UN HABITAT
FOR A BETTER URBAN FUTURE

الشركة القابضة لمياه الشرب والصرف الصحي

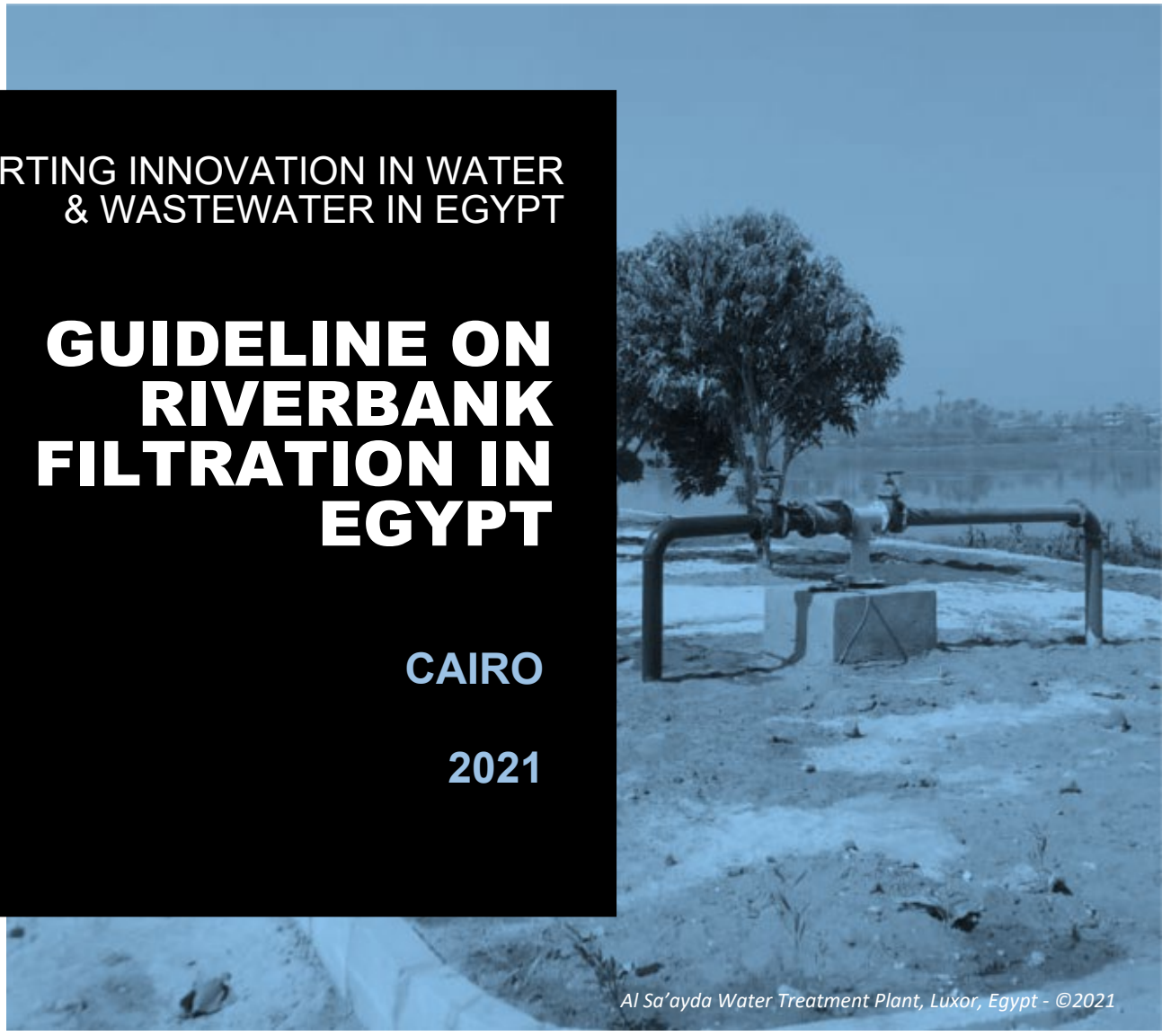
وزارة الإسكان والمرافق والمجتمعات العمرانية
Ministry of Housing, Utilities & Urban Communities

