Toxicity monitoring at the inlet of wastewater treatment plants (WWTP)

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Abstract

There is growing pressure to increase the efficiency of wastewater treatment plants (WWTP). The efficiency of these plants is mostly measured by its rate of biodegradation and removal of nutrients which can be optimized by controlling the effect of toxic substances prior to reaching the plant. All substances that are detrimental to the respiration rate of bacteria can lead to a significant reduction of biodegradation in wastewater treatment plants. Activated sludge used in the treatment plant is a mixture of different bacteria species which degrade substrates in order to grow, mainly based on the continuous consumption of oxygen. This process is conventionally named respiration and has a direct relationship between growth and biodegradation. Experiments show that with advanced respiration technology, online monitoring of toxicity in wastewater treatment plants is possible.

Keywords: toxicity, activated sludge, respiration rate, wastewater treatment plant (WWTP).

1. Introduction

Most of municipal and industrial wastewater treatment plants (WWTP) depend on activated sludge processes to eliminate the organic and nutrient load. Main component of activated sludge are bacteria which have to be protected and fed properly to optimize the removal processes.

A typical design of an activated sludge process consists of an (1) aeration tank where air or dissolved oxygen is injected in order to create ideal conditions for the bacteria and (2) a settling tank where the biological floc can settle and be separated from the clarified water. The combination of raw sewage and biological mass is commonly known as Mixed Liquor (ML). Part of the settled material, the sludge, is returned to the inlet of the aeration system to re-seed the new sewage entering the tank. This fraction of the flock is called return sludge.

The analytical method to determine *toxicity* in water is respirometry, which is defined as the measurement of the oxygen uptake rate, expressed as amount of DO taken up per unit of volume per unit of time. Monitoring toxicity allows to protect the microorganisms in activated sludge from toxic substances in the wastewater influent. The measuring results are given in % inhibition of the respiration rate.

The instrument used for semi-continuous, online monitoring of toxicity in wastewater using respirometry technology is Hach's EZ7900 analyzer. Acute toxic compounds present in the wastewater can be detected in a very early stage by the analyzer. This is accomplished before the wastewater reaches the treatment plant. The system functions as an 'early-warning' system which can help to divert the toxic load to an emergency tank.

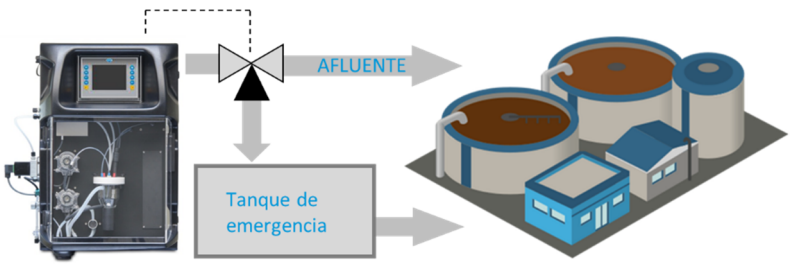

Fig 1. Integration of EZ7900 toxicity analyzer in plant operation control

2. Measuring principle respiration rate

Activated sludge responds to the variation of loading of biodegradable compounds in WWTP and consequently, shows dynamic behavior. Knowledge of this dynamic behavior is important for:

- the design of an activated sludge wastewater treatment plant (WWTP),
- the development of dynamic models of the WWTP process, and
- the (automatic) control of the process to minimize energy costs for aeration, optimize sludge loading, maintain nitrification and prevent sludge wastage with the effluent

A good measure of this dynamic behavior is the oxygen consumption rate or respiration rate of the sludge in mg O2/l.h. The dissolved oxygen is measured by means of a single electrode.

Fig 2. Respiration module of EZ7900 toxicity analyzer

First step of the analysis: determination of the oxygen consumption on fresh activated sludge as reference measurement (difference in oxygen concentration between point 2 and 1 in figure 3 below).
Second step of the analysis: determination of the oxygen concentration of activated sludge after addition of the wastewater sample (difference in oxygen concentration between point 4 and 3 in figure 3 below).

Nutrient solution is added, and an oxygenation step is executed before both steps as described above to ensure suitable conditions for good microbial respiration.

