RADIOACTIVIDAD NATURAL EN AGUAS DE CONSUMO HUMANO

NATURAL RADIOACTIVITY IN WATER FOR HUMAN CONSUMPTION

Life ALCHEMIA

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RESULTS OF LIFE ALCHEMIA PROJECT (ESTONIA)

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RAW WATER (GROUNDWATER) QUALITY PARAMETERS

- Viimsi drinking water treatment plant (DWTP) is fed by Cambrian-Vendian groundwater with elevated radium content
- Besides the presence of radionuclides, groundwater consists of other inorganic constituents, e.g. Fe, Mn, and NH_4^+

Table 1. Average values of water quality parameters and corresponding threshold limits

Parameter	Measured value (average)	Threshold limit
Fe, mg/L	0.197	0.200
Mn, mg/L	0.147	0.050
NH_4^+, mg/L	0.654	0.500
Ra-226, Bq/L	0.359	-
Ra-228, Bq/L	0.483	-
Indicative Dose (ID), mSv/year	0.317	0.100
pH	8.12	6.5-9.5
Conductivity, µS/cm	883	2500

Figure 1. Iron and manganese staining
(https://www.americanwatercollege.org/)

Figure 2. Iron staining
(https://www.americanwatercollege.org/)

GENERAL DESCRIPTION

- The HMO-pilot plant was designed for removing radionuclides (Ra-226, Ra-228) and other water constituents, i.e. Fe, Mn, and NH_4^+ .
- The HMO-pilot plant is situated in the filtration hall of Drinking Water Treatment Plant (DWTP) of Viimsi Vesi AS.

Figure 3. HMO-pilot plant, main facility, and Viimsi Vesi AS location on map (Map data © Google)

