A PROCESS TO REDUCE THE COST OF LEACHATES TREATMENT

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ABSTRACT : The cost of leachate treatment can be reduced by an appropriate selection of the unit operations needed. Moreover in some cases other liquid residues (waste) can be used as reactants to reduce the operating costs. The biological part of the system is based on a SBR process whose operating parameters are fitted on data collected on site. A sophisticated control scheme depending on the specific characteristics of the leachates is used to optimize the treatment

KEYWORDS

Leachates, SBR, GAC, nitrification, denitrification, cheap carbon source

1. INTRODUCTION

Leachate treatment is a very important issue in the scope of sanitary landfill management. It is well known that the cost of leachate treatment, especially during the aftercare period has a huge effect on the final operating costs of the landfill. Moreover leachate treatment is a difficult problem compared to domestic wastewater treatment, due to the fact that the characteristics of the leachates : the flow rates, but also most of the concentrations of the many pollutants change drastically with time. However it is rather difficult to estimate how fast those changes will occur as a result of many factors (climate, water balance, composition of the solid wastes, age of the landfill, compaction…). Schematically the leachates produced by a new landfill site have very high concentrations of pollutants (BOD, COD,…) but are easy to degrade (high level in fatty acids). On the opposite an old landfill will generate less concentrated leachate but containing mainly non biodegradable organic substrates such as humic and fulvic acids.

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This is one of the reasons of the interest to create data bases in order to better understand the long term behavior of those landfill sites (Jupsin *et al,* 2003, Rodriguez- Ruiz *et al*, 2009). The new approach focusing on models of the landfill itself as a bioreactor is also promising.

The cost also depends on the national standard for effluent COD. If a high removal of COD is required then quite expensive technologies will be needed (RO, AOP, GAC…) combined with bioreactors such as MBR (Praet *et al*, 2002; Jupsin *et al*, 2003, Jupsin and Vasel, 2005) increasing drastically the costs of the treatment. Another specific factor of leachates is their very high content in ammonium (often > 1gN-NH_4^+/L) and the fact that this ammonium concentration decreases less rapidly than C compounds. This means that for most of the old leachates, N removal will be the limiting factor and the final issue of leachate treatment. Nitrogen removal technologies can be considered but we have to take into account that in many cases for leachates from old landfills there will be no biodegradable organic carbon source for denitrification by heterotrophs.

How can we take those very important facts into account to select appropriate technologies and to minimize the cumulative costs of the treatment?

Our process is composed of a SBR System associated with a post removal of humid acids to reduce the non biodegradable COD. CAG adsorption is the final part of the treatment but only for remaining compounds that cannot be separated.

2. SBR PROCESS

The SBR process is a well know treatment scheme (Hoang *et al*, 2008) that appears as one of the most efficient for leachate treatment due to its high adaptability. In our case two operating modes can be used: partial nitrification followed by denitrification or Anammox process if the conditions to maintain the stability of the process are achieved.

