Aalto University
School of Engineering

Biological treatment processes of water and waste
Lecture 8

WAT - E2180

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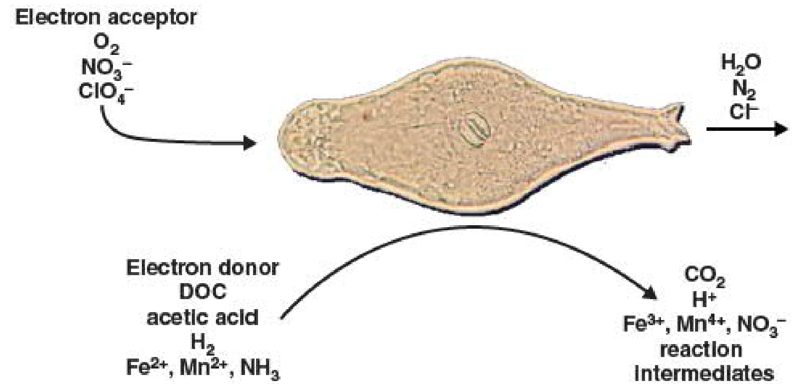
Biological treatment of drinking water

- Rely on naturally occurring bacteria to mediate transfer of electrons
- These oxidation-reduction processes convert contaminants to harmless or less toxic products

FIGURE 1 Bacterial mediation of electron transfer between reduced compounds (electron donors) and oxidized compounds (electron acceptors)



ClO_4^-—perchlorate, Cl^-—chlorine, CO_2—carbon dioxide, DOC—dissolved organic carbon, Fe^{2+}—iron(II), Fe^{3+}—iron(III), H^+—hydrogen ion, H_2—hydrogen, H_2O—water, Mn^{2+}—manganese(II), Mn^{4+}—manganese(IV), N_2—nitrogen, NH_3—ammonia, NO_3^-—nitrate, O_2—oxygen

Brown et al 2015

Potential in different biological processes

TABLE 1 Biological drinking water treatment classifications and contaminant degradation potential[a,b]

System Classification	Generalized Potential Effectiveness				
			Specific organic contaminants		
	Biological stability (e.g., low assimilable organic carbon)	Natural organic matter, disinfection by-product precursors	Naturally occurring compounds taste and odor–causing (e.g., MIB and geosmin) microtoxins	Synthetic compounds (e.g., ozonation by-products, pharmaceutical and personal care products)	Inorganic compounds (e.g., iron, manganese, ammonia, nitrate, perchlorate)
Engineered systems					
Slow-sand filtration (1°)	High	Moderate	Moderate	High to none	Moderate
Rapid-rate filtration					
Without preozonation	Moderate (1°)	Low to moderate (2°)	Moderate to high (1°–2°)	Moderate to none (1°–2°)	High to none (1°–2°)
With preozonation	Moderate (1°)	Moderate (2°)	High (1°–2°)	High to none (1°–2°)	High to none (1°–2°)
Anoxic biological treatment	Low	Low	Low	Low	High (1°)
Natural systems					
Riverbank filtration (1°–2°)	High	Moderate	Moderate	High to none	Low
Aquifer filtration (1°–2°)	High	Moderate	Moderate	High to none	Low

MIB—2-methylisoborneol

[a]1° = primary removal process—biotreatemt process is solely relied on to control the problem of concern
[b]2° = secondary removal process—requires other processes to resolve the problem of concern

The potentials for treatment effectiveness are solely intended to be used as a general guide and are not intended to be used for design. Actual treatment effectiveness is affected by many factors including the specific contaminant, source water quality and conditions, treatment process design and operation, and presence of specific strains of bacteria.

