Wastewater treatment facilities for isolated buildings

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Key words: isolated buildings, small population nuclei, decentralized wastewater treatment, non-collective treatment, on-site treatments, individual sanitation, soil infiltration

Abstract

In 1991 the European Economic Community issued a Directive on Urban Waste Water treatment (91/271/EEC). This Directive required that urban wastewater treatments should have been amended between 2000 and 2005, depending on the amount of served population and the discharge area according to different requirement criteria. In case of agglomerations of less than 2,000 population equivalent an appropriate treatment is required, based on the fulfillment of quality objectives in the receiving environment. Within this agglomeration size, nuclei with less than 50 inhabitants (from isolated buildings to small villages) are further regulated by the European sanitation legislation prEN/12566. Such target areas are focused in the present memory firstly differentiating between collective sanitation nuclei versus non collective sanitation ones, where the dispersion of sanitation infrastructures requires the adoption of non collective or individual sanitation solutions, as it is the case of many discharges from isolated buildings and small villages in Spain still lacking appropriate treatment to comply with such legislation. To overwhelm the gap different technical solutions can be used which are discussed in this paper: from those with a pre-processing step such as septic tanks down to the compact solutions followed by soil infiltration (by means of shallow trenches or similar) in case the soil permeability is intermediate. Furthermore it is laid down the use of non-drained sand filters suitable in case of high permeability and the use of constructed wetlands, zeolite filters, drained sand filters, biological filters, etc. followed by superficial disposal in case of low permeability. Criteria are set out for choosing among the different systems depending on the type of soil, slopes, phreatic level, etc. Space requirement layout per household is defined for the different solutions and bibliographical references on individual treatment are provided.

1 Introduction

European Economic Community issued a directive on Urban Wastewater treatment in 1991: 91/271/EEC, which concerns with the collection, treatment and discharge of urban wastewater (including certain industrial sectors). The main objective is to protect the environment from the adverse effects of the above mentioned wastewater discharges. The Directive requires that urban wastewater shall undergo a treatment to be implemented between the year 2000 and 2005, depending on the size of the served population and the discharge area according to different requirement criteria. For agglomerations with less than 2,000 population equivalent (p. e.) an appropriate treatment is required, defined as “any process and/or disposal system which allows the receiving water bodies to meet the relevant quality objectives and the relevant provisions of this and other Community Directives”. Isolated buildings and individual households included within agglomerations of less than 2,000 population equivalent, represent a significant number of discharges. Namely, Article 3 indicates that where the establishment of a collecting system is not justified either because it would produce no environmental benefit or because it would involve excessive cost, individual systems or other appropriate systems which achieve the same level of environmental protection shall be used.

This Directive is already transposed to a mandatory Spanish regulation but there is no specific regulation neither agencies nor organisms which thoroughly handle with individual sanitation. Other European countries, such as France, have developed very specific regulations for individual sanitation [1, 2]. The United States Environmental Protection Agency (USEPA) edited a Code of Practice for wastewater treatment systems for single houses, establishing an overall framework of best practices and providing guidance on the provision of such systems [3]. Furthermore, several European Member States are adopting standards on small wastewater treatment systems for up to 50 p. e. In Spain the standard UNE-EN 12566 were transposed from the European Standard [4].

This paper reviews a variety of process and technologies that can be applied to individual sanitation, making it possible to meet the regulations concerning wastewater treatment. Selection criteria are set out for choosing among them.

2 Non-collective sanitation

Differentiating between collective and non-collective sanitation areas is the first step required for rural areas sanitation (Fig. 1). At municipal level the competent authorities should subdivide the territory on the basis of collective and non-collective sanitation areas, taking into account the distribution of the population and ground suitability. Collective sanitation can be provided by activated sludge treatments or biofilm processes or similar, whilst non-collective sanitation requires an alternative on-site treatment.

