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Performance assessment of Etueffont (France) lagooning treatment system: Report from a 16-year survey

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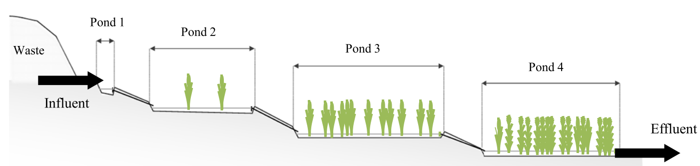
HIGHLIGHTS

- Leachate characteristics over a period of 16-year period of maturation
- Rapid decrease in pollution load over time
- Early onset of methanogenic conditions
- Lack of compaction and cover hasten removal of polluting components
- Leachates in the methanogenic phase can be treated efficiently by lagooning.

GRAPHICAL ABSTRACT

1993 to 2009 ➔ 16 years' survey



- pH, EC: electrical conductivity
- Carbon, nitrogen and phosphorus
- Trace metal elements

➔ At the end of monitoring (2008-2009), mean efficiency (in the flows) ranged from 75 to 90% for all parameters.

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ABSTRACT

This study examined the lagooning treatment system of the Etueffont landfill (France) over a period of 16 years. Outflow concentrations in total suspended solids, biological oxygen demand (BOD_5) and trace metal elements largely met outflow standards and were on average of 5, 8 and 6 times lower than those observed at inflow, respectively. In 2000, however, high levels of BOD_5 were observed in both the influent and effluent, exceeding the authorized outflow limits. At that time the lagooning ponds were subjected temporarily to organic pollution, coinciding with the arrival of the first leachates from a new cell. Though the chemical oxygen demand (COD) and total organic carbon in the influent exceeded authorized limits, overall values conformed to official standards with outflow exhibiting mean concentrations four times lower than those observed at inflow. The first period took place just after the arrival from the new cell of young leachates containing a very high level of COD (>10,000 mg L^{-1}), causing an organic overload that led to a temporary dysfunctioning of the treatment installation lasting approximately two years. Additionally, the COD in the leachates fell below the strictest limits (125 mg L^{-1}) at the end of monitoring (2005–2009). The initial nitrogen load brought in by the influent decreased progressively over time, evidence of continuous degradation. At the end of monitoring, regardless of the arriving inflow load, the discharge presented stable concentrations of approximately 30 mg L^{-1}, appearing to indicate that the limits for nitrogen elimination. Total phosphorus elimination was optimal as the concentrations at outflow were minimal throughout most of monitoring, even though the phosphorus load at inflow was from two to thirty-five times greater. Thus, the findings show that landfill leachates in the methanogenic phase can be treated efficiently by lagooning without risk to the surrounding environment.

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1. Introduction

Landfill is an easy means of disposing solid waste and the most widely used in the world today, yet the fate of the leachates produced by waste degradation remains a major environmental concern due to the risk caused to both ground and surface water as well as to the soil (Gibbons et al., 2014; Ben Salem et al., 2014a, b; Bichet et al., 2016). In order to comply with the new French legal requirements for liquid effluent disposal, leachates must be treated before being released into the natural environment (Decree of September 9, 1997, amended). The quantity and quality of leachates generated in the long and short term are specific to each site and weigh heavily in the decision about the selection of wastewater treatment system (Pessoaa et al., 2014). Several different methods exist for leachate treatment, which are classified according to where they are treated, whether in situ or in an off-site installation requiring transport. Off-site leachate treatment is costly and involves undue risk during transport and manipulation, and thus can be treated in situ preferably (Bulc, 2006). Lagooning is an attractive ecotechnology due to its very small energy input and economic cost, as well as its insertion into landscapes and local biodiversity as a wetland (Fortin-Chevalier et al., 2007). In fact, floating vegetation and emergent plants characterize an ecosystem which attracts a variety of wildlife, animals, insects, fish, birds, etc. (Kadlec and Knight, 2008; Scholz and Lee, 2005; Ben Salem et al., 2017). Additionally, this treatment system presented a better performance in eliminating organic, nitrogen and phosphorus components, suspended matter, pathogenic microorganisms, and well adapted to wide variations in element concentrations (Frascari et al., 2004). Pond system is commonly used to treat used domestic wastewater generated by small rural communities in Europe, but it is perfectly adapted to treat a variety of wastewaters, from domestic to complex industrial effluent (EPA, 2011). The first lagooning treatments for landfill leachates appeared at the end of the 1980s (Kadlec and Zmarthie, 2010). However, few large-scale studies have been published on lagooning use for wastewater treatment (Frascari et al., 2004).

