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Research article

Comparison of the design criteria of 141 onsite wastewater treatment systems available on the French market

V. Dubois*, C. Boutin

IRSTEA, Freshwater Systems, Ecology and Pollution Unit, 5 rue de la Doua, BP 32108, 69616 Villeurbanne Cedex, France

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ABSTRACT

New EC standards published in 2009 led to a surge in onsite wastewater treatment systems reaching the European market. Here we summarize their technical aspects and compare them to known values used in centralized wastewater treatment. The paper deals with two types of processes: attached-growth systems (AGS) on fine media and suspended-growth systems (SGS). Covering 141 technical approvals and 36 manufacturers, we compare onsite design criteria against the centralized wastewater design criteria for each process.

The systems use a wide range of materials for bacterial growth, from soil, sand or gravel to zeolite, coconut shavings or rockwool cubes, with a huge range of variation in useful surface, from 0.26 m^2/PE for one rockwool cube filter to 5 m^2/PE for a (traditional system) vertical sand filter. Some rockwool can handle applied daily surface load of 160 g BOD_5/m^2.

SGS design parameters range from 0.025 to 0.34 kg BOD_5 per kg MLVSS/d with hydraulic retention times of 0.28–3.7 d. For clarifier design, water velocity ranges from 0.15 to 1.47 m/h. In the sludge line, sludge storage volume ranges from 0.125 down to just 0.56 m^3/PE.

1. Introduction

New onsite wastewater treatment systems developed fast in Europe with the arrival of a new standard in construction products (EN NF 12566-3, 2009). The European market for on-site wastewater systems holds great promise as many people live in rural areas, especially in France where 5 million houses are concerned (Reinberg, 2015; Szkarowski and Janta-Lipiñska, 2015; Kärrman et al., 2007). Until September 2009, only 'traditional' systems (sand filter and soil-based systems) were allowed in France, but now that regulations have changed (Arrêté 7 septembre, 2009; Arrêté 7 mars, 2012), new systems are available, with over 60 national or international companies selling over 600 different products. The various solutions offered fall into three technical families: attached-growth systems on fine media (AGS), suspended-growth systems (SGS) and biofilm systems (BS). The treated wastewater has to be i) infiltrated, ii) reused, or iii) evacuated to freshwater if there is technical demonstration that infiltration or reuse are impossible. The aim of this article is to present a technical comparison of two families: AGS and SGS. We thus compare onsite design criteria against treatment plant design criteria.

The AGS analysis concerns 40 French approvals and the 4 traditional systems. AGS are composed of:

- a septic tank (except where the reed bed filter (RBF) which receives raw wastewater)
- a filter filled with fine materials.

After a mechanical filtration of the suspended solids at the surface, the dissolved pollution is degraded by fixed-film bacteria. Oxygen is conveyed by molecular diffusion and/or convection driven by natural ventilation. These systems can operate without electric power.

AGS systems are classified according to the material used in the filter: i) soil, ii) sand and gravel, iii) zeolite, iv) coconut shavings, v) rockwool.

The SGS analysis concerns 97 approvals and 25 companies developing 18 activated sludge systems (ASS) and 7 sequential batch reactors (SBR).

Among these 18 ASS, 7 share a similar scheme named "general course" in Fig. 1.

The other 11 ASS are different, as: i) with a tertiary treatment, ii)

* Corresponding author. Tel.: +33 (0)4 72 20 89 34.
E-mail address: vivien.dubois@irstea.fr (V. Dubois).

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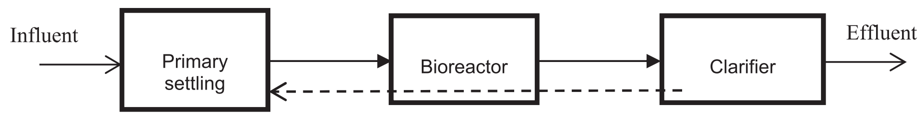

Fig. 1. General course of 7 ASS.

without primary settling, or iii) with an complementary biofilm device.

The 7 companies developing SBR work to a similar scheme to the ASS in Fig. 1.

In centralized treatment, biological sludges are extracted, stored and treated separately.

In onsite treatment, water and sludge treatments are undertaken in the same tank, which is why technical analysis of the end-to-end process is carried out according to features of both the water line and the sludge line.

2. Materials and methods

All the data used for comparison came from the technical approvals and their associated user manuals as published on the official website (MEDDE, 2014): http://www.assainissement-non-collectif.developpement-durable.gouv.fr/agrement-des-dispositifs-de-traitement-r92.html. We thus created a database with classical design parameters (Table 1).