SUPPORTING INNOVATION IN WATER & WASTEWATER IN EGYPT

GUIDELINE ON RIVERBANK FILTRATION IN EGYPT

CAIRO

2021



Al Sa'ayda Water Treatment Plant, Luxor, Egypt - ©2021

UN HABITAT
FOR A BETTER URBAN FUTURE

United Nations Human Settlements Programme (UN-Habitat)
P.O. Box 30030 00100 Nairobi GPO KENYA
Tel: 254-020-7623120 (Central Office)
www.ar.unhabitat.org

UN HABITAT
FOR A BETTER URBAN FUTURE

GUIDELINE ON RIVERBANK FILTRATION IN EGYPT

PARTNERS

This guideline report was produced under "Supporting innovation in Water and Sanitation in Egypt" Project in partnership and collaboration of the Ministry for Housing, Utilities and Urban Communities, the Egyptian Holding Company for Water and Wastewater, the United Nations Human Settlement's Programme (UN Habitat), Replenish Africa Initiative - Coca-Cola and Global Environment & Technology Foundation.

CONTACT DETAILS:

Holding Company for Water and Wastewater (HCWW)

Prof. Dr. Rifaat Abdel Wahaab
Project Director
Head sector, Research and Development (R & D)
Nile Corniche, Al Sahel, Road al-Farag Water treatment plant
Cairo, Arab Republic of Egypt
Tel.: +(202)24583596 – 24583591 / Fax: +(202) 24583884
E-mail: rifaat.abdelwahaab@hcww.com.eg
Website: https://www.hcww.com.eg/

United Nations Human Settlements Programme (UN-Habitat)

Dr. Salma Yousry
Project Coordinator
Programme officer, Housing and Urban Upgrading
Egypt Office
87 Tahrir St., Cairo, , Arab Republic of Egypt
Tel.: +(202) 27923086 / Fax: +(202) 27923086
E-mail: salma.yousry@un.org
Website: www.unhabitat.org

Drafted by:

- **Prof. Dr.-Ing. Thomas Grischek,** Division of Water Sciences, University of Applied Sciences Dresden, Germany.
- **RBF Project Coordinators**, Holding Co. For Water & Wastewater(HCWW) & its Affilited Companies.

Table of Contents

ABBREVIATIONS		5
1	INTRODUCTION TO RIVERBANK FILTRATION IN EGYPT	7
1.1	Definition and purpose of RBF	7
1.2	Favourable hydrological and hydrogeological conditions	10
2	PLANNING A RIVERBANK FILTRATION SCHEME	11
2.1	Basic site assessment	11
2.2	Detailed site assessment	15
3	CONSTRUCTION AND TESTING OF A RBF SCHEME	20
3.1	Well design	20
3.2	Well construction	27
3.3	Well development	31
3.4	Well yield test	33
3.5	Well head protection measures	38
3.6	Monitoring wells and devices	39
3.7	Water quality monitoring	41
4	POST-TREATMENT OF RBF WATER FOR DRINKING WATER SUPPLY	42
4.1	Removal of iron and manganese	42
4.2	Disinfection	45
5	OPERATION AND MAINTENANCE OF RBF SCHEMES	49
5.1	Operation principle for well scheme (continuous vs. discontinuous)	49
5.2	Maintenance requirements	49
5.3	Monitoring concept: data collection and analysis	50
5.4	Operation of post-treatment facilities (Fe/Mn removal, disinfection)	51
REFERENCES		56