HMO-BASED PILOT PLANT STRUCTURE

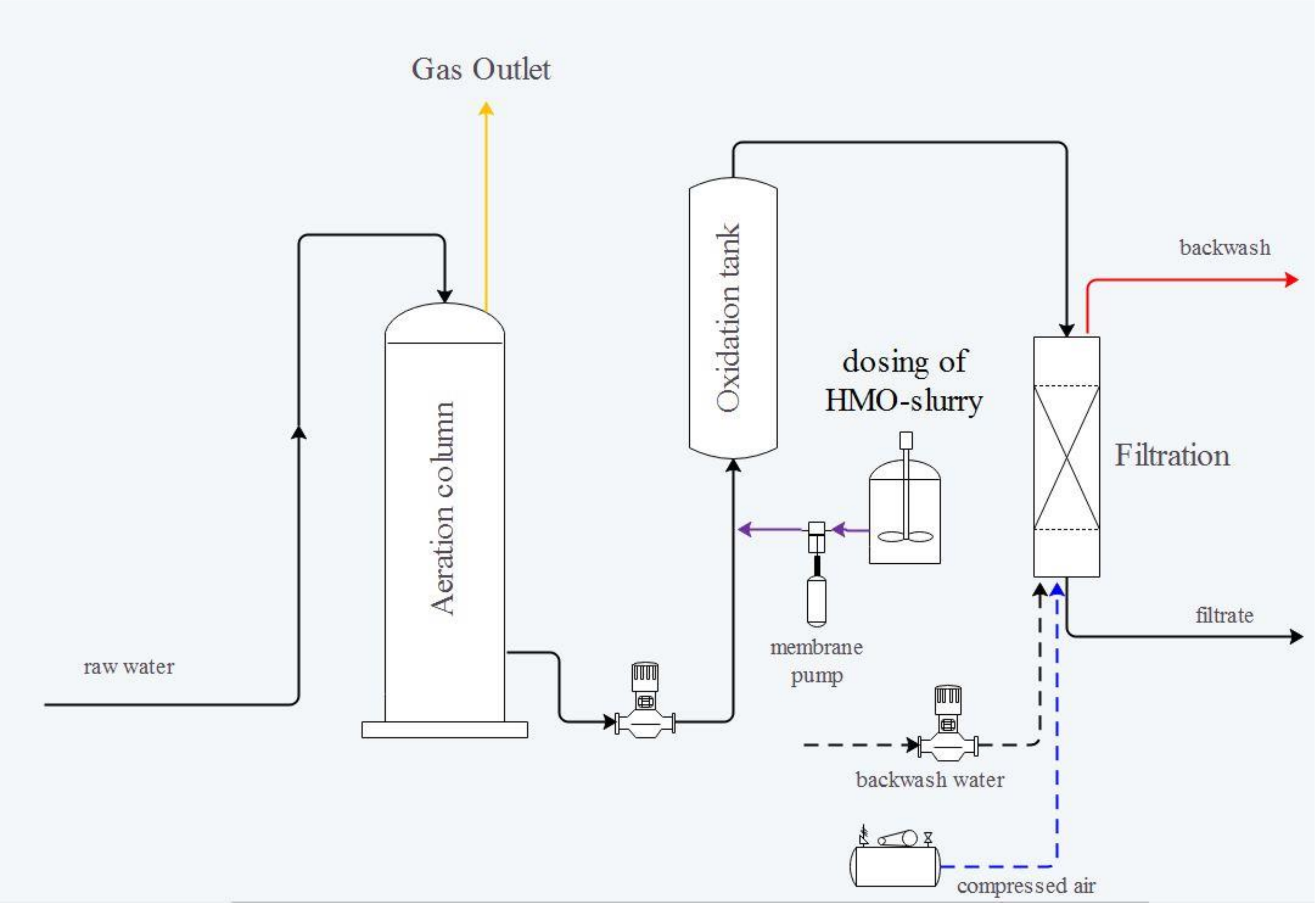


Figure 4. Process flow diagram

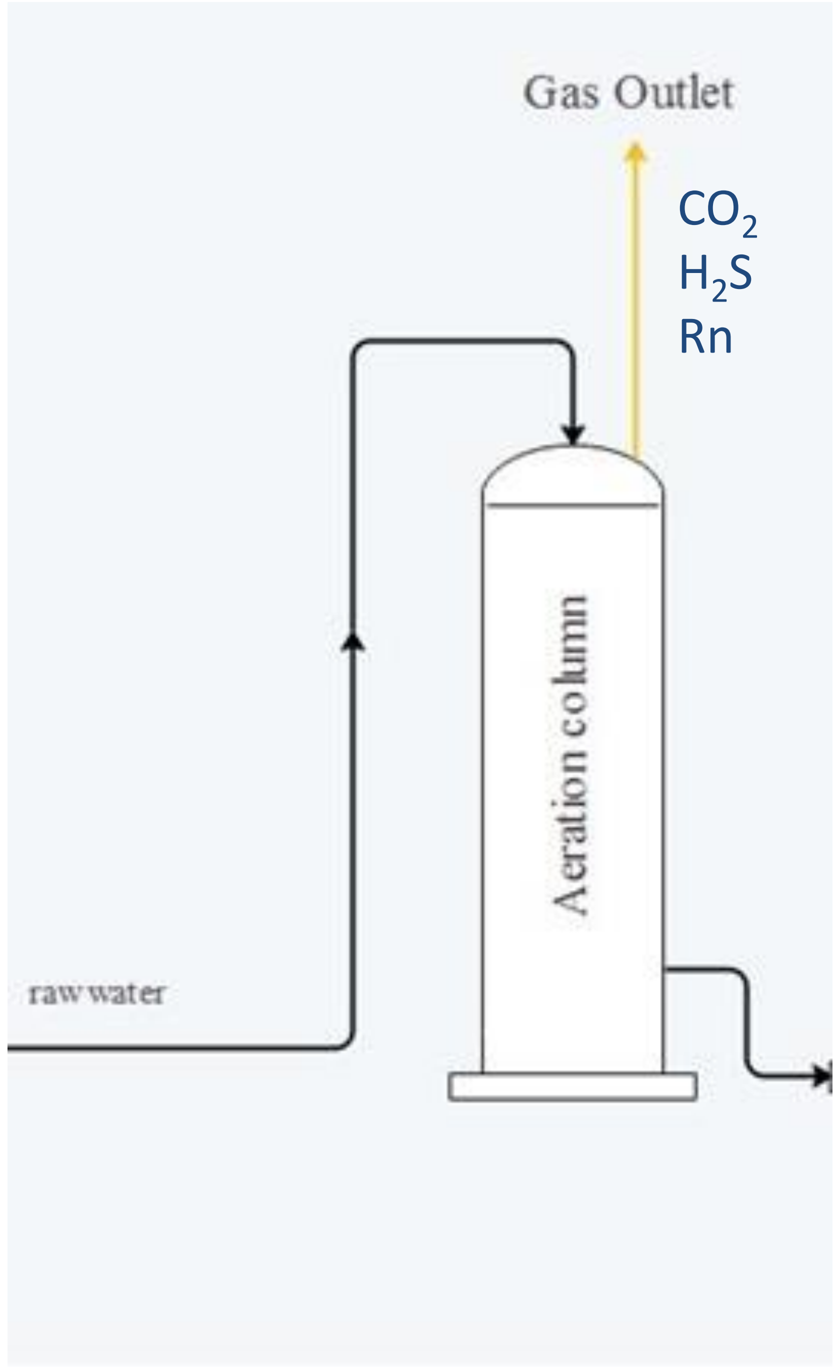
General water treatment steps:

- Aeration
- Injection of HMO slurry
- Filtration (sand filter)

Table 2. Process parameters

Parameter	Value
Electricity consumption (kWh/m^3)	**1.9**
Water flow (L/h)	**300**
Total water produced (m^3) (September 2018 – September 2020)	**4360**
The rate of HMO-slurry injection (L/h)	**0.10 – 0.20**
MnO_2 (g/m^3)	**0.8 – 1.6**