In terms of assessing lagooning performance the two most frequently used methods are 1) the percentage reduction of concentration and 2) the percentage of mass removal between entry and exit (Hijosa-Valsero et al., 2010, 2011). The appreciation of the purification degree can also be carried out by comparing the concentrations at the entry and the exit of the lagoon since the minimum requirements to the effluent discharges in the natural environment are expressed as well (Decree of 9 September, 1997, amended). However, calculations of treatment efficiency undertaken on inflow-outflow concentration measurements for the same day are contestable because of the high residence time in the ponds and climatic variability which causes the flow changes. Thus, the efficiency should be based on inflow-outflow rates (Racault et al., 1995), which associating concentration with flow. In France, this calculation method was used since 1997 for wastewater discharge in smaller agglomerations. Moreover, it is more representative of the impact on the receiving environment, particularly in dry season when flows were low or non-existent due to high evaporation (Racault and Boutin, 2004). The use of different parameters to performance assessment makes it difficult to compare results of different authors. In addition, widely varying performances among different lagooning systems have been reported in the literature, a variability dependent on: 1) the influent type (wastewater, leachates); 2) their organic load; and 3) the associated physicochemical parameters, along with operating conditions (pond nature (aerobic/anaerobic, with or without purifying plants, configuration, residence time, etc.) (Frascari et al., 2004; Renou et al., 2008; Hijosa-Valsero et al., 2010; Grisey and Aleya, 2016).

The lagooning treatment system of landfill site (Etueffont - France) was designed and built in function of leachate-contained pollutants, of available surface area for building and of the site's climatic conditions (Hijosa-Valsero et al., 2010). However, this pond system type could be adapted to many different sites due to the wide variety of considered parameters allowing for an infinite number of different configurations such as the base layer of pond soil, the presence or absence of purifying plants, the selected plant species, the outlet flow type (surface or subsurface), the organic load to be treated and residence time in the ponds.

The aim of the present study is to give a detailed description of how the lagooning treatment system of landfill site (Etueffont - France) evolved over a period of 16 years (1993–2009).

2. Materials and methods

2.1. Historical and description of the Etueffont lagooning installation

This study was carried out in the Franche-Comté region (northeastern France), in the leachate treatment wetland of a municipal solid waste landfill located at Etueffont (47° 43′ 19″ N/6° 56′ 57″ E). In operation from 1976 to 2002, the landfill received and shredded household waste from 66 communities (totaling 47,650 inhabitants), representing about 200,000 t of waste which were deposited over an area of 28,000 m^2 until the site was closed. The natural lagooning installation at the Etueffont landfill consists of a series of four shallow ponds (P1 to P4) (0.8–1 m depth) spread over a total surface area of 5344 m^2 (Fig. 1). Together, the ponds, whose main characteristics are given in Table 1, comprise a deep and well-exposed daytime aerobic zone (Khattabi, 2002); though oxygenation in the pond water fluctuates over time, it is not dependent on season (Belle, 2008). From 1993 to 1999, only leachates from the former landfill were treated at Etueffont. In 1999, leachates from the new cell (NC) were also treated. In 2000 the lagooning performance began progressively to decline due to disturbed by the high level of pollutants contained in the NC leachates. Consequently, at the end of 2000 two sand filters were installed in P1 (Fig. 2). The first consisted of a gravel layer (Ø20–80 mm) horizontally traversed by perforated drains (Ø160 mm) at depths of 0.2 m and 0.6 m. The second drain was comprised of a gravel layer (Ø5–15 mm) placed between two other gravel layers (10/25 mm). Two rows of perforated drains (Ø100 mm) were laid between the layers at depths of 0.2 m and 0.6 m.

When first built, the four ponds were designed to treat pollutants using aquatic microorganisms (Khattabi et al., 2006). Then, beginning in 2007, the last three ponds were naturally colonized by macrophytes (P2, P3 and P4 with *Typha latifolia*, and P4 also with *Phragmites australis*), thus becoming composite ponds (microphytes and macrophytes). Most macrophytes and especially *P. australis* or *T. latifolia* do not improve water oxygenation as they release oxygen into the atmosphere not into the water. They also eliminate phytoplankton due to shading, thus limiting the penetration of photosynthetically active radiation (PAR) into the water column. As a result, there is less oxygen released by phytoplankton (Piétrasanta and Bondon, 1994; Mulderij et al., 2005; Aleya et al., 2011). They are also able to tolerate the high available nutriments and the physico-chemical fluctuations (Steinmann et al., 2003; Ben Salem et al., 2017). Therefore, the macrophytes colonize virtually all pond habitats. The leachates move downstream from pond to pond to flow in a ditch which becomes the beginning of Gros Près Brook (Khattabi et al., 2006).

2.2. Sampling procedure

Wastewater influent (raw leachates) and effluent (treated leachates) were monitored (chiefly monthly) over a period of 16 years (1993–2009). Samples were taken directly in polyethylene bottles at the entry to P1 and at the exit from P4, transported in ice chest and then stored in the dark at 4 °C until analysis. Inflow and outflow were measured during each sampling period using a graded liter bucket.