LAB EXPERIMENTS

Aeration

Cascade aeration

Framework
This module explains the lab experiment on Aeration.

Contents
This module has the following contents:

1. Objective

In groundwater treatment the first stage in the purification process is often aeration/gas stripping. Oxygen is added to anaerobic groundwater while gasses like carbon dioxide and methane are removed by stripping. A cascade is one of the possibilities for gas stripping.

The purpose of this experiment is an acquaintance with adding oxygen and the process parameters. The experiment will be evaluated with computer models on the website www.stimela.com. One model used to verify the efficiency of cascades

A full-scale treatment plant has to be designed, using the results of the laboratory experiment.

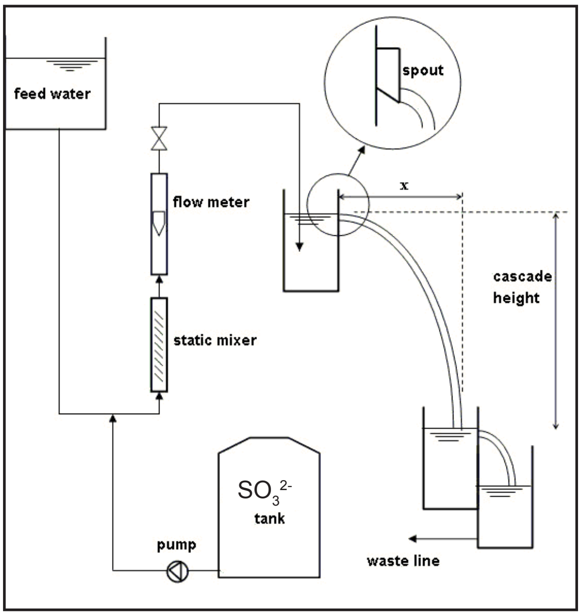

Figure 1 - Experiment set-up

2. Experiment set-up

The pilot plant is built as a cascade with an adjustable cascade height. A schematic drawing is given in figure 1. The pilot plant is fed with tap water. Sulfite is added to the tap water to achieve a sufficiently low oxygen content.

$$2\,SO_3^{2-} + O_2 \rightarrow SO_4^{2-}$$

The Sulfite is stored in a container and pumped into the feed pipe of the cascade. A static mixer in the feed pipe makes that the Sulfite is thoroughly mixed with the water. This influent flows into the division chamber to which eventually a second cascade can be connected. From the division chamber the water falls into the top compartment with a volume of 15 litre and falls in a second step into the second compartment that can be adjusted in height. After the second compartment the water is discharged to the sewer.

The flow is read on a flow meter and controlled by a valve in the feed pipe.

3. Theory

3.1 General

The overall efficiency of gas transfer in a cascade is expressed by:

$$K = \frac{(c_0 - c_e)}{(c_0 - c_s)} = \frac{\text{what is removed}}{\text{what could be removed}}$$

in which:

K = total efficiency of the cascade (-)
c_e = gas concentration downstream (mg/l)
c_0 = gas concentration upstream (mg/l)
c_s = saturation concentration of the gas in water (mg/l)

The efficiency of one step in a cascade is a function of the cascade height. The appearance of this function, which has not to be strictly linear, has to be determined from the results of the experiment.

$$k_2 = f(h)$$

k_2 = efficiency of one cascade step (-)
h = cascade height (m)

The overall efficiency K of a series of n cascades with equal heights is calculated from the efficiency k_2 of one step: $K = 1 - (1-k_2)^n$

3.2 Design

The design of the experiment is described below.

Weir loading

This is the flow rate per meter of weir length. The effect of the weir loading is insignificant for weir loadings up to 120 $m^3/(m \cdot h)$.

Depth of cascade chamber

Application of a shallow chamber reduces the gas transfer because the penetration rate of gas bubbles in the liquid is lower. This effect is significant for aeration processes. For the removal of carbon dioxide the depth is less important. In general the depth is chosen 2/3 of the cascade height.

Weir configuration

The overflow can be sub-divided into smaller jets.