Non-collective sanitation, also known as individual sanitation, is in fact a substantial alternative to the costly collective sanitation system. It is assessed as the suitable solution when the collective sewer is more than 200 m from the household, as a rough average value [5]. In France, 10% of the population uses individual sanitation by means of 4 million treatment plants [6, 7] and around one third of the population of Ireland lives in the countryside, in individual dwellings not connected to a public sewer [3]. The main drawback of individual sanitation is that the systems are not always properly designed and very rarely maintained. A proper design capability can be achieved providing training and information. Besides, maintenance is the biggest concern of sanitation systems in small communities and especially in individual sanitation. An appropriate solution could be delivered by the community services, taking in charge the maintenance of individual sanitation systems.

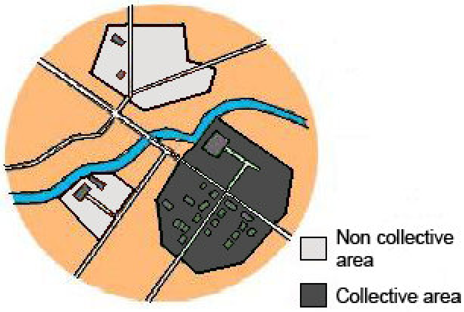


Figure 1: Collective and non-collective sanitation areas [8]

On-site or decentralized wastewater treatment systems for non-collective sanitation can be carried out in three phases, hereby briefly described:

- Phase 1: anaerobic pretreatment, by means of a septic or an Imhoff tank or similar, which receives the wastewater.
- Phase 2: aerobic treatment of first phase effluent via soil infiltration in the natural, existing soil or in the on purpose constructed soil.
- Phase 3: final disposal of treated effluent by (in priority order): subsoil infiltration, discharge to surface water, deep infiltration wells.

The following figure 2 shows an example of a typical non-collective wastewater treatment system. The specific treatment process settings depend on the soil and subsoil type, slope, surface availability, groundwater level, etc. There are several solutions, such as infiltration trenches, infiltration beds, sand filters, constructed wetlands, compact treatments, etc., that may be considered on a case by case basis. More generally, the system should be kept away from car circulation and parking areas, far from crops and easily accessible for maintenance. Technical specifications related to implantation requirements of this type of treatment can be found in the French technical norms [2].

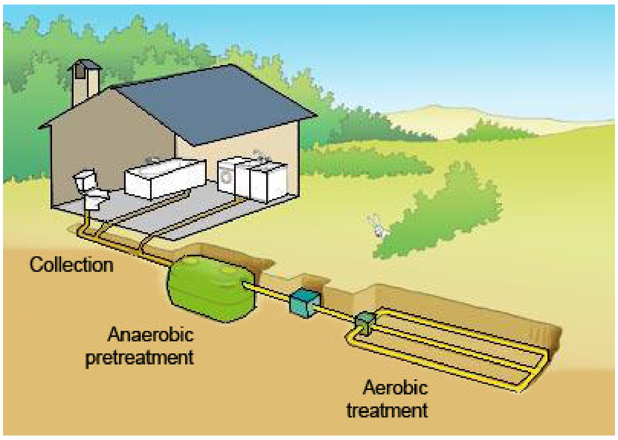


Figure 2: Non-collective wastewater treatment

3 Onsite treatment systems

Wastewater treatment facilities for isolated buildings should present low energy requirement, easy maintenance, efficient and stable operation under high fluctuations of flowrate and organic load, and simple sludge management [9]. Alternative on-site treatments provide this feature.

3.1 Pretreatment devices

As shown in the previous section, in most cases an anaerobic pre-treatment is the first step necessary for non-collective sanitation systems. It allows for the retention and the anaerobic digestion of suspended solids coming from the wastewater. Septic tank and Imhoff tank are the typical devices for non-collective sanitation pretreatment stage. The tank dimensions should fit in the possible excavation height, accordingly to the depth of the installation. Access and inspection openings should be incorporated into the roof of the tank for its maintenance. Some septic and Imhoff tanks are provided with an effluent filter located at the outflow of the tank (Fig. 3). Such filter retains solid particles present in the effluent, avoiding the risk of clogging of the subsequent treatment device, even in case of malfunctioning pretreatment tanks. If the effluent filter is not integrated in the device, it is recommended to install one following the septic or Imhoff tank.