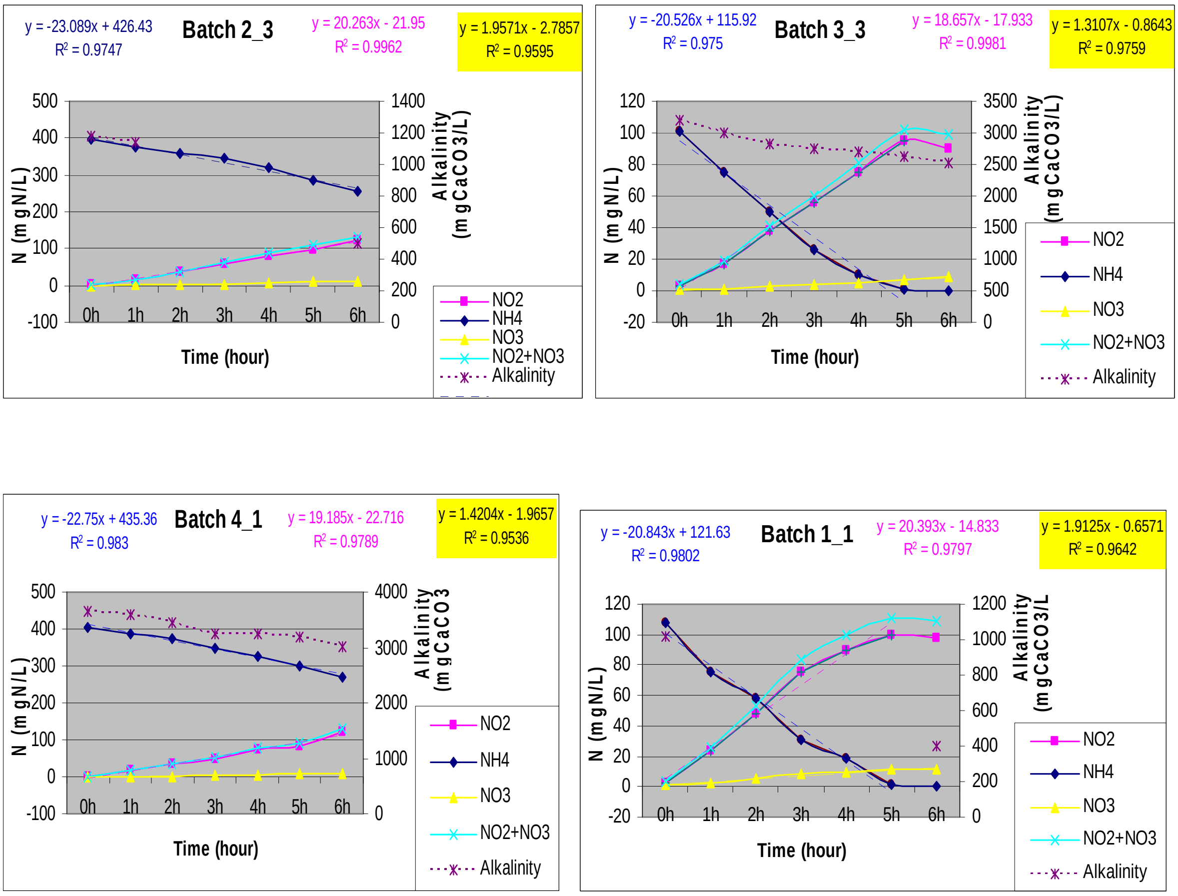
For partial nitrification combined with denitrification the process can be operated on internal biodegradable COD (for young leachates) or on external carbon source. For example ethylene glycol as a residue from antifreeze products appeared to be a very efficient carbon source (Praet *et al*, 2002; Jupsin and Vasel, 2003). Of course one of the ways to reduce the operating costs of leachate treatment is to use selected liquid wastes as chemicals for part of the treatment.

If SBR is a good system to treat leachates (Hoang *et al*, 2008; Hoang *et al*, 2010) especially for nitrogen removal processes such as partial nitrification and denitrification, and even more Anammox processes, are rather sophisticated systems. It is necessary to control the system with appropriate sensors (O_2, Redox, pH, sequences and flow rates) and with a specific control scheme based on a mathematical model of the process. This has been done successfully at various scales and an industrial and mobile pilot scale has been developed treating around 1 m^3/d. This pilot is available with the selected sensors and the developed management tool that can be controlled through internet. By this way the biological parameters specific to a given location can be fitted on data collected on the landfill site.

The SBR (Sequential Batch Reactor) is thus a batch treatment system. Thus it is necessary to define really a SBR system to describe the various sequential steps of the treatment such as feeding, aeration, nitrification, denitrification, settling, withdraw, idle as well as the duration of those various steps in the selected treatment mode.

An example of the response of state variables such as N-NH_4^+, N-NO_2^-, N-NO_3^- is given on the next figure during the nitrification-denitrification periods of a lab scale SBR system.

Figure 1 Examples of results during the partial nitrification step



As can be seen partial nitrification can be obtained (N-NO2 > N-NO3) but nearly total N-NH4 consumption has to be achieved even at high initial concentrations.

3. PHYSICO-CHEMICAL

After the biological treatment the humic acid part of the leachate is removed by a physicochemical treatment. By this way about 30% of the refractory COD can be removed at a cost much lower than GAC. The remaining non biodegradable COD is adsorbed on GAC. The design of GAC towers has been made after dynamic columns tests on various types of GAC, including cheap ones, to reduce the operating costs.

By this way the cost of leachate treatment has been reduced (of about 5 €/m^3 in Belgium).

4. MATHEMATICAL MODELS

SBR are biological treatment systems that have a great adaptability as the treatment is usually realized in only one or two reactors. On the other hand as the process is not continuous the state variables (NH^+_4, NO^-_2, NO^-_3, pH, O_2,…) are changing with time. It is thus important, as we will see, to have good sensors to follow the main state variables continuously but also to anticipate or to predict the evolution of the system. Mathematical models are very useful tools in this case to simulate the dynamic response of the system.

In our case we have been developing mathematical models for various types of biological leachates treatment systems (Praet *et al*, 2002; Jupsin and Vasel, 2005; Jupsin *et al*, 2003).

In the case of SBR systems a first model has been developed (Hoang *et al*, 2008; Hoang *et al,* 2010) taking into account the partial nitrification (2 steps nitrification) and denitrification with and without external carbon addition.

This model has been calibrated and validated on two lab scale bioreactors : one located in Belgium and the other one under hot climate conditions (Vietnam).

