora. However, other strains grow into pathogenic *E. coli* by acquiring virulence, which is caused by bacteriophages, plasmids, transposons, and pathogenicity islands. Differences in survivability, external structure, size, shape, and zeta potential are some of the factors that influence the behavior of these bacteria. This pathogenic *E. coli* can be categorized based on pathogenicity mechanisms, serotypes, clinical symptoms, or virulence factors (**Guionet *et al*., 2015**). Several of the enterohaemorrhagic *E. coli* are defined as pathogenic *bacteria* that produce Shiga toxins, and cause the life-threatening sequelae of haemolytic uraemic syndrome, and haemorrhagic colitis in humans (**Shamsul *et al*., 2016**). An illustration of the *E. coli* bacteria is in Fig. 1.

Indicator bacteria, including the total coliforms, *E. coli*, *Enterococci*, and *Clostridium perfringens*, are commonly used to measure drinking and raw water quality. The presence of faecal coliform and *E. coli* is likewise a potable water contamination indicator through animal or human faecal matter (**Wang *et al*., 2015**). *E. coli* bacteria indicate the potential presence of pathogenic microorganisms in natural and treated waters. *E. coli* can cause a variety of intestinal and extra-intestinal infections, such as diarrhoea, urinary tract infection, meningitis, peritonitis, septicemia, and gram-negative bacterial pneumonia (**Bajpai *et al*., 2012**). To date, many treatment methods for the removal of *E. coli* have been introduced in treatment plants, such as membrane filtration (**Modified, 2002**), soil aquifer treatment (**Levantesi, 2010**), slow sand filtration (**Bauer *et al*., 2011**), granular activated carbon (GAC) adsorption (**Zietzschmann *et al*., 2016**), and advanced oxidation (**Tijani *et al*., 2014**). All these methods have long been used in water treatment, and proved effective for bacteria removal. However, there is no information about non-ionizing radiation applications in water treatment plants in Malaysia. This method is a better option for new applications in RBF systems based on the requirements of packing materials around the well screen.

Riverbank Filtration (RBF)

Subsurface or groundwater in Malaysia are natural water sources that can be exploited to meet the demands for water of high quality. The RBF process is an existing method referring to the process of extracting potable water at the riverbank, utilizing subsurface or groundwater

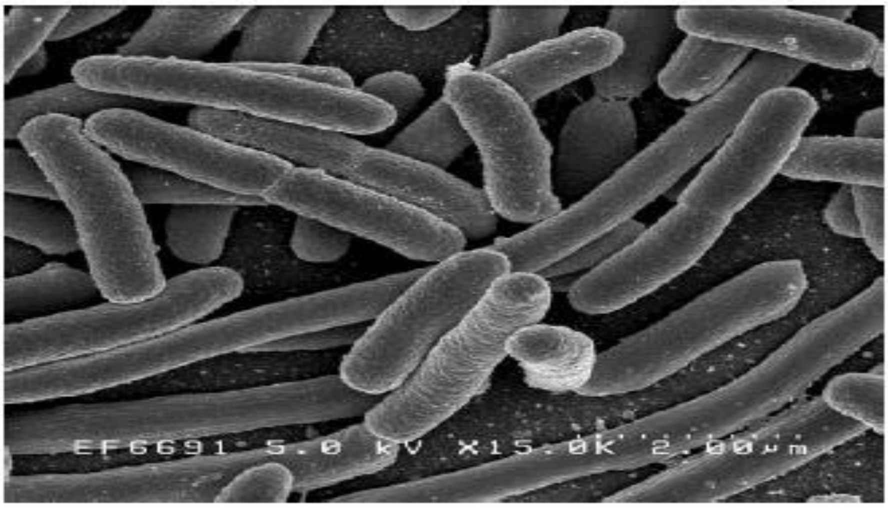

Fig. 1. Scanning Electron Micrograph of *E. coli* Isolated from River Water. Sources from; (http://www.bacteriainphotos.com/bacterial-biofilm.html#)

to supply sources of high-quality water (**Mustafa *et al*., 2016 and Hu *et al*., 2016**). RBF systems and natural treatment processes typically take place during water infiltration. Fig. 2 shows the natural process of extracting treated water from an adjacent pumping well to a river.