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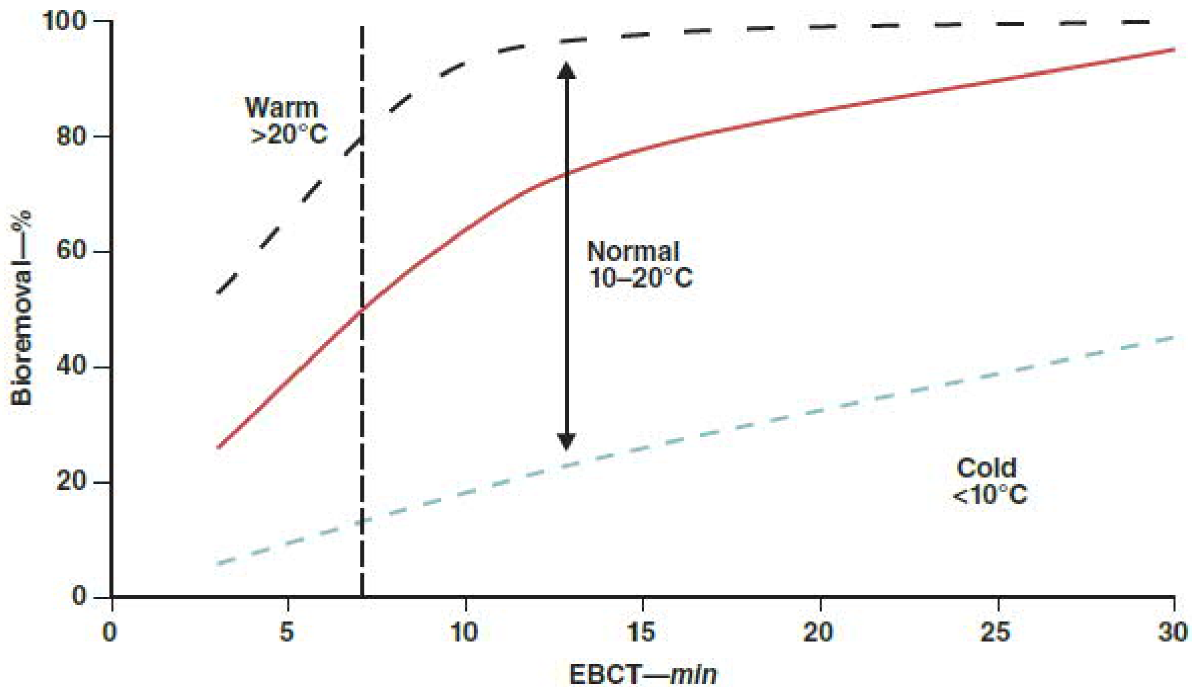
Effect of temperature