WATER OPEN AERATION



- Aeration is often the first major process at the drinking water treatment plant
- Aeration is the process of bringing water and air into close contact in order to
  - ✓Remove dissolved gases
  - ✓Saturate water with oxygen
  - ✓Oxidize iron

$$4Fe(HCO_3)_2 + 2H_2O + O_2 = 4Fe(OH)_3 \downarrow + 8CO_2$$

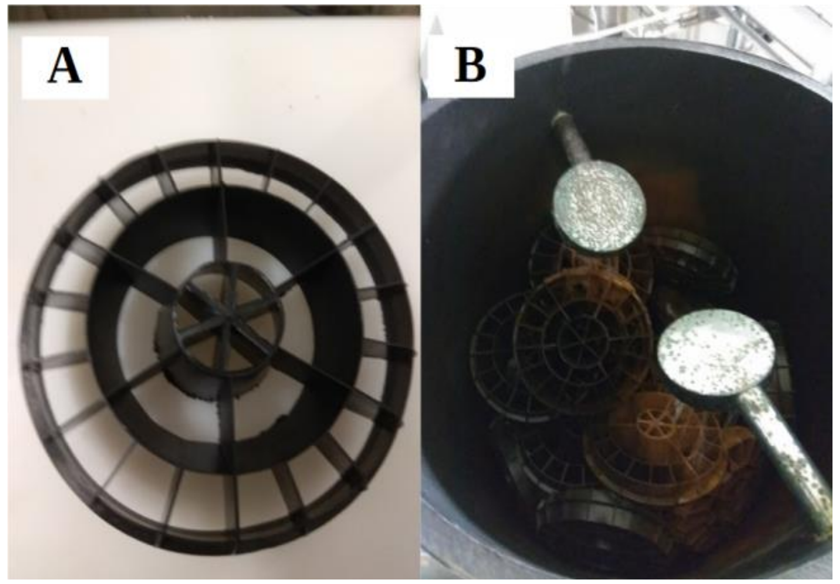
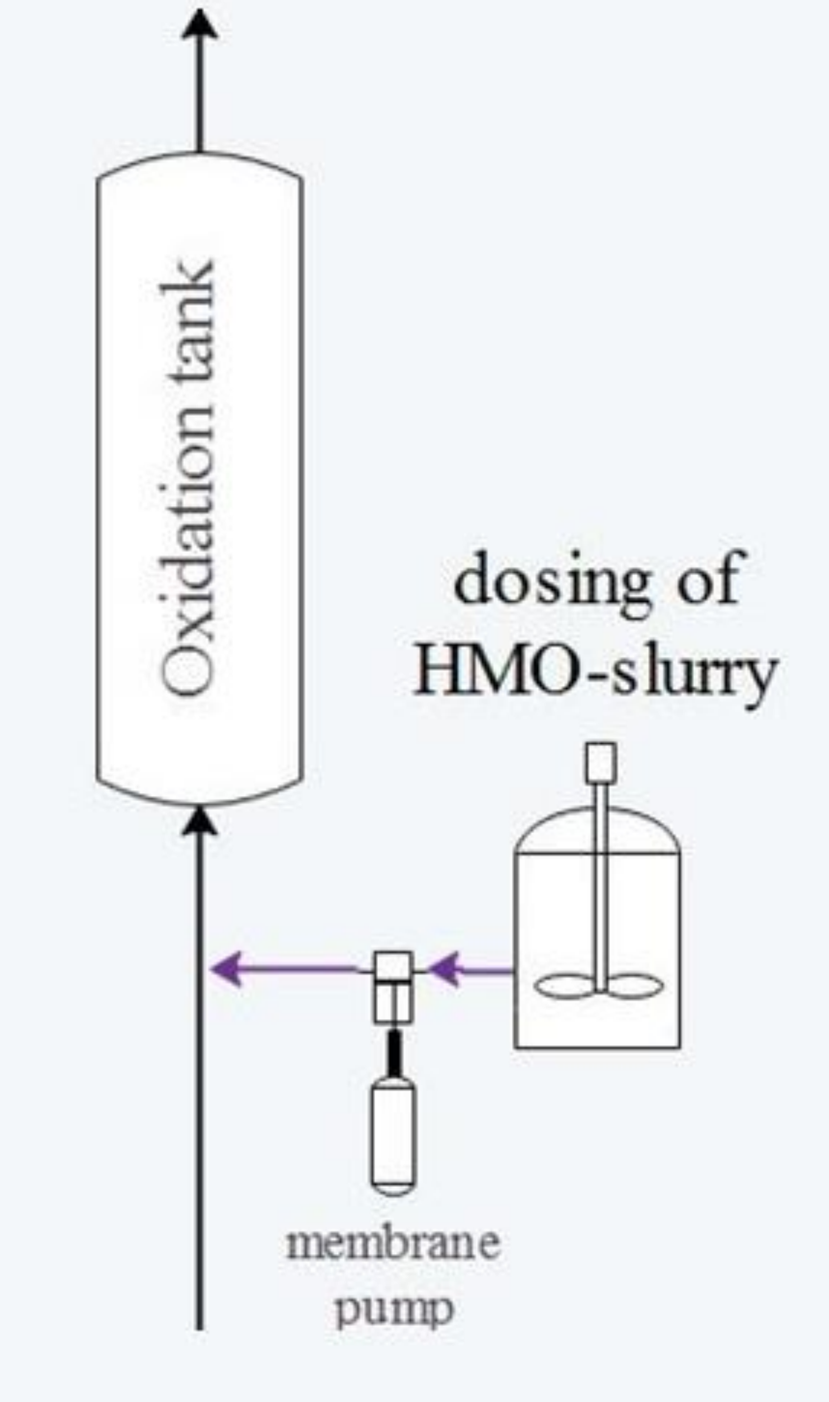


Figure 5. A – Clean filler, B – Fillers during operation in aerator

APPLICATION OF HMO SLURRY

- Manganese dioxide is often called hydrous manganese oxide **(HMO)**
- HMO slurry can be prepared using $MnSO_4 \cdot H_2O$ and $KMnO_4$ according to the reaction:
- $3MnSO_4 \cdot H_2O + 2KMnO_4 \rightarrow 5MnO_2\downarrow + K_2SO_4 + 2H_2SO_4 + H_2O$
- NaOH solution is used to maintain pH between 8 - 9.5
- The average dose of HMO could be as low as 1.0 mg MnO_2 per liter of water. At such low concentration HMO does not pose any risk to human health!