As illustrated in the figure above, the difference in hydraulic gradient causes the water from the river to flow towards the well during the pumping process (**Boving *et al*., 2014**). Additionally, the RBF process is known as a sustainable and economical method to improve poor surface water quality (**Umar *et al*., 2017**). A complex attenuation method occurs during the transportation of water through the aquifer layer, resulting in raw water of high quality. The high-quality raw water is then supplied to the water treatment plants, making it easier to be treated at low operating costs by conventional treatment systems (**Partinoudi** and **Collins, 2007**). Therefore, water from the well can be directly consumed with very minimum treatment in certain areas.

Riverbank filtering (RBF) is an attractive option that can be applied for effective water treatment. RBF is a technique that covers both shallow groundwater and river water that have crossed through the banks of rivers, or riverbanks to well extractions. Most of the suspended and dissolved contaminants, including viruses and pathogenic bacteria, are filtered out as surface water is filtered through aquifer materials, and the sediments of the riverbed. Abstracting of riverbank water can overcome water shortage due to extreme events such as floods and droughts that cause water levels to increase on the ground, or reduce underwater intake pipes, causing disruptions in water transfer to treatment plants. Although RBF is a capable method for improving surface water quality, it does not abolish the problem. Abstracted well water quality is highly dependent on several factors, such as groundwater and river water quality, temperature and pH of water, water residence time, medium porosity, and oxygen concentrations. According to **Levantesi (2010**) study, the breakthrough of bacteria and turbidity occurred in a shallow drilled well (3–6 m) due to the short travel time, especially during monsoon seasons. This condition urges for appropriate treatment applications to further enhance the ability of RBF in bacteria and inorganic substance removal.

E. coli Removal via Riverbank Filtration

RBF is a water treatment technology that involves extracting water from rivers by pumping wells located in the adjacent alluvial aquifer. In the underground passage, a series of physical, chemical, and biological processes take place, improving the quality of the surface water, while substituting or reducing conventional drinking water treatments.

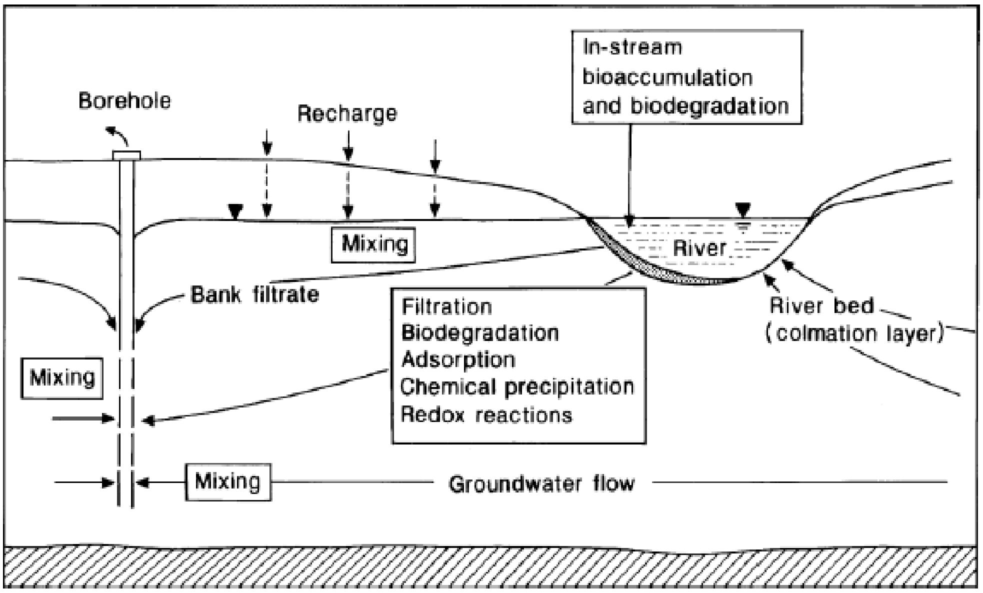

Fig. 2. Schematic Diagram of Mechanisms in Natural Filtration by RBF System (Hiscock and Grischek, 2002)