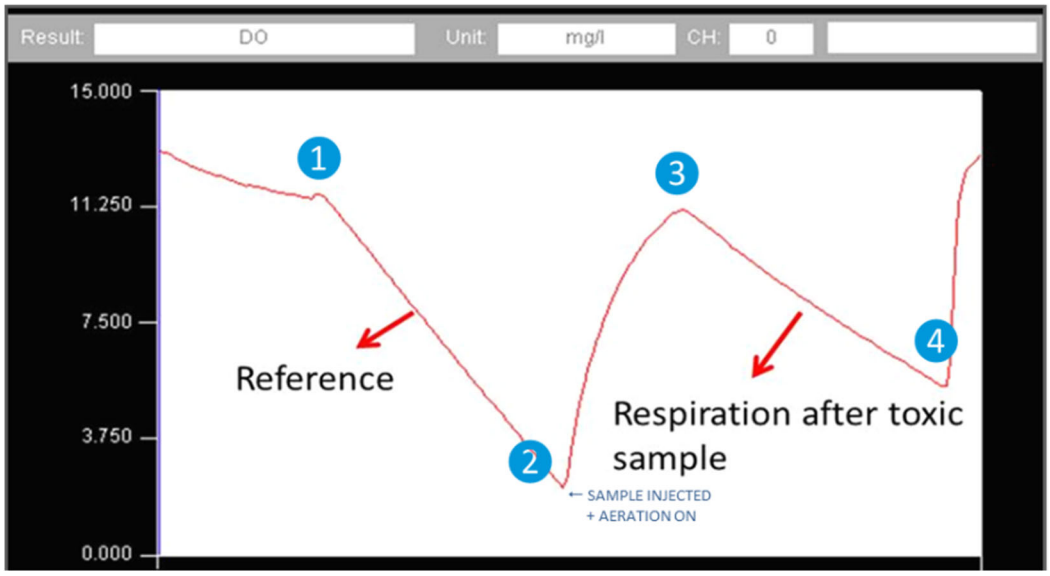

Fig 3. Dissolved Oxygen vs time graph during analysis

- Calculation of the respiration rate 1 (reference): (M1-M2)/120*3600 mg/(lh)
- Calculation of the respiration rate 2 (wastewater): (M3-M4)/120*3600 mg/(lh)

- Inhibition (%) of the respiration = 100 – (Resp 2 / Resp 1)*100)

The higher the inhibition %, the higher the toxicity of the wastewater on the respiration performance of the activated sludge.

3. Toxicity measurement as online monitoring parameter

For online toxicity monitoring of the incoming wastewater in a treatment plant, a good preconditioning system is required to allow automatic sampling and analysis without need for human intervention.
Activated sludge and wastewater can be pumped to the filtration preconditioning panel of the EZ7900. Operation of the panel is controlled by the instrument during each analysis cycle. Automatic rinsing and backflush cleaning steps are programmed to minimize manual cleaning actions.