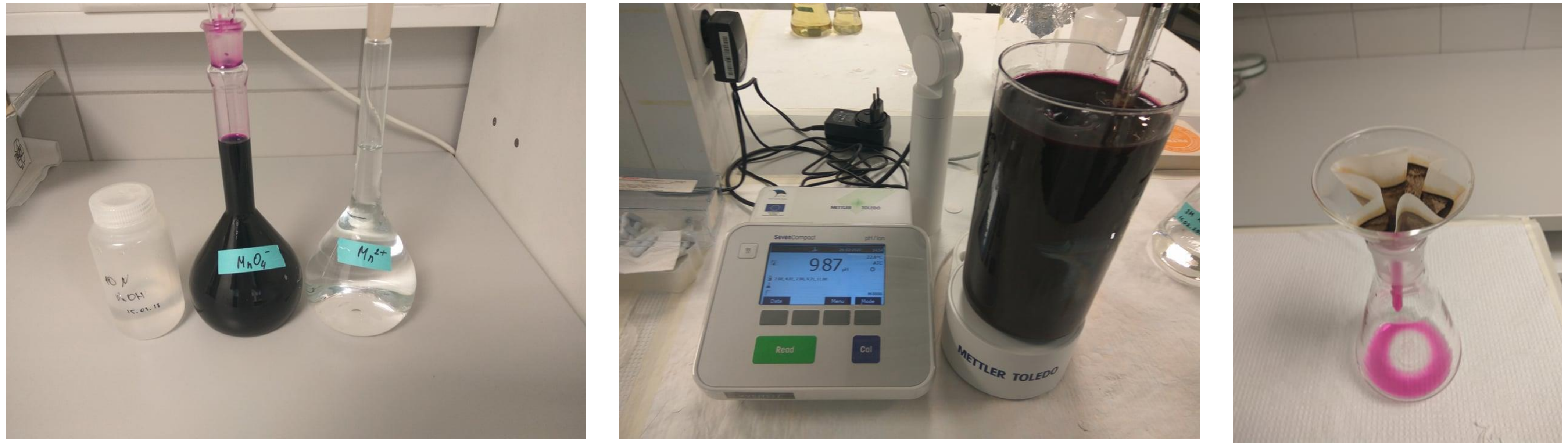
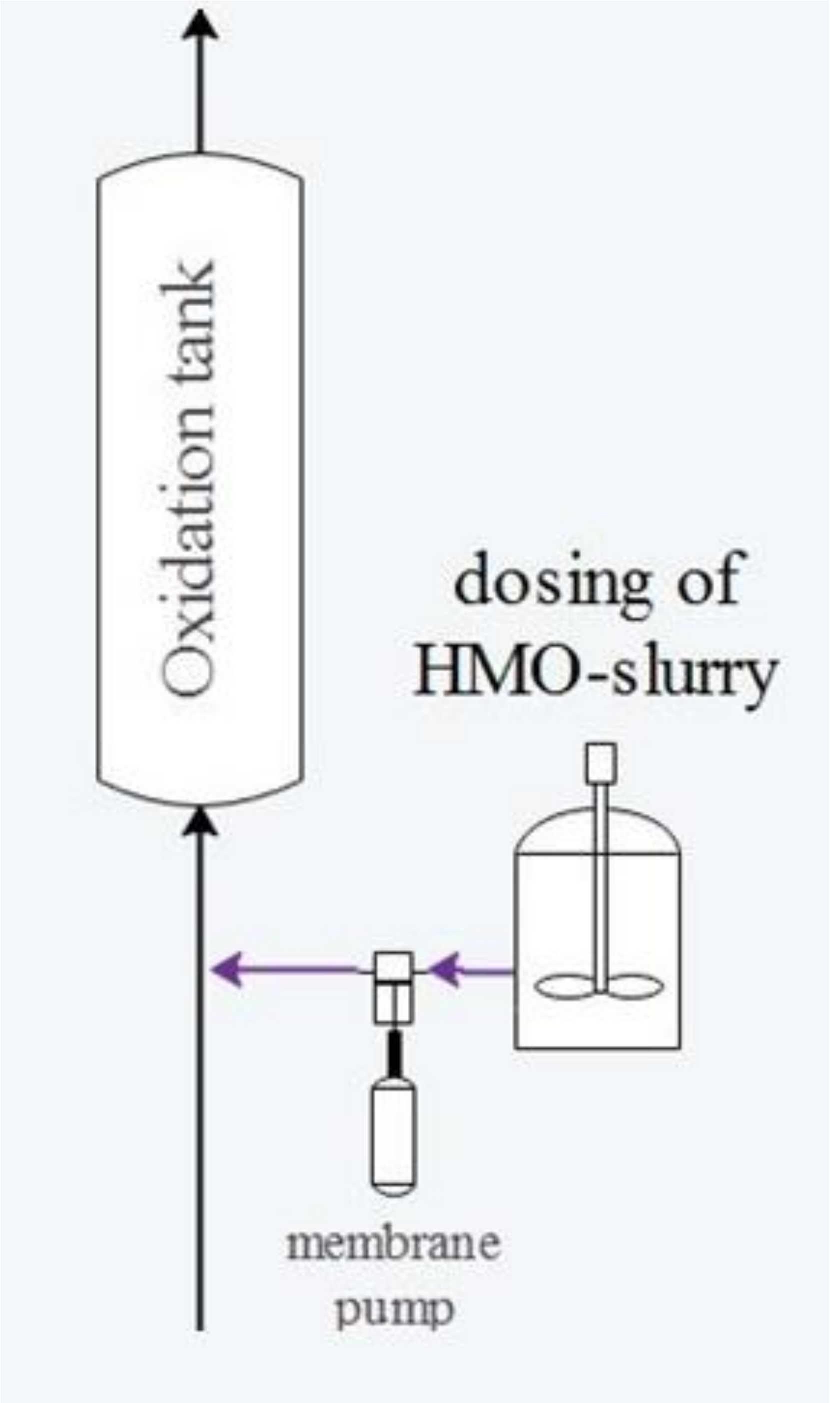