A study based on a model-oriented approach by **Wang *et al.* (2015)** used an example of riverbank wells near the Kuybyshev Reservoir, Russia. The wells were designed in order to minimize the uncertainties in the estimated hydraulic parameters. During water transport towards the RBF wells, the water quality improved significantly, aided by processes like microbial degradation, ion exchange, precipitation, sorption, filtration, dispersion, and groundwater dilution. Faecal and total coliforms are bacterial indicators that are widely used to monitor microbial water quality in developed and developing regions of the world. Faecal contamination of drinking water supplies is a public-health concern because they could contain pathogens that cause gastroenteritis, meningitis, and other waterborne diseases. Potential sources of faecal contamination include direct discharge from human and animal wastes as well as non-point sources (agricultural and storm water runoffs). Majority of the RBF systems used in European countries and America alike have achieved excellent total coliform removal percentages, ranging from 99.2% to 99.99% (2.1 to 5 logs).

Drawbacks of RBF Treatment System

Implementation of RBF has higher potential advantages for conjunctive use with infiltrated surface water and groundwater from the alluvial catchments of intake structures (**Wang *et al.*, 2015**), which ensure the long-term productivity and stability of the water supply. Additionally, surface water contaminants can be significantly removed or degraded as the infiltrating water moves from the river or lake to the production wells due to a combination of physicochemical and microbiological processes (**Hiscock and Grischek, 2002; Maeng *et al.*, 2010 and Singh *et al.*, 2010**). While RBF has good pollutant attenuation, there is still a possibility for this source to be contaminated by anthropogenic or natural pollutants. For example, short flow paths, high heterogeneity, high hydraulic gradients, and accompanying high flow velocities (**Derx *et al.*, 2013**) can impair the efficiency of removal of microbial contaminants with RBF. Nevertheless, an important benefit of RBF processes is that they can remove pollutants, and dilute contaminant concentrations during the infiltration process.

Conclusion

In order to understand and develop further knowledge on RBF, the Universiti Sains Malaysia (USM) research team embarked on the study of RBF at different locations in Malaysia. Three pilot projects of RBF facilities were constructed in the states of Selangor, Perak, and

Kedah. The results from the proposed analytical model are well matched with the data collected from a RBF site in France. After this validation, the model was then applied to the first pilot project of a RBF system conducted in Malaysia. Sensitivity analysis results highlighted the importance of the degradation rates of contaminants on groundwater quality, for which higher utilization rates led to the faster consumption of pollutants. The development perspective of RBF in Malaysia is promising. With the establishment of a management system, improvement of the monitoring system, reinforcement of legal protection, and promotion of civic awareness, Malaysia RBF will play an important role in development of the water resource industry.

REFERENCES

Adlan, M.N., M.F., Ghazali and M.A. Zainol (2016). Removal of *E. coli* and turbidity using riverbank filtration technique (RBF) for riverside alluvial soil in Malaysia. Inst. Eng., Malaysia, 77 (1): 30–35.

Azrina, A., K. He, I. Ma and I. Amin (2011). Major inorganic elements in tap water samples in peninsular Malaysia. Malaysian J. Nutr., 17(2): 271-276.

Bajpai, I., N. Saha and B. Basu (2012). Moderate intensity static magnetic field has bactericidal effect on *E. coli* and *S. epidermidis* on sintered hydroxyapatite. J. Biomed. Mat. Res. Part B: Appl. Biom., 100 (5): 1206-1217

Bauer, R., H. Dizer, I. Graeber, K. Rosenwinkel and J.M. Lo (2011). Removal of bacterial fecal indicators, coliphages and enteric adenoviruses from waters with high fecal pollution by slow sand filtration. Water Res., 45 (2): 439-452.

Bauer, R., H. Dizer, I. Graeber, K. Rosenwinkel, and J.M. Lo (2011). Removal of bacterial fecal indicators, coliphages and enteric adenoviruses from waters with high fecal pollution by slow sand filtration. Water Res., 45 (2): 439–452.

Boving, T.B., B.S. Choudri, P. Cady, A. Cording, K. Patil and V. Reddy (2014). Hydraulic and hydrogeochemical characteristics of a riverbank filtration site in Rural India. Water Environ. Res.

Cady, P., T.B. Boving, B.S. Choudri, A. Cording, K. Patil and V. Reddy (2013). Attenuation of Bacteria at a Riverbank Filtration Site in Rural India. Water Environ. Res., 85 (11): 2164 – 2174.