Abbreviations

AOX	Adsorbable Organic Halogenes [µg/l]
AQTESOLV	AQuifer TEst SOLVer (aquifer test analysis software)
BDOC	biologically degradable organic carbon [mg/l]
BF	bank filtration
d_{10}	grain size diameter corresponding to 10% cumulative undersize particle size distribution [mm]
d_{60}	grain size diameter corresponding to 60% cumulative undersize particle size distribution [mm]
DALYs	disability adjusted life years
DBP	disinfection by-products
DOC	dissolved organic carbon [mg/l]
DW	deep groundwater well
EC	electrical conductivity [µS/cm]
GC	gas chromatography
GHB	general head boundary [m^3/s]
GIS	geographic information system
GW	groundwater
GWL	groundwater level
HCWW	Holding Company for Water and Wastewater
HPLC	high performance liquid chromatography
HTWD	University of Applied Sciences Dresden
IP	inner piezometer
IWRM	Integrated Water Resources Management
K	hydraulic conductivity [m/s]
LPCD	liters per capita per day
M	saturated thickness of aquifer [m]
MAR	managed aquifer recharge
masl	meter above sea level
mbgl	meter below ground level
MS	mass spectrometry
NOM	natural organic matter

OP	outer piezometer
OTP	organic trace pollutants
OW	observation well
PAH	polycyclic aromatic hydrocarbons
PW	production well, pumping well
Q	abstraction rate [m^3/s]
RBF	riverbank filtration
s	drawdown in a well [m]
SS	suspended solids
SW	surface water
T	transmissivity [m^2/s]
TDS	total dissolved solids [mg/l]
THM	trihalomethanes
TOC	total organic carbon [mg/l]
WL	water level
WSP	water safety plan
WTP	water treatment plant
WWTP	waste water treatment plant

1 Introduction to Riverbank Filtration in Egypt

1.1 Definition and purpose of RBF

Riverbank filtration (RBF) or simply bank filtration (BF, a unified term for river and lake bank / bed filtration) is a process in which the subsurface at a river, canal, reservoir or lake bank serves as a natural filter and biochemically removes potential contaminants present in the surface water (Fig. 1-1). RBF is initiated by the lowering of the groundwater (GW) table below that of an adjoining surface water (SW) table which induces SW to infiltrate through the permeable riverbed and river bank (or lake bank) into the aquifer as a result of the hydraulic gradient. The infiltration may be the direct result of an influent river under natural conditions or be induced by GW abstraction wells.

The pumped raw water is a mixture of up to three different water sources, which usually have different qualities. Main components of the raw water at most sites are the bank filtrate, meaning the infiltrating river water, and the landside groundwater, which flows into the wells from the landside. Under appropriate geohydraulic conditions, the third source is groundwater from the opposite riverside, flowing beneath the river towards the wells (Grischek & Paufler 2017).