The model is still being improved and modified. Another version of the model has been developed to take the Anammox process into account. The model is developed using the WEST® software which facilitates model development by use of user friendly interfaces, integration and graphic tools, parameter fitting (Amerlinckx *et al*, 2003).

5. UPSCALING PROCESS

One of the problems associated to the field application of rather sophisticated bioreactors is the upscaling of a process that has been developed at lab scale.

In our case we have been working at three different scales to upscale the process to the field. The first bioreactors that were built were at lab scale (7 L). They have been used to develop the model and to check the feasibility of leachate treatment with SBR technology.

The daily volume of leachate that was treated was then in the range (5-7 Ld^{-1}).

A second reactor has been designed (150L of reactor) aiming at a daily flowrate of 150 Ld^{-1}. The mathematical model remains the same, but the type of sensors has been changed.

A data acquisition system (National Instruments and Labview®) has been designed in such a way that it can be utilized for the larger bioreactors.

The last scale before full scale facilities is a special SBR aiming at a treatment of approximately $1m^3d^{-1}$ combined with physicochemical treatment unit operations. The system has been designed to be moved easily on real scale landfill facilities. With this reactor it is possible to check the treatment efficiency of a given leachate and to fit the main parameters of the mathematical model in order to optimize the treatment.

The SBR has SCADA facilities and a Programmable Logic Controller (PLC) and thus is easily controlled by internet or smart phone.

Of course for each scale various processes (settling velocities, oxygen transfer, hydrodynamics) have to be characterized to be used in the mathematical model.

6. SENSORS

As already mentioned the counter part of the adaptability of SBR is the need of an appropriate control system. In SBR with nitrification-denitrification processes various types of sensors have been used but few with leachates. The most commonly used are DO and ORP for the aerobic phase and ORP and pH for the anoxic phase. (Holman and Wareham, 2003; Puig *et al.,* 2005; Casellas *et al*., 2006; Wu *et al.,* 2007; Won and Ra, 2011)

In our case (at the $1m^3$ scale) we are using :

- Level sensors (ultrasonic and threshold value)
- oxygen sensors
- ORP sensors
- pH sensors

As the signals of the sensors will be used to control the process it is important to select accurate sensors providing signals that can be sent to the control system.

Another reason to pay a special attention to the choice of the sensors is related to the fact that those signals will be used during the first weeks (months) of operation to fit the parameters of the mathematical model associated to the leachate being treated and corresponding to the local environment.

7. CONTROL SCHEME

In the case of SBR, sensors are needed to define the duration of the various steps of the process but better control can be obtained by appropriate signal processing and use of control strategies.

A patent is pending for our control scheme strategy and no details will be provided in the present paper.

But we can indicate that we use PLC with PID controller :

- in the aerobic phase to control oxygen transfer to maintain the DO in a short range;
- to manage the inlet flow rate in accordance to the variation of Total Potential Acidity (TPA) (Hissel, 1975)

For the anoxic phase derivatives of ORP, pH and also slope of the TPA are used. By this way the biomass activities are controlled at a high level and the duration of a complete cycle can be shortened.

The records of the data are stored and can be send to the operators. The parameters of the PLC can also be changed thought a protected internet interface.

8. PHYSICO-CHEMICAL TREATMENT

- The final treatment for non biodegradable COD is done by GAC columns when severe local standards are defined. The design of full scale columns can be based on dynamic tests (not usual adsorption batch tests) on columns that are located on the experimental mobile pilot.

- To reduce drastically the cost of GAC about 30% of the non biodegradable COD are removed by a preliminary cheap separation method using a waste as chemical. In the same time a huge reduction of the color is observed. A patent is also pending on this part of the process.

9. CONCLUSIONS

Leachate treatment is an issue for sustainable landfill. Since more than 20 years many systems have been used for leachates treatment, including physicochemical and biological systems.

Many failures have also been observed very often related to the fact that the systems had been designed usual industrial waste water treatments not taking into account the dynamic behaviour of leachates (quantity and composition).

The SBR process due to its inherent adaptability is an attractive system for biological leachates treatment. It appears as a rather simple system, with no separate settlers and even previous bioreactors such as aerated lagoons can be upgraded quite easily into a SBR process.

Due to the batch operation mode the duration of the successive steps in a complete cycle can be modified to fit the prevailing conditions (t°, pH, COD, C/N, …).

But the crucial counterpart of this adaptability and apparent simplicity is that very efficient sensors and an appropriate automatic control scheme are absolutely needed.

If only the concept of SBR is choosen but with no or too simple management tools it will also fail to fit the standards as many systems before.

In our case we developed a SBR concept including the mathematical model of the bioreactor, appropriate sensors and a innovative control procedure to get a good efficiency at low cost.

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