FIGURE 3 Impact of temperature on bioremoval of a range of contaminants



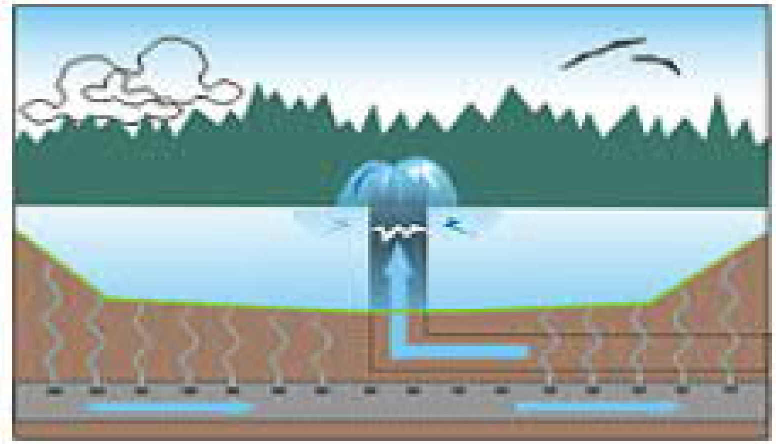
EBCT—empty bed contact time

Brown et al 2015

Biological processes in drinking water treatment

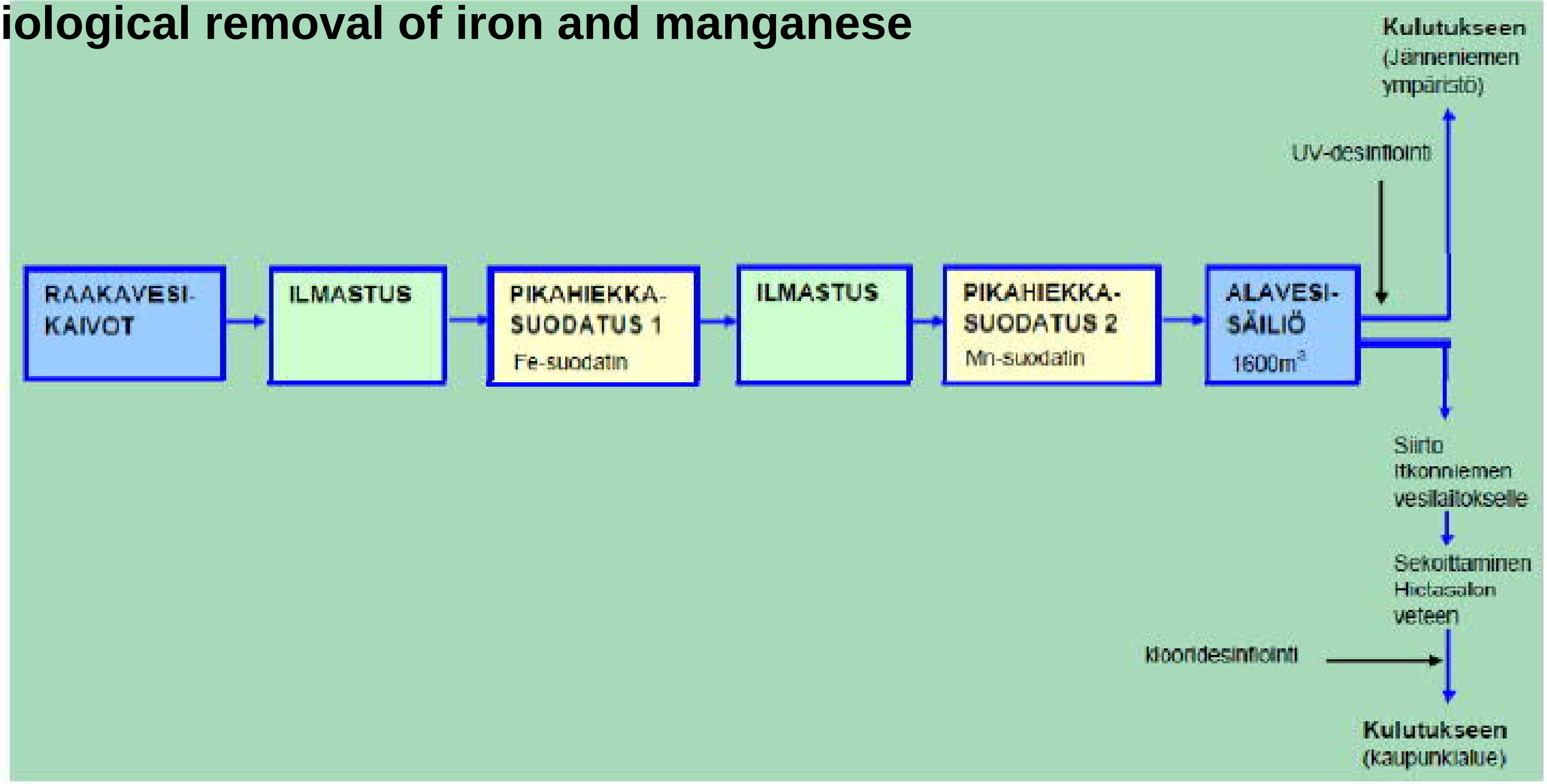
Example: Slow sand filtration in Vaasa

- **Water flows slowly through the sand layer (retention time 10 hours)**
- **Based on bacteria that grow on the sand**
- **Removal of taste and odour**



Biological processes in drinking water treatment

Example: Kuopio Rapid sand filtration
Biological removal of iron and manganese



Kuva 14. Kuopion Jänneniemen pikahiekkasuodatuslaitos (Lehtola ym, 2008).