Figure 6. Preparation of HMO-slurry in a laboratory

APPLICATION OF HMO SLURRY



The mechanism of redox precipitation of Fe and Mn

$$2Fe(HCO_3)_2 + MnO_2 + H_2O \rightarrow 2Fe(OH)_3 \downarrow + MnO + 4CO_2 + H_2O$$

Why does HMO adsorb Ra^{2+} ?

- At acidic conditions H^+ reacts with MnO_2 surface to give an anionic exchanger site

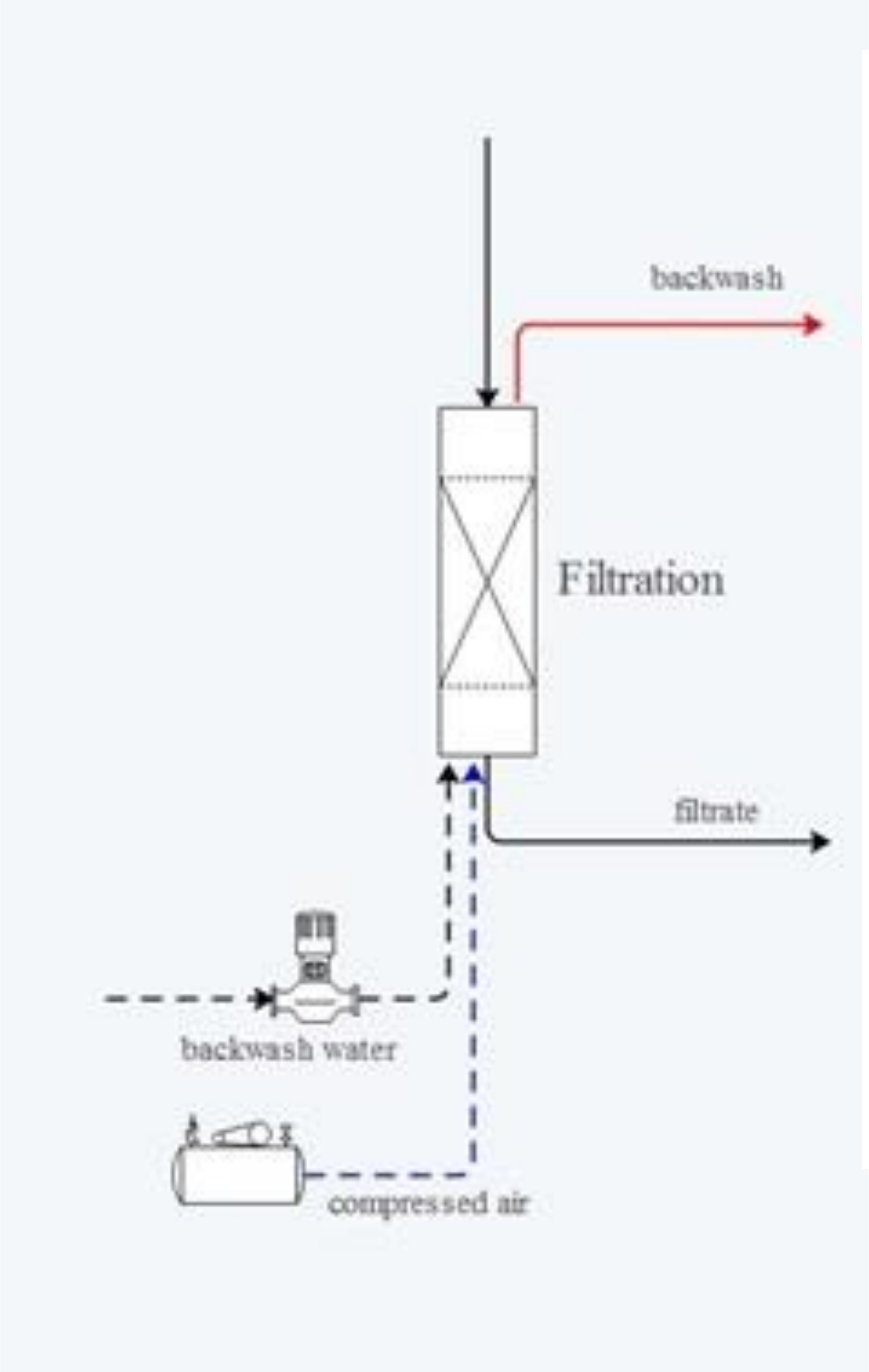
$$MnO_2 + H^+ \rightarrow MnO_2H^+$$

- At alkaline conditions hydroxide ion (OH^-) produces the surface for removing cationic species

$$MnO_2 + OH^- \rightarrow MnO_2OH^-$$

- The rise of water pH supports the increase of cationic capacity of HMO particle