These parameters were chosen based on the rationale that the manufacturers had tested how efficiently their products treat carbon and nitrogen. Many parameters were calculated using our own design hypotheses:

Hypothesis 1. Calculations are based on the hypothesis of a 30% reduction of BOD_5 in the septic tank or primary settlement tank (Chen and Guan, 2013; Nasr and Mikhaeil, 2013) and a daily residual pollution of 42 g/PE on the next step.

Hypothesis 2. For SGS, a mixed liquor volatile suspended solids (MLVSS) concentration of 3 $g.L^{-1}$ in the bioreactor device.

Hypothesis 3. For the sedimentation process in the clarifier, we calculated hourly peak flow based on Annex 2 of the French government order of 7 September 2009, notably for the time slot receiving the highest percentage of daily flow to which we added 200 L from a bathtub drain, as also provided for in Annex 2 of the decree.

The following results and graphs focus on the size of the most popular commercial systems in France, i.e. scaled to 4, 5 and 6 PE.

3. Results and discussion

3.1. Attached-growth systems on fine media

3.1.1. Water line

The filter material surfaces are variable and can range from 0.26 to 12 m^2/PE. The most compact filters are those filled with rockwool, then come the coconut shavings (in two sizes: 0.63–0.8 m^2/PE), and finally zeolite, with a useful surface of 1. Sand filters or those with planted gravel are more extensive. One type of sand filters remains very compact (1.68 m^2/PE) compared to the traditional sand filter (5 m^2/PE).

As a reference value, the sand-filled AGS used in centralized wastewater treatment are sized based on a useful area of 3 m^2/PE and use different operating conditions with an imposed alternating feeding (Boutin et al., 1993).

This comparison of daily applied surface loads (g $BOD_5.m^{-2}.d^{-1}$) aims to assess the degree of solicitation of all the filters that work on the principle of the AGS process.

This comparison has to be taken with a pinch of salt, as the settings used are extremely varied and their impact on quality of effluent or lifetime of the plants still not clearly known. However, we can rationally assume that the robustness of a system without clogging risk is closely linked to the pollutant load applied (McKinley and Siegrist, 2011), and consequently to how frequently the material is renewed.

Fig. 2 shows the daily applied surface organic loads to filters. For the RBF, the first stage receives raw water.

In centralized wastewater treatment, the daily applied organic load of an AGS filled with sand is up to 12.5 BOD_5/m^2. This value is based on the overall useful area of two or three filters. A key factor is that onsite treatment works to different operating conditions than centralized treatment: the alternated rhythm or the system requiring 7 days on/7 days off (in two-filter cases only) helps maintain tight control of clogging risk. The organic load imposed on the filter in operation therefore amounts to 25 g $BOD_5.m^{-2}$.

In onsite treatment, the systems akin to ‘buried filters’ and considered to be ‘extensive’ will take daily applied loads of less than the 12.5 g BOD_5/m^2 threshold commonly accepted in centralized treatment. This concerns the systems filled with sand and the soil-based system.

All “new” filling lines have greatly reduced their useful surfaces, reflecting a general drive towards greater compactness to further shrink in-plot footprints. However, this intensification of treatment processes likely imposes earlier renewal of material before it clogs.

3.1.2. Sludge line

Septic tank volumes all range from 3 to 5 m^3, since a 5 m^3 value is a legal requirement for zeolite-filled filters with a 5 PE capacity (Boutin et al., 2008). If we exclude zeolite filters, the amplitude of the unit volumes is in the interval 0.5–0.75 m^3/PE.

This diversified situation undermines the assumption, presenting a unique yield, independently of hydraulic retention time, form and other non-synthesized elements such as deflectors (or other flow-breaking devices) or the number of compartments, etc. The 30% BOD_5 removal by the sludge-line septic tank is a default value that warrants complementary measures to differentiate the features of different geometries and “accessories”.

3.1.3. Discussion

The reduction of surfaces leads to intensive use of the filters (McKinley and Siegrist, 2011). Filters filled with zeolite, coconut shavings, and rockwool operate at applied loads of 4 times, 5–6

Table 1
Design parameters serving comparison.

Family of systems	Lines	Parameters
AGS	Water line	Useful surface of the filter
		Daily applied organic load per surface unit
	Sludge line	Volume of preliminary treatment
SGS	Water line	Food to micro-organisms ratio (F/M)
		Hydraulic retention time (HRT)
		Clarifier area
	Sludge line	Sludge storage volume

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