Derx, J., A.P. Blaschke, A.H. Farnleitner, L. Pang, G. Blöschl and J.F. Schijven (2013). Effects of fl uctuations in river water level on virus removal by bank filtration and aquifer passage-A scenario analysis. J. Contaminant Hydrol., 147: 34–44.

Guidelines for Drinking-water Quality (2011). 4th Ed. Geneva: World Health Oragnisation (WHO).

Guionet, A., F. David, C. Zaepffel, M. Coustets, K. Helmi, C. Cheype, D. Packan, J.P. Garnier, V. Blanckaert and J. Teissié (2015). *E. coli* electroeradication on a closed loop circuit by using milli-, micro-and nanosecond pulsed electric fields: comparison between energy costs. Bioelectrochem., 103: 65-73.

Gutiérrez, J.P., D.V. Halem and L. Rietveld (2017). Riverbank filtration for the treatment of highly turbid Colombian rivers. Drinking Water Eng. and Sci., 10 (1): 13- 26.

Hafiza, N., A. Razak, S.M. Praveena, Z. Hashim and A. Zaharin (2015). Drinking water studies: A review on heavy metal, application of biomarker and health risk assessment (a special focus in Malaysia). J. Epidemiol. and Global Health, 5 (4): 297-310

Hanafiah, Z.M., A.R. Azmi, W.A.A.Q.I. Wan-Mohtar, F. Olivito, G. Golemme, Z. Ilham, A.A. Jamaludin, N. Razali, S.A. Halim-Lim, W.H.M. Wan Mohtar (2024). Water quality assessment and decolourisation of contaminated ex-mining lake water using bioreactor dye-eating fungus (BioDeF) System: A Real Case Study. Toxics, 11 12 (1): 60. doi: 10.3390/ toxics 12010060. PMID: 38251015; PMCID: PMC10818540.

Hiscock, K.M. and T. Grischek (2002). Attenuation of groundwater pollution by bank filtration. J. Hydrol., 266:139–144.

Hu, B., Y. Teng, Y. Zhai, R. Zuo, J. Li and H. Chen (2016). Riverbank filtration in China: A review and perspective. J. Hydrol., 541 (B): 914-927.

Ibrahim, N., H.A. Aziz and M.S. Yusoff (2018). Removal of total coliform and E. coli using zeliac as filter media. In AIP Conf. Proc., 1892 (1): 070008). AIP Publishing

Ishii, S., W.B. Ksoll, R.E. Hicks and M.J. Sadowsky (2006). Presence and growth of naturalized Escherichia coli in temperate soils from Lake Superior watersheds. Appl. and Environ. Microbiol., 72 (1): 612-621.

José Figueras, M. and J.J. Borrego (2010). New perspectives in monitoring drinking water microbial quality. Int. J. Environ. Res. and Public Health, 7 (12): 4179-4202.

Kostyla, C., R. Bain, R. Cronk and J. Bartram (2015). Seasonal variation of fecal contamination in drinking water sources in developing countries: A systematic review. Sci. Total Environ.

Kuehn, W. and U. Mueller (2000). Riverbank filtration: an overview. J. Ame. Water Works Assoc., 92 (12): 60-69.

Levantesi, C. (2010). Quantification of pathogenic microorganisms and microbial indicators in three wastewater reclamation and managed aquifer recharge facilities in Europe. Sci, Total Environ., 408 (21): 4923-4930.

Lim, J.Y., J.W. Yoon and C.J. Hovde (2010). A brief overview of Escherichia coli O157: H7 and its plasmid O157. J. Microbiol. and Biotechnol., 20 (1): 5.

Maeng, S.K., E. Ameda, S.K. Sharma, G. Grützmacher and G.L. Amy (2010). Organic micropollutant removal from wastewater effluent-impacted drinking water sources during bank filtration and artificial recharge. Water Res., 44: 4003–4014.

Manap, M.A., W.N.A. Sulaiman, M.F. Ramli, B. Pradhan and N. Surip (2013). A knowledge-driven GIS modeling technique for groundwater potential mapping at the Upper Langat Basin, Malaysia. Arabian J. Geosci., 6 (5): 1621-1637.

Mead, P.S. and P.M. Griffin (2010). Escherichia coli O157. The Lancet, 376 (9750): 1428–1435.http://doi.org/10.1016/S0140-6736(10): 60963-4

Modified, F.U. (2002). *E. coli* in water by membrane Escherichia coli agar (Modified mTEC). U.S. Environ. Prot. Agency, 821: 2-23.