Biological processes in drinking water treatment

Example: Biological activated carbon filtration
Biological removal of organical matter and emerging pollutants

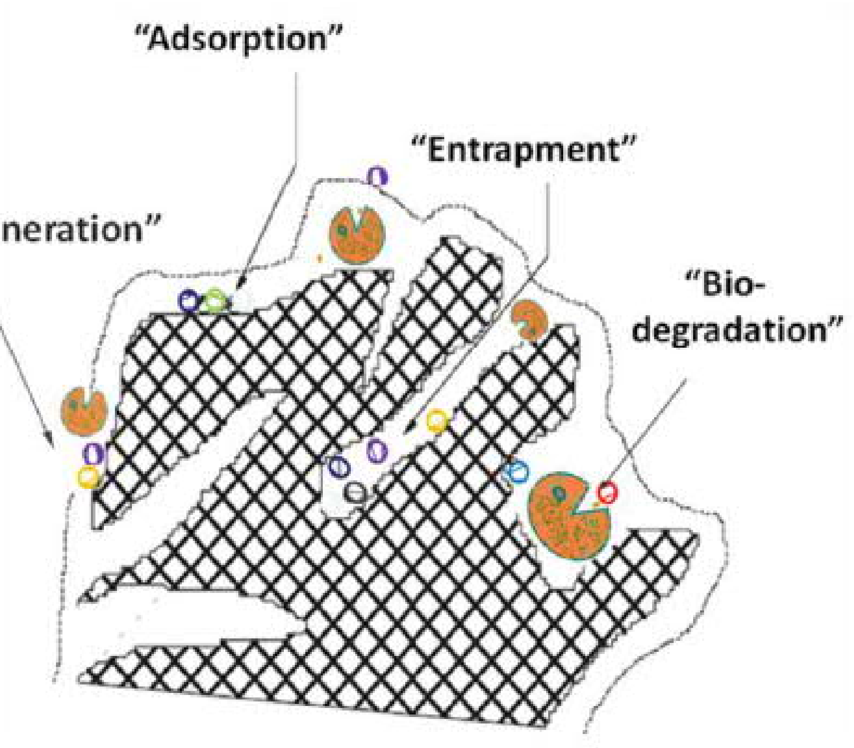


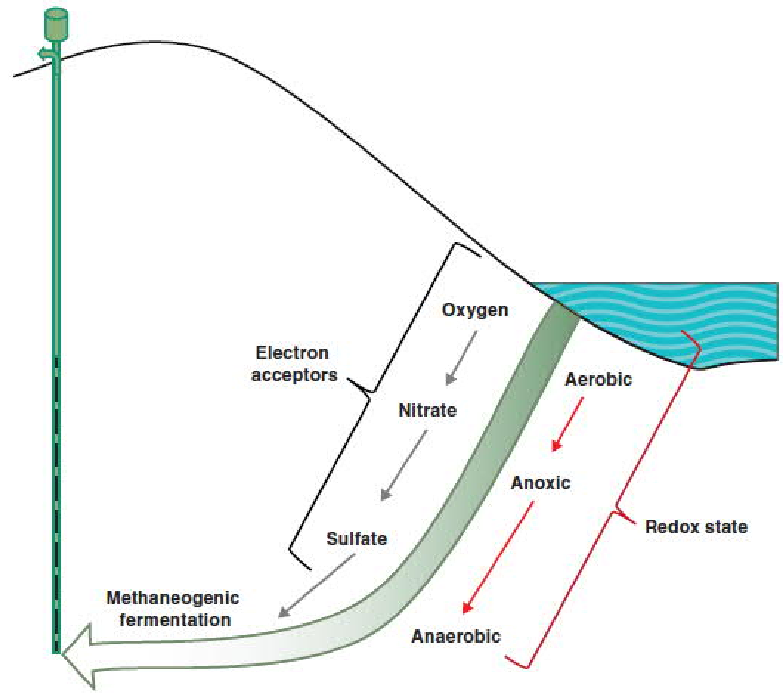
Figure 7: Biological Activated Carbon removal mechanisms. Adapted from Simpson (2008).

Natural biotreatment systems

- River bank filtration (RBF)
- Soil aquifer treatment
- Aquifer storage and recharge

- The biological processes are uncontrolled except for the flow rate

FIGURE 6 Biologic regimes in RBF



RBF—riverbank filtration

RBF acts like a plug-flow bioreactor.

