Exercises VII (answers): Treatment of wastewater solids III and Air emission control I

Applied wastewater engineering

Exercise 1: Biofiltre for waste air treatment

A wastewater facility mandates you to compute the size of a biofiltre for their waste air treatment. They plan to build a new building (6m (width) x 25 m (length) x 5 m (height)) where the following instruments will be installed: screen, screenings washer and compactor, thickener for mixed primary and secondary sludge. The waste air generated in this building should be treated. Based on the design criteria given in the course answer the following questions:

a) How much air has the biofiltre to treat per day?

$$V_{building} = width \times length \times height = 6m \times 25m \times 5m = 750m^3$$

The room is accessible and people enter and exit it several times a day. However, it is not considered a workspace as people do not spend long periods of time in this room, therefore I decide to design the biofiltre with six air exchanges per hour:

$$Q_{waste\ air} = V_{building} \times air\ exchange\ rate_{accessible,no\ workplace} = 750m^3 \times 6h^{-1} \times \frac{24h}{1d}$$
$$= \mathbf{108'000 m^3/d}$$

The biofiltre will have to treat 108'000 m³ of waste air per day.

b) How much surface is required to build such a biofiltre? Could it be placed on the roof of the same new building?

Based on the design criteria given in the course, a biofiltre should be designed with a surface loading rate between 50 and 100 m³/(m²·h). As we have no additional data about the composition of the gas, we decide to retain a 'conservative' 50 m³/(m²·h) surface loading rate:

$$surface\ loading\ rate_{biofiltre}\ (SLR_{biofiltre}) = \frac{Q_{waste\ air}}{S_{biofiltre}}$$

$$S_{biofiltre} = \frac{Q_{waste\ air}}{SLR_{biofiltre}} = \frac{108'000m^3/d}{50m^3/(m^2 \cdot h)} \times \frac{d}{24h} = \mathbf{90 m^2}$$

The roof of the building has:

$$S_{building} = lenght \times width = 25m \times 6m = 150m^2$$

Hence, the roof of the building (150m²) is larger than the surface required for the media of the biofiltre (90 m²). Even though the biofiltre also requires a construction around the filter media, the roof of the new building will be large enough to build the biofiltre for the waste air treatment on it.

c) Assume a filter media depth of 1 m and a porosity of 40 %. What will be the effective gas residence time in the biofiltre (in seconds)?

$$residence\ time_{\ gas}(RT_{gas}) = \frac{V_{biofiltre} \times \alpha}{Q_{waste\ air}} = \frac{S_{biofiltre} \times depth_{biofiltre} \times \alpha}{Q_{waste\ air}}$$
$$= \frac{90m^2 \times 1m \times 0.40}{108'000m^3/d} \times \frac{60 \times 60 \times 24s}{1d} = \mathbf{29s}$$

The gas residence time will be 29s if the porosity of the filter material is 40 % and the filter media depth 1m.

Exercise 2: Treatment processes of odorous compounds

The treatment processes to remove odorous compounds are based on biological, chemical, and physical processes.

a) Explain how the biological treatment process permits to remove odorous substances and indicate a possible process.

In order that bacteria or fungi can degrade substances biologically, these substances generally must in a first step transfer from the gas phase to the liquid phase where the bacteria or fungi live (e.g., a biofilm). Then bacteria or fungi can absorb them and degrade them (bioconversion).

An example of a biological process to remove odorous compounds is a biofiltre.

b) Explain how the chemical treatment process permits to remove odorous substances and indicate a possible process.

The odorous compounds first need to transfer from the gas phase to the liquid phase. They remain there because of two types of chemicals reactions: a) acid-base reactions or b) oxidation which can be enhanced by temperature or catalysers. The liquid phase containing the odorous compounds needs further treatment (often done in the treatment steps of the wastewater treatment plant).

An example of a chemical process to remove odorous compounds is a chemical scrubber using different treatment steps: acid, base, and chlorine.

c) Explain how the physical treatment process permits to remove odorous substances and indicate a possible process.

The odorous compounds adsorb or absorb on a material that generally has a large surface area (transfer from the gas phase on a solid phase). The material needs to be replaced or regenerated once it is saturated with odorous compounds.

An example of a physical process to remove odorous compounds is an activated carbon filter.