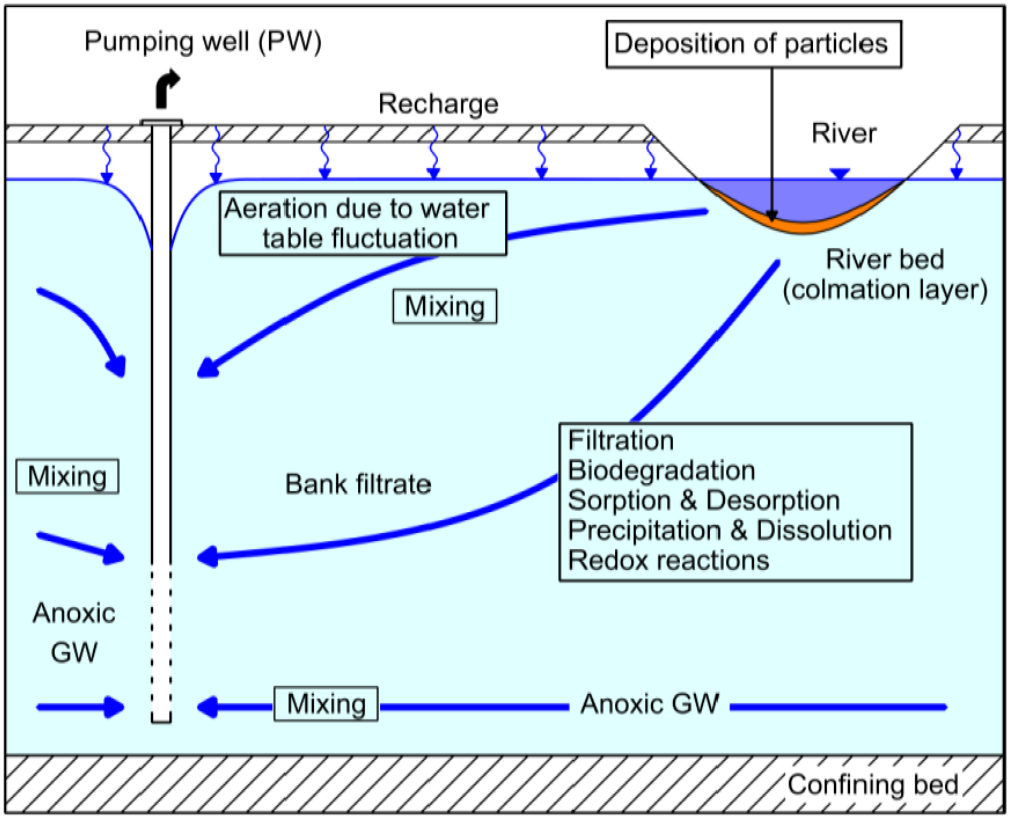


Fig. 1-1: Processes of riverbank filtration (Grischek & Paufler, 2017)

The aquifer serves as a natural filter and also biochemically attenuates potential contaminants present in the SW. Compared with direct SW abstraction, RBF with its effective natural attenuation processes removes suspended solids, particles, biodegradable compounds, bacteria, viruses and parasites; partly attenuates adsorbable compounds and equilibrates temperature changes and concentrations of dissolved constituents in the bank filtrate.

The success of RBF schemes is dependent on the microbial activity and chemical transformations that are commonly enhanced in the clogging layer within the river bed compared to those that take place in surface water or groundwater. The actual biogeochemical interactions that sustain the quality of the pumped bank filtrate depend on numerous factors including riverbed and aquifer structure and mineralogy, SW quality, particle content and composition, oxygen and nitrate concentrations in the SW, types of organic matter in the surface and ground water environments and land use in the local catchment area (Grischek et al. 2002).

For the quantitative and qualitative management of bank filtration systems, the catchment zones, infiltration zones, mixing proportions in the pumped raw water, flow paths and flow velocities of the bank filtrate need to be known. Flow conditions during bank filtration are commonly described using interpretations of water level measurements and hydrogeological modelling. An important factor is the formation of the clogging (colmation) layer within the riverbed (Fig. 1-1) that has a reduced hydraulic conductivity due to clogging from the input and precipitation of sediment particles, micro-organisms and colloids, precipitation of iron and manganese (hydr)oxides and calcium carbonate as well as gas bubbles. The hydraulic conductivity of the river bed varies with the dynamic hydrology and therefore cannot be regarded as constant.

During floods that have sufficient hydraulic transport energy, the riverbed can be reworked and the clogging layer eroded. In general, a higher portion of infiltrated water in the pumped raw water is expected due to removal of the clogging layer and the greater hydraulic gradient from the river to the wells. Severe floods can also have a detrimental effect by eroding the river bank and thus affecting the installed production wells and the GW flow regime; for example flow path lengths in the aquifer and retention times of the bank filtrate.

The beneficial attenuation processes listed subsequently result mainly from mixing, biodegradation and sorption processes within two main zones (Fig. 1-1): the biologically active clogging layer, where intensive degradation and adsorption processes occur within a short residence time; and along the main flow path between the river and abstraction borehole where degradation rates and sorption capacities are lower and mixing processes greater. Compared with SW abstraction, RBF with its natural attenuation processes has the following