Mustafa, S., A. Bahar, Z. Abdul and S. Suratman (2016). Modelling contaminant transport for pumping wells in riverbank fi ltration systems. J. Environ. Manag., 165: 159–166.

Mwabi, J.K., B.B. Mamba and M.N.B. Momba (2013). Removal of waterborne bacteria from surface water and groundwater by cost-effective household water treatment systems (HWTS): A sustainable solution for improving water quality in rural communities of Africa. Water SA., 39 (4): 445-456.

Naubi, I., N.H. Zardari, S.M. Shirazi, N.F.B. Ibrahim and L. Baloo (2016). Effectiveness of water quality index for monitoring Malaysian river water quality. Polish J. Environ. Studies, 25 (1): 231-239.

Odonkor, S.T. and J.K. Ampofo (2013). Escherichia coli as an indicator of bacteriological quality of water: an overview. Microbiol. Res., 4 (1): 2.

Ong C, Ibrahim S, Sen Gupta B. A survey of tap water quality in Kuala Lumpur. A survey of tap water quality in Kuala Lumpur. Urban Water J., 4 (1): 29-41.

Partinoudi, V. and M.R. Collins (2007). Assessing RBF reduction/removal mechanisms for microbial and organic DBP precursors. J. Ame. Water Works Assoc., 99 (12): 61–71.

Public, A. and H. Association (2005). APHA method 4500-CL: Standard methods for the examination of water and wastewater.

Revetta, R.P., V. Gomez-Alvarez, T.L. Gerke, J.W. Santo Domingo and N.J. Ashbolt (2016). Changes in bacterial composition of biofilm in a metropolitan drinking water distribution system. J. Appl. Microbiol., 121 (1): 294-305.

Saxena, T., P. Kaushik and M.M. Krishna (2015). Prevalence of *E. coli* O157: H7 in water sources: An overview on associated diseases, outbreaks and detection methods. Diagnostic Microbiol. and Infectious Dis., 82 (3): 249-264

Shamrukh, M. and F.A. Abdalla (2010). Riverbank filtration to improve water supply quality along nile towns in upper Egypt. In Sustainable Water Supply and Sanitation, 1-14.

Shamsuddin, M.K.N., W.N.A. Sulaiman, S. Suratman, M.P. Zakaria and K. Samuding (2014). Utilisation d'eau souterraine et de surface par une technique d'infiltration en berge en Malaisie. Hydrogeol. J., 22 (3): 543 – 564.

Shamsul, B.M.T., M.T. Adamu, M.N.M. Desa and S. Khairani-Bejo (2016). Prevalence of *Escherichia coli* O157: H7 and Enterobacteriaceae on hands of workers in halal cattle abattoirs in peninsular Malaysia. The Malaysian J. Med. Sci.: MJMS, 23 (5): 65.

Shoaib, M. (2016). Prevalence of pathogenic microorganisms in drinking water of Rawalpindi and Islamabad. World J. Fish and Marine Sci., 8 (1): 14-21.

Singh, P., P. Kumar, I. Mehrotra and T. Grischek (2010). Impact of riverbank filtration on treatment of polluted river water. J. Environ. Manag., 91 (5): 1055–1062.

Standard, K.A. and S.K.D. Indeks (2020). Environmental Quality Report 2020. DOE-WQI, Department of Environment Malaysia; Putrajaya, Malaysia.

Tijani, J.O., O.O. Fatoba, G. Madzivire and L.F. Petrik (2014). A review of combined advanced oxidation technologies for the removal of organic pollutants from water. Water, Air, and Soil Pollution, 25 (9): 1-46.

Umar, D.A., M.F. Ramli, A.Z. Aris, W.N.A. Sulaiman, N.U. Kura and A.I. Tukur (2017). An overview assessment of the effectiveness and global popularity of some methods used in measuring riverbank filtration. J. Hydrol., 550: 497–515.

Wang, P., S.P. Pozdniakov and V.M. Shestakov (2015). Optimum experimental design of a monitoring network for parameter identification at riverbank well fields. J. Hydrol., 523:531-541.