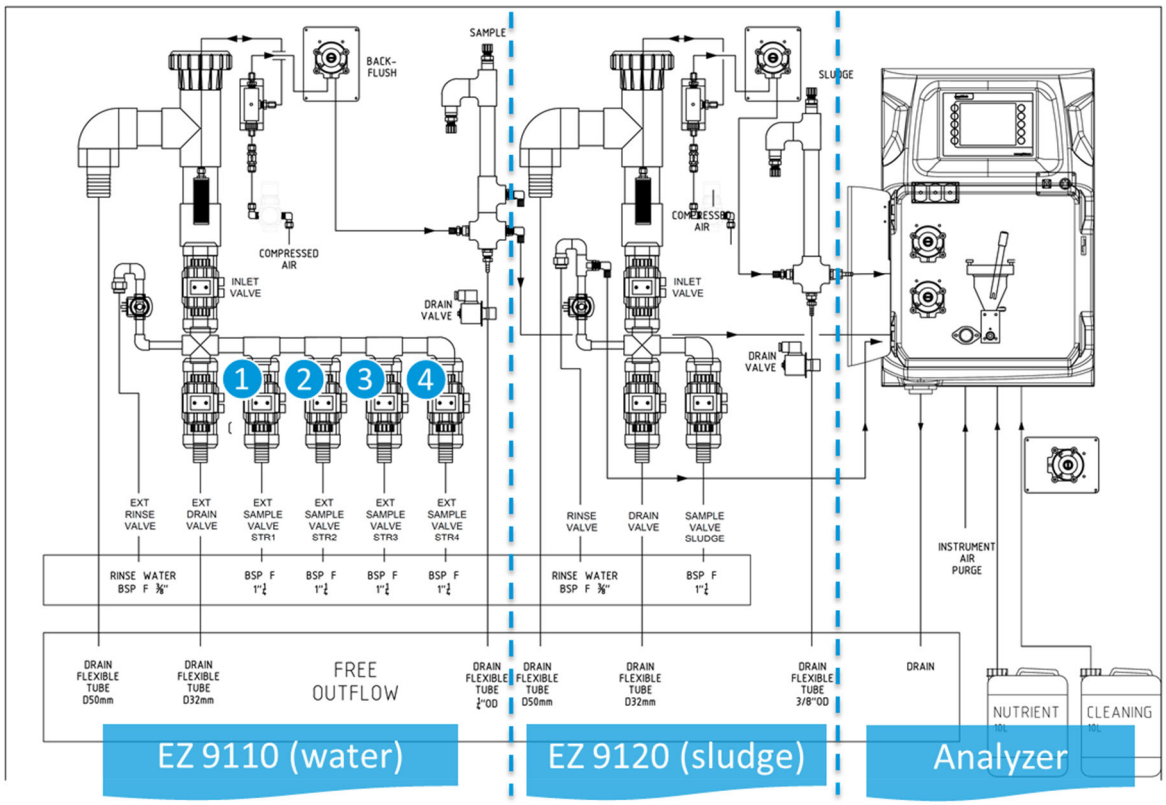

Fig 4. Sample filtration preconditioning panel and analyzer setup

The analyzer also displays the maximum respiration rate of the activated sludge determined during the reference analysis. This can give information regarding the state of the activated sludge and a potential build-up of chronic toxicity in the basin.

4. Analyzer design

Measuring principle for the on-line determination of toxicity is based on respirometry. Sludge of the treatment plant is mixed inside the analyzer with a simple to digest food-source substrate and maximum oxygen concentration for having most optimal respiration conditions.

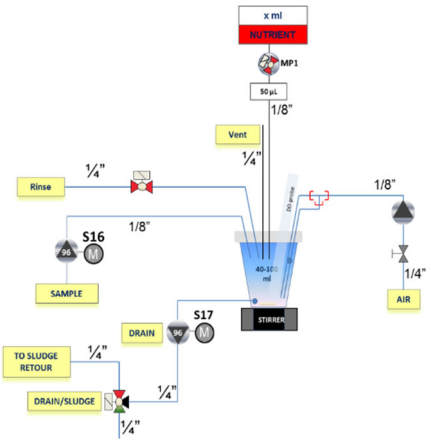

Fig 5. Flow diagram of EZ7900 analyzer

After this first respiration measurement (= reference) a portion of sample is added. Then a second respiration measurement is done. The ratio between the first and last respiration is the value for the toxicity of the influent.

The quantity of oxygen consumed per unit of time and per unit of volume, called respiration rate (mg O2/l.h) is one of the most important parameters for the biological activity of activated sludge. Consequently, the determination of the respiration rate is of great importance in gaining insight in activated sludge plants. For the on-line determination of the respiration rate of activated sludge, or any other oxygen consuming liquid the measured values must be available with short intervals and must be reproducible and of high accuracy.

The EZ7900 toxicity analyzer meets these requirements. Every 20 minutes, a new value of the respiration value is available.

The design of the analyzer includes wet chemical components (reagent pumps, stirrer, valves, etc) that follow a program of commands to ensure repeatable and precise results. Following analytical steps are carried out continuously:

- Flushing with sample + Rinse with tap water + Flush of the sludge
- Sampling of sludge (40ml [Variable]) + Addition of nutrient to get maximum respiration
- Aeration of 120 s
- Measuring dissolved oxygen (DO1)
- Stop aeration during a predefined time
- Measuring Dissolved oxygen (DO2)
- Start aeration + addition of sample (10ml [Variable])
- Measuring Dissolved oxygen (DO3)
- Stop aeration during a predefined time
- Measuring Dissolved oxygen (DO4)
- Drain/rinse
- Calculation of toxicity: 100 – (Resp 2 / Resp 1)*100)

5. Toxicity detection in experiments

Below experiments illustrate the detection of toxic events caused by dosing of two different toxic compounds which are to be detected by the EZ7900 on-line Toxicity analyzer. After each dosage, you can see a drop-down of the respiration rate. This drop-down can be interpreted as ‘TOXIC’.