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Biological treatment of waste gas

- **Commmoly used reactor types:**
  - Bioscrubbers
  - Biotrickling filters
  - Biofilters
- **Type of reactor selected based on air-water partition coefficient (Henry's constant)**
- **More volatile substances treated with biofilter**

		Liquid phase		
		Mobile	Immobile	
Biomass	Free	Bioscrubber		Scrubber + treatment tank
	Fixed	Biotrickling	Biofilter	Packed column
		Nutrient solution	Nutrient solution, packing assimilation	
		Nutrient supply		Reactor

LeCloirec et al 2014

Concepts of gas stream treatments

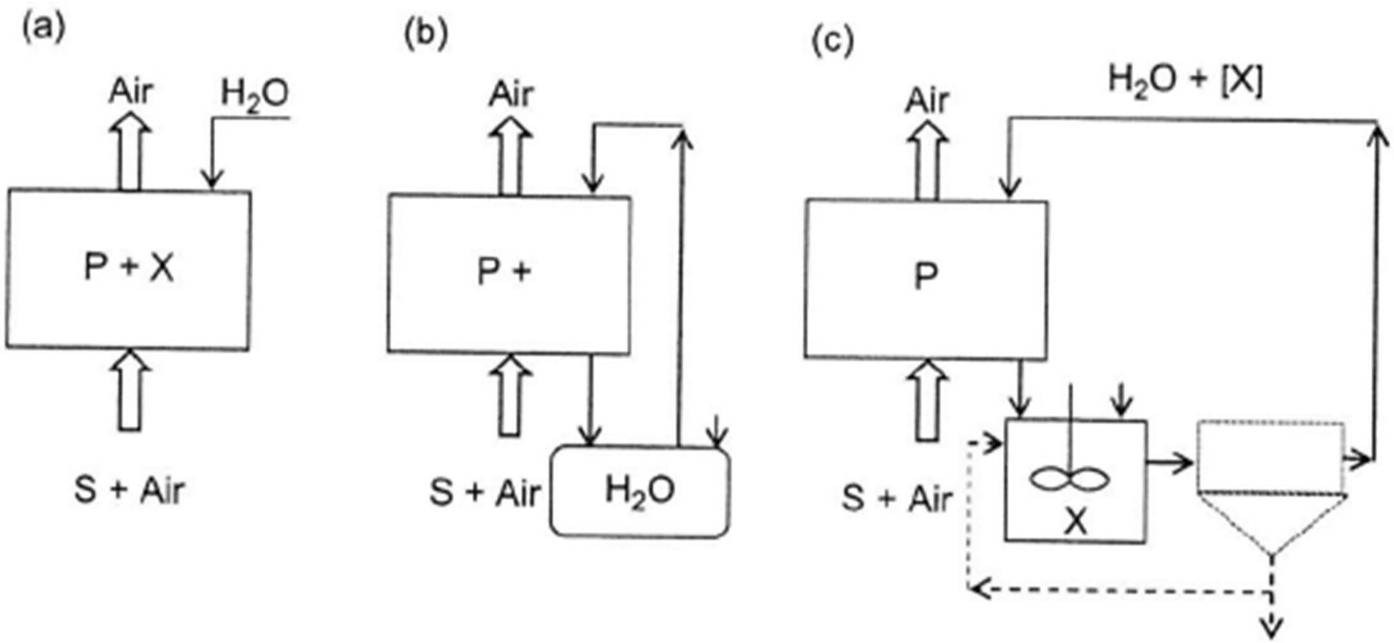

Figure 5.1 Schematic presentations of the different biological processes used in gas stream treatment: (a) biofilter; (b) trickling bed; and (c) bioscrubber (S = substrate; X = biomass; P = packing materials).

