Landfill Leachate Treatment by the Active Clay Sediments Process

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Landfill leachate is one of the most recalcitrant industrial liquid wastewaters. The characteristics of landfill leachate depend on the nature of the municipal solid waste (MSW), the stage of the landfilling process, and the precipitation rate (in case that the land fill has not been sealed, yet). In general, landfill leachates are characterized by low BOD_5/COD ratios (often below 0.2), which are getting smaller with time, as the biodegradable materials in the leachate are gradually consumed. COD concentrations can be above 30,000mg/L, while $N\text{-}NH_4^-$ may be above 2,000mg/L. On the other hand, landfill leachate contains heavy metals at high concentrations. The presence of the above contaminants, make landfill leachate almost non receptive of biological treatment, even the latter is often selected as treatment process, due to lack of alternative processes. Stand alone or in combination with biological treatment, a number of processes have been employed for landfill leachate treatment, such as coagulation-flocculation, chemical oxidation, reverse osmosis (RO), etc. However, even a combination of treatment processes is not usually effective for complete treatment of landfill leachate, while some processes lead to the production of non-stabilized sludge (e.g. coagulation) or to recalcitrant concentrates (e.g. RO) (Gao *et al.*, 2015). The present study presents a complete process for the treatment of landfill leachate, based on adsorption on active clay sediments (Gikas, 2016a,b).

The process (Fig. 1) is of batch type and comprises of a number of sub-processes aiming to the coagulation of the colloidal mater, the oxidation of various pollutants, the adsorption of the oxidation products and heavy metals and finally to the stabilization of the produced sludge. RO treatment and disinfection, may be used optionally, for the reduction of conductivity and pathogens, respectively. A number of specific coagulation and flocculation nano-agents are used in various sub-processes, the composition of which is covered by IP protection. The main reduction of pollutant concentrations takes place in the geochemical reactor, on active clay sediments powder. In the later reactor, the various organic and inorganic substances of the leachate are irreversibly adsorbed on the ative clay sediments, which leads to the production of sludge; the latter is removed from the bottom of the reactor during the idle phase of the process. The produced sludge may be returned in the landfill, as leaching tests indicated that organic mater, nitrogen, phosphate and heavy metals were irreversibly adsorbed on the geopolymers, leading to a stabilized sludge.

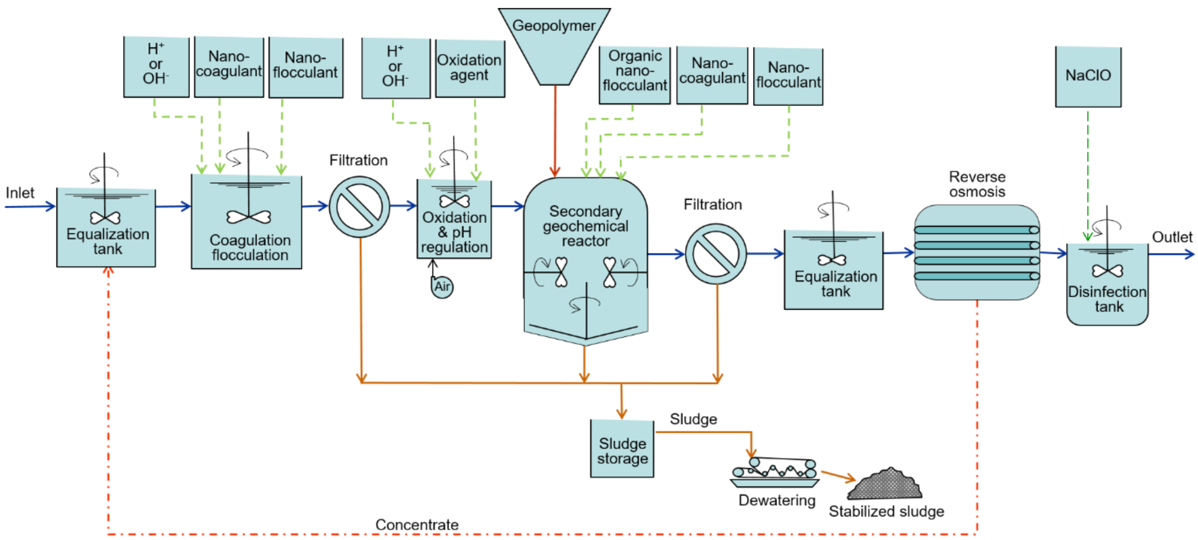

Figure 1. Flow diagram of landfill leachate treatment process, based on the active clay sediments process.

Experiments have been carried out at lab scale, using landfill leachate from a large landfill with sealed and active cells. A visual observation of the landfill leachate, through the various stages of the treatment may be found in Fig.

2. Significant colour reduction is observed during the various treatment stages, while the RO effluent is colourless and contains no solids.

Figure 2. Visual observation of the landfill leachate at various stages of the treatment process: (a) raw, (b) after coagulation-filtration, (c) after chemical oxidation, (d) after geochemical reaction, (e) after reverse osmosis.

The characteristics of raw wastewater and those measured after the treatment through the various sub-processes are shown in Table1. From Table 1, it is obvious that the main reaction takes place in the geochemical reactor, apart from the reduction of conductivity, which is achieved only by the RO process, as alkali and alkaline earth ions (which are the main source of conductivity) are not removed by adsorption on active cay sediments. The initial COD/BOD_5 ratio has been measured as 0.23. Most of COD and BOD_5 is removed during the geochemical reactions, while at the same stage the concentration of the monitored heavy metals is also reduced dramatically, as geopolymers are potent heavy metal adsorbents (Ariffn *et al.*, 2017). At the inlet, nitrogen is primarily in ammoniac form, while it is massively transformed into nitrate after the chemical oxidation stage. The effluent may be used in the landfill, to keep moisture at the desirable level. In such case, there is no need for treatment by RO system. However, treatment by RO system is recommended if the effluent is to be used for agricultural irrigation, so to prevent the release of high salinity water into the soil (Dogan *et al.*, 2016).

Table 1. Landfill leachate characteristics at various stages of treatment.

Parameter	Unit	Inlet	Primary filtration	Chemical oxidation	Geochemical reaction	Final filtration	Reverse osmosis
COD	mg/L	24,730	19,620	17,826	115	111	80
BOD_5	mg/L	5,735	1,280	342	20	20	9
TSS	mg/L	519	265	265	3	3	N/D
TN	mg/L	1,430	910	903	6.5	6.5	2.4
TP	mg/L	62.2	57.2	57.0	4.0	4.0	0.5
pH	-	9.7	8.4	6.8	7.0	7.0	8.0
Conductivity	μS/cm	36,925	36,892	36,922	36,872	36,871	1,124
As	μg/L	340	295	295	2.7	2.7	N/D
Ni	μg/L	1,913	1,857	1,857	24.2	23.9	N/D

N/D: non detectable

The capital cost for a complete landfill leachate treatment system with capacity of $50m^3$ per 8 hours of operation and the relative operational cost (including reagents, energy and personnel cost) have been estimated by Zeologic S.A., Greece, at the range of 800,000-900,000 € and 8-9 €/m^3, respectively.

All things considered, the proposed process is a complete solution for the management of land fill leachate. The system is flexible, and can be design in accordance with the environmental standards requirements, with respect to the fate of the effluent (e.i.: recirculation into the cell or reuse for agricultural irrigation).

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