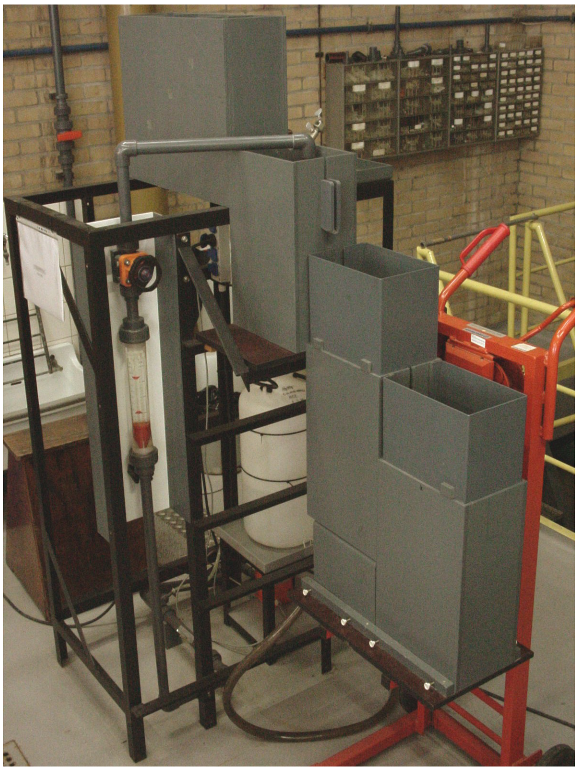

Figure 2 - Cascade in the laboratory

The effect on gas transfer can be found in literature.

Width of chamber

The width is measured perpendicular to the overflow weir. The point where the jet falls into the receiving chamber determines the width. The width depends of the weir loading. In the pilot plant a spout is used to prevent too much splashing. The spout is inclined downward with an angle of 30°. The width is calculated with a formula for the path of a free-falling body with an initial velocity v_0 under an angle α^0:

$$h = \frac{1}{2} g t^2 + v_0 t \sin\alpha$$

$$x = t v_0 \cos\alpha$$

in which:

x	= the horizontal distance of a falling water jet	(m)
v_0	= the initial velocity of the water jet	(m/s)
g	= gravity acceleration	(m/s^2)
α	= angle of spout with horizontal (30°)	(-)
t	= time	(s)

4. Procedure

The experiment is performed with a constant flow rate of 1000 l/h and 5 different cascade heights of. 0.20, 0.35, 0.50, 0.65 and 0.80 m. Also the water jet can be broken by a sieve. Sulfite with a concentration of 25 g Na_2SO_3 /l is dosed in the water. The water inflow and Sulfite dosage have to be controlled regularly.

The velocity of the water jet leaving the spout is calculated with the spout-width of 1 cm, the inflow rate and the height of the water jet where it leaves the spout. This velocity is constant during the experiment, provided that the flow rate is constant.

Influent

Adjust the sulfite dosing to an oxygen concentration between 2 and 4 mg/l. Measure the temperature, pH and oxygen concentration 3 times. It is assumed that the quality of the inflow is represented by the average of the three samples.

Effluent
Control the inflow rate and sulfite dosing regularly.
- set the required cascade height. This is the distance between the spout bottom and the overflow weir of the receiving chamber. Start with the smallest height.
- measure the horizontal distance of the water jet from the overflow weir.
- measure the pH, temperature and oxygen concentartion in the receiving chamber (3 times) and find the average.
- continue with the next setting.
- switch off the dosing pump after the last setting and 10 minutes later the inflow.

5. Elaboration

Execute the following steps:
- calculate the solubility of oxygen from the temperature.
- find the relationship between the efficiency and the cascade height.
- calculate k_2 for every height.
- calculate the theoretical distance of the water jet and compare it with the measured value.
- design and draw a full-scale unit for adding O_2 in a flow of 500 m^3/h. Assume the feed water has a temperature of 10 °C and a O_2-concentration of 0.4 mg/l. The required effluent concentration is 9.5 mg O_2/l. Use the calculated k_2 values. Determine the heght and the amount of steps.
- design the chamber width, the cascade height and the total weir length. Assume a chamber depth of ⅔ of the cascade height.

Table 1 - Equilibrium concentration of O_2 in water

Temperature (°C)	C_s (mg/l)
5	12.8
10	11.3
15	10.2
20	9.2