FILTRATION



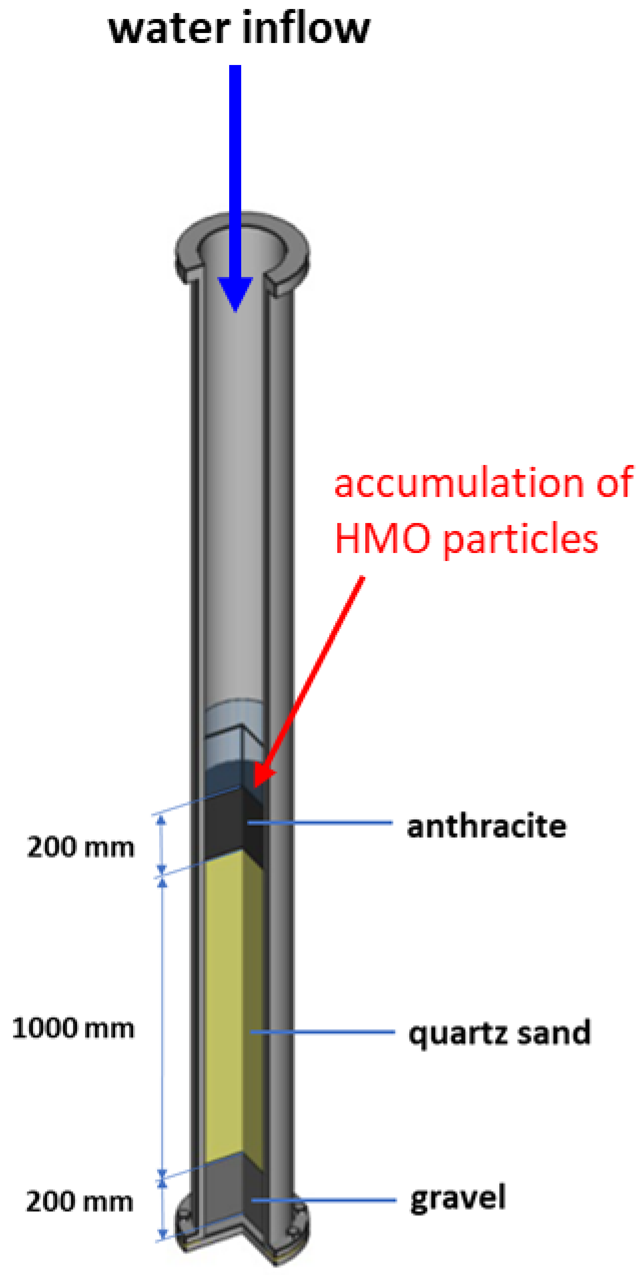


Figure 7. Filter bed composition

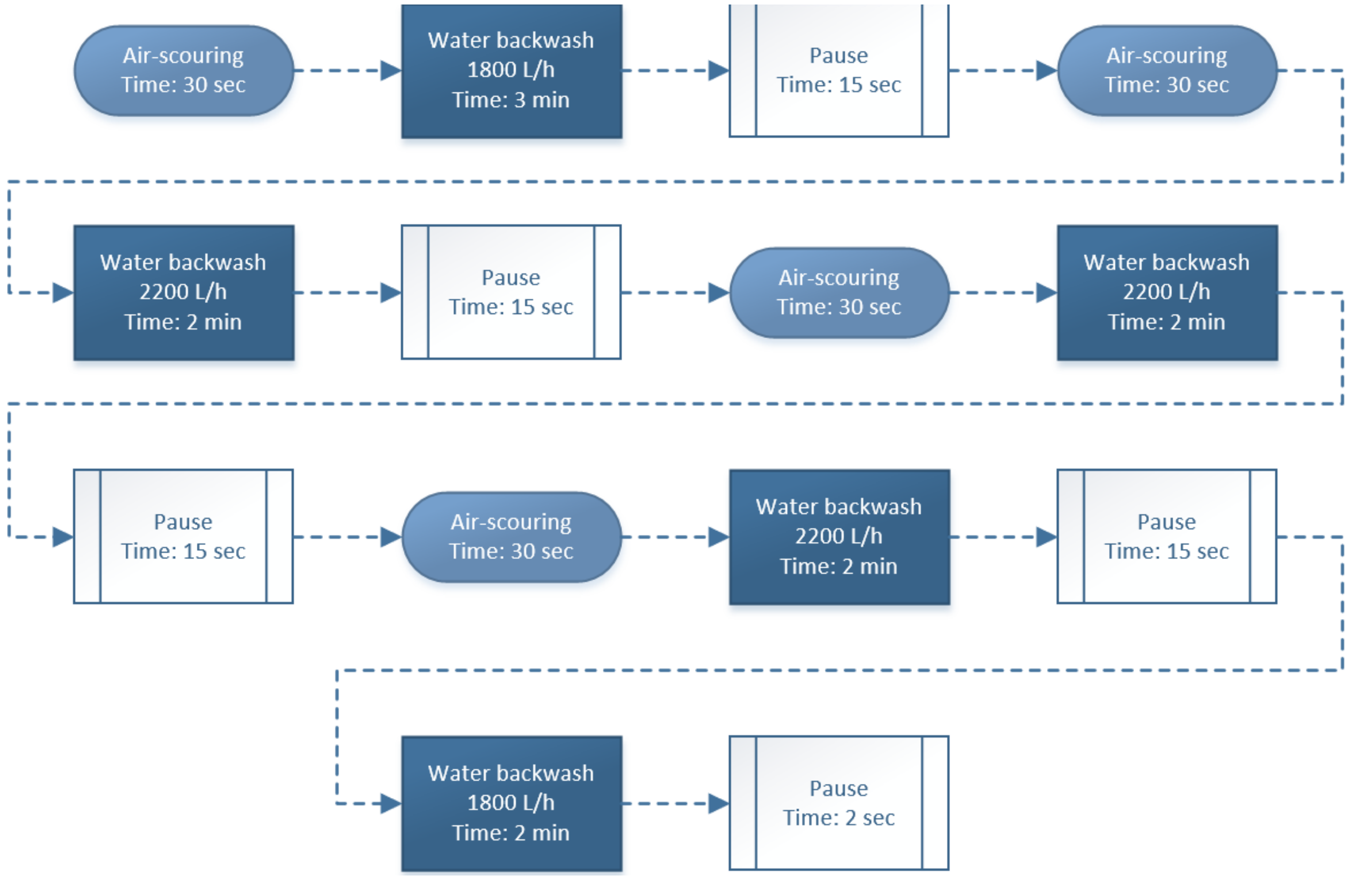


Figure 8. Backwashing algorithm

REMOVAL OF IRON AND MANGANESE

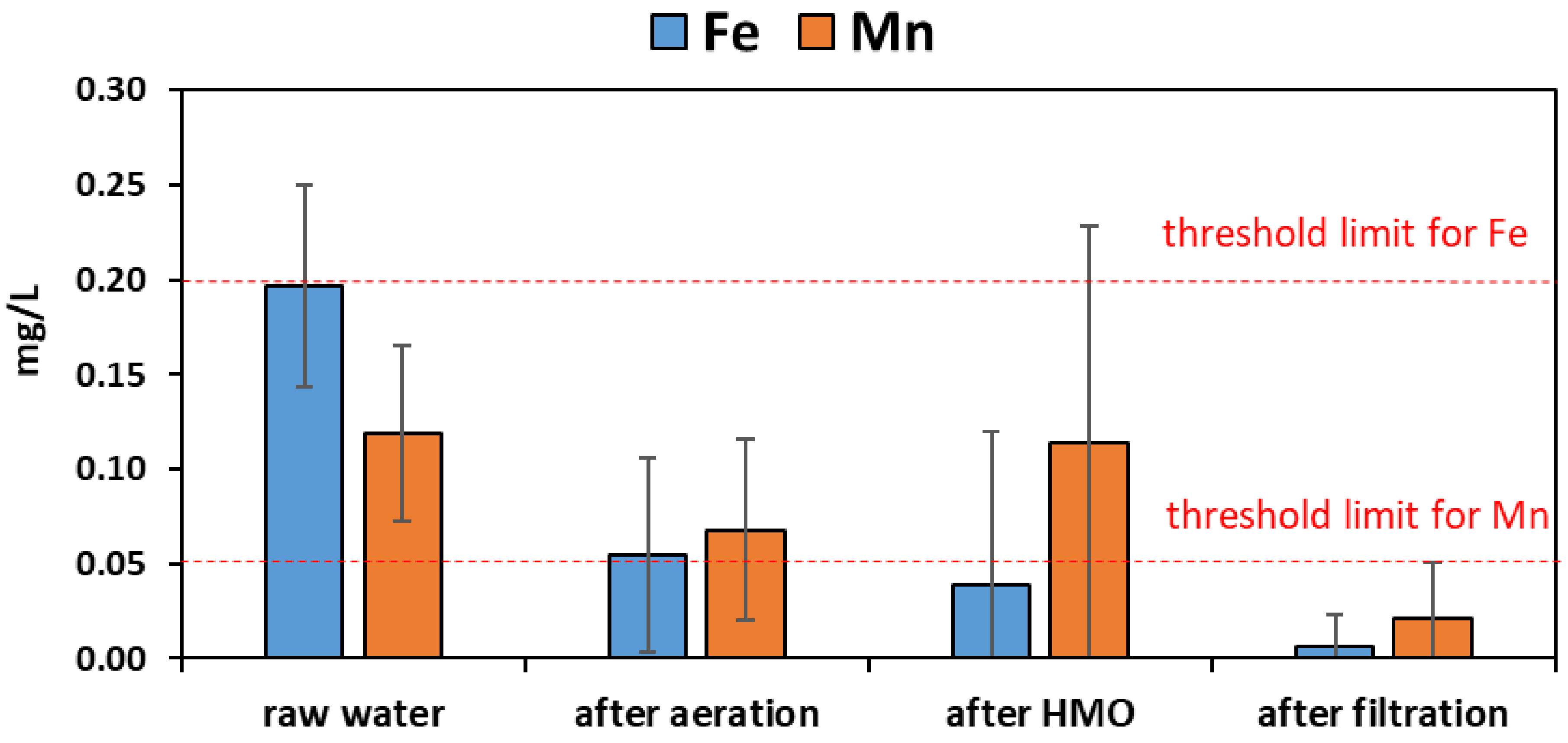


Figure 9. Average concentration of Fe and Mn after each step of treatment

WHAT ABOUT AMMONIUM ION?

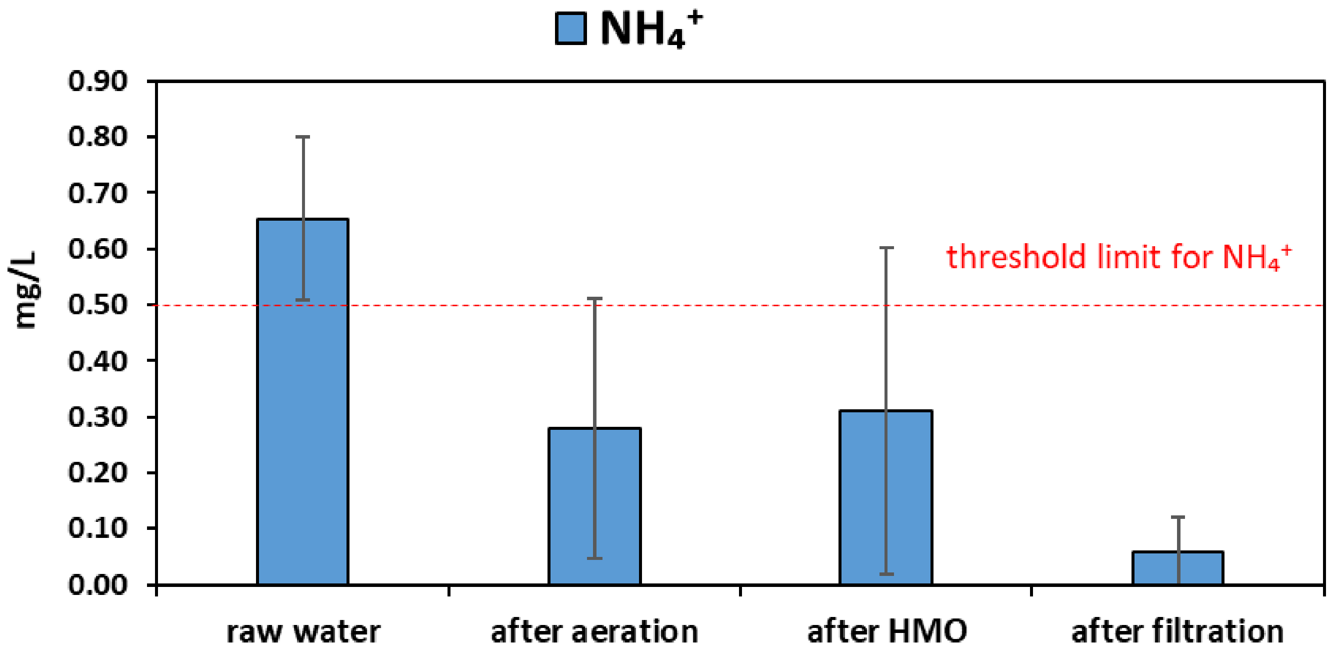


Figure 10. Average concentration of NH_4^+ after each step of treatment

Biological oxidation of NH_4^+ to nitrate could be described by the net reaction:

$$NH_4^+ + 3.3O_2 + 6.7HCO_3^- \rightarrow 0.129C_5H_7O_2N + 3.37\ NO_3^- + 1.04\ H_2O + 6.46H_2CO_3$$

The nitrification process consists usually of two stages:

- ammonium-oxidizing bacteria, i.e. *Nitrosomonas, Nitrosospira, Nitrosococcus, Nitrosolobus* and *Nitrosovibrio*, oxidize ammonium ion to nitrite as follows:

$$NH_4^+ + O_2 \rightarrow 2H^+ + H_2O + \mathbf{NO_2^-}$$

- the nitrite-oxidizing bacteria, i.e. *Nitrobacter, Nitrospira, Nitrospina, and Nitrococcus,* oxidize next the nitrite to nitrate:

$$NO_2^- + 0{,}5O_2 \rightarrow NO_3^-$$