LeCloirec et al 2014

Biofiltration process of gas

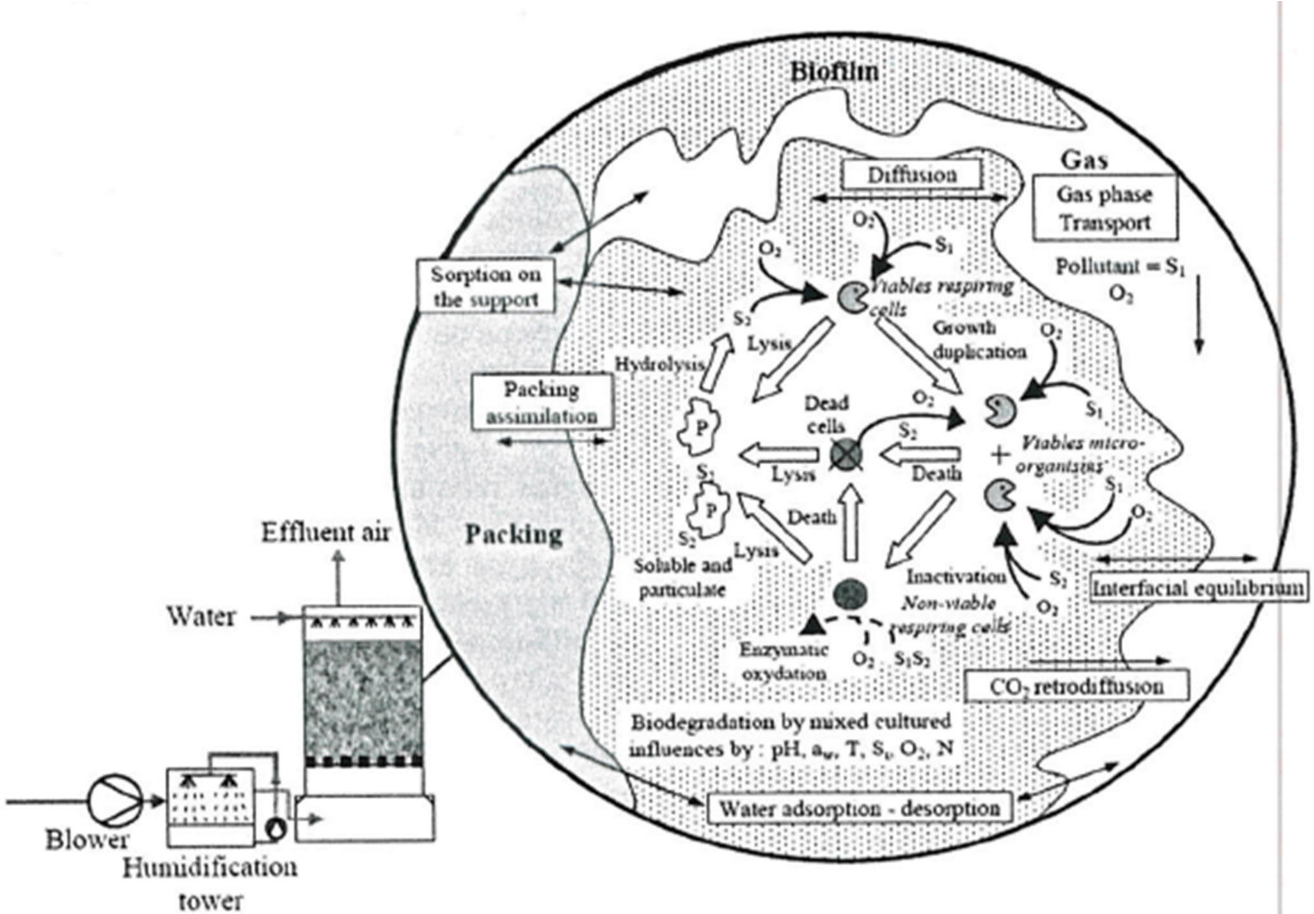

Figure 5.4 Representation of the biological and physical mechanisms involved in the biofiltration process (adapted from ref. 37).

LeCloirec et al 2014

Some examples

– Siasconset WWTF Biofilter for Odor Control

Bio scrubber for ammonia removal

Reading material

Two review papers:

Biological Drinking Water Treatment? Naturally. **Article** *in* JOURNAL American Water Works Association · December 2015

Biological waste gas treatments

Book *in* RSC Green Chemistry · January 2014