Wang, L., X. Ye and X. Du (2016). Suitability Evaluation of River Bank Filtration along the Second Songhua River, China. Water 2016,8, 176. https://doi.org/10.3390/w8050176.

Weiss, W.J., E.J. Bouwer, R. Aboytes, M.W. Lechevallier, C.R.O. Melia, B.T. Le and K.J. Schwab (2005). Riverbank filtration for control of microorganisms: Results from field monitoring. Water Res., 39:1990–2001.

WHO (2017). World Health Organisation Filration Fact Sheet 2.13. Retrieved from http://www.who.int/water_sanitation_health/hygiene/emergencies/fs2_13.pdf.

WHO (2006). World Health Organisation. Guidelines for Drinking-Water Quality, 1.

Yuk, F., T.S.L. Huang, S.Y. Ang and K.M. Lee (2015). Quality of water resources in Malaysia.

Zietzschmann, F., G. Aschermann and M. Jekel (2016). Comparing and modeling organic micro-pollutant adsorption onto powdered activated carbon in different drinking waters and WWTP ef fl uents. Water Res., 102: 190-201.

كفاءة ترشيح ضفاف النهر في إزالة مسببات الأمراض لتحسين جودة المياه في ماليزيا- دراسة مرجعية

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إن زيادة البكتيريا المسببة للأمراض (*E. coli*) في مياه الأنهار تشكل مصدر قلق لأنها تشكل مصدرا رئيسا للمخاطر الصحية في أنظمة معالجة مياه الشرب التقليدية. ومن بين الاحتمالات التي تجذب اهتمامًا متزايدًا بمرافق المياه هي تقنية الترشيح بضفاف الأنهار riverbank filtration (RBF). وتُعد تقنية الترشيح على ضفاف الأنهار RBF طريقة جديدة يمكن أن تقدم تقنيات غير كيميائية ومعالجة طبيعية في ماليزيا. ورغم أن أنظمة الترشيح على ضفاف الأنهار فعالة في تقليل أو إزالة تركيزات الملوثات، إلا إنها غير فعالة في الغالب في إزالة البكتيريا المسببة للأمراض وخاصة أثناء مواسم الفيضانات والأمطار. لذلك، تم التركيز على البحوث والتقارير المنشورة في العقد الماضي، والتي تم الاحصول عليها من المصادر المختلفة والمتعلقة تقنية الترشيح على ضفاف الأنهار وايضا بعض المعايير الاخرى مثل الطلب البيوكيميائي للأكسجين، والأكسجين الذائب، والأمونيا-النيتروجين، والرقم الهيدروجيني وغيرها. وكذا بعض الميكروبات المرتبطة بالتلوث والمسببة لبعض الأمراض مثل *E. coli*، و*Chlorophylla*، و*Clostridium perfringens*،، و *Giardia lamblia* ، و*Leptospira interrogans*و. sp "*Cryptosporidium*، و*Enterococci*، و *Cyanobacteria* وTotal Coliform، والعدد الكلي *E. coli*. في ماليزيا قد قام فريق بحثي من جامعة العلوم الماليزية باستخدام تقنية الترشيح على ضفاف الأنهار RBF وقدم نظرة عامة على معدلات إزالة مسببات الأمراض كمؤشرات رئيسية لكفاءة طريقة تقنية الترشيح على ضفاف الأنهار RBF في ثلاثة مواقع مختلفة في ماليزيا. وقد كانت النتائج متوافقة مع النتائج تالمتحصل عليها من مواقع تقنية الترشيح على ضفاف الأنهار RBF في فرنسا. وقد أبرزت نتائج تحليل الحساسية أهمية معدلات تحلل الملوثات على جودة المياه السطحية (الأنهار والبحيرات والمياه الجوفية) بعد إزالة مسببات الأمراض، حيث أدت معدلات الاستخدام الأعلى إلى استهلاك أسرع للملوثات. وتعتبر آفاق تطوير تقنية الترشيح على ضفاف الأنهار RBF في ماليزيا من التقنيات الواعدة لتنقية المياه. ومع إنشاء نظام إدارة وتحسين نظام المراقبة وتعزيز الحماية القانونية وتعزيز الوعي المدني، ستلعب تقنية الترشيح على ضفاف الأنهار RBF في ماليزيا دورًا مهمًا في تطوير صناعة موارد المياه.

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