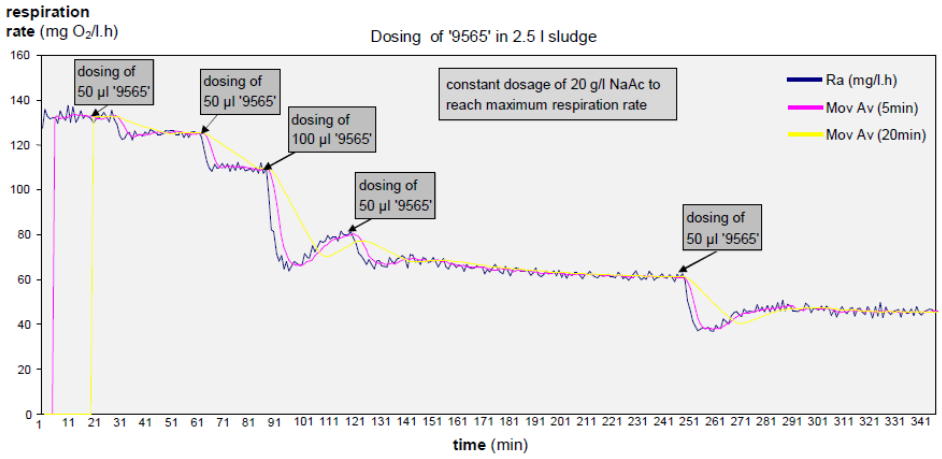

Fig 6. Toxicity measured by EZ7900 analyzer after dosing of '9565' in 2.5 l sludge

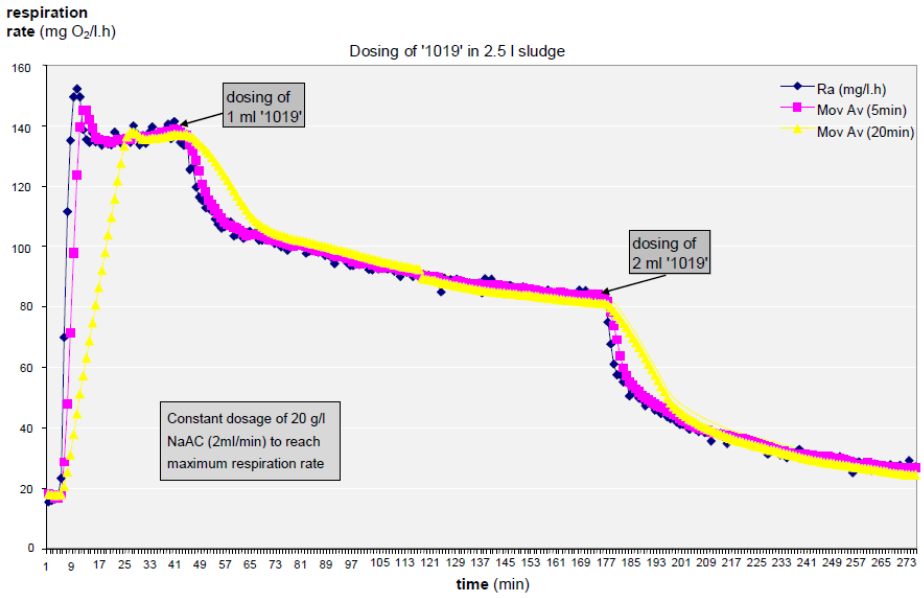

Fig 7. Toxicity measured by EZ7900 analyzer after dosing of '1019' in 2.5 l sludge

6. Conclusions

Because of the close relationship between biodegration and respiration, toxicity analysis based on respirometry is a key parameter to control and protect the wastewater treatment plant, experiments and many references around the globe show that it can be used as an early-warning indicator. The EZ7900 can play a significant role in optimization the treatment processes leading to an increased efficiency of the plant operation.

7. References

Brouwer H, Klapwijk A, Keesman KJ. 1998. Identification of activated sludge and wastewater characteristics using respirometric batch-experiments. *Water Research* 32(4), pp. 1240-1254.

Buys BR, Klapwijk A, Keesman KJ. 2004. Improvements in the measurement of oxygen uptake rate with a continuous flow respirometer.