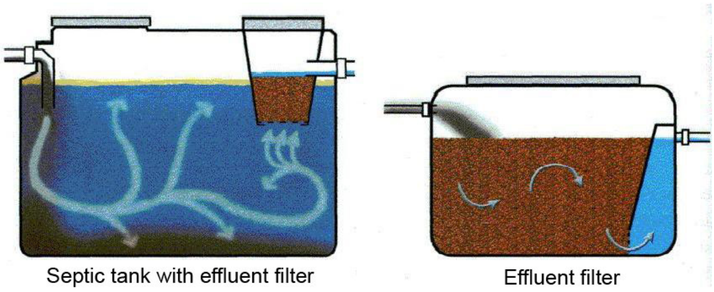


Figure 3: Septic tank and effluent filter schemes [10]

3.2 Infiltration trenches and infiltration beds

Infiltration trenches and bed are a rapid infiltration land treatment and they can be applied when the ground presents the following characteristics: slope up to 5%, sufficient infiltration surface and good permeability. The septic tank effluent is distributed in shallow infiltration trenches. The existing soil is used as a treatment system where the wastewater gets most of its treatment by physical, chemical and biological mechanisms [11]. The water percolates through the trenches and finally infiltrates into the ground at the bottom and lateral edge of the trenches (Fig. 4a). In some cases the construction of infiltration trenches can be difficult for the instability of lateral walls (i.e. sandy soils). In this case, the shallow trenches can be replaced by a shallow bed (Fig. 4b). Infiltration chambers are an alternative infiltration trenches system which can reduce the space requirement up to 40% with reference to conventional systems. The chambers are domed plastic compartments whose bottom is opened, allowing for water to drain away. The septic tank effluent is conduced to infiltration chambers trenches and it is stored until infiltrate into the ground, operating like conventional systems. The main advantages of such technology are that the chamber is made of a lightweight material that can be easily transported and installed in the trench and there is no need of perforated pipelines or geotextile.

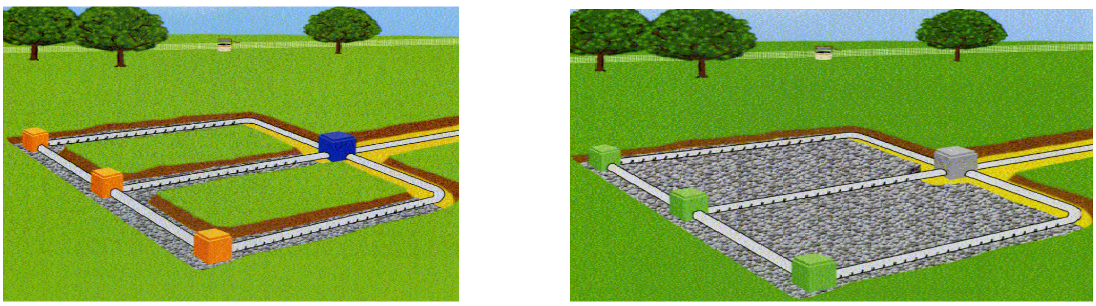


Figure 4: (a) Infiltration trenches and (b) Infiltration beds [10]

3.3 Non drained sand filters, drained sand filters and infiltration mounds

Non drained sand filters are used for high permeability soils or cracked soils. Washed siliceous sand replaces the original soil as treatment system. The water is transferred to the permeable subsoil by infiltration at the bottom of the sand filter (Fig. 5a). Sand filters can be used also in case of very low permeability soils, installing drainage pipes (similar to infiltration pipes) at the bottom of the filter, which collect and discharge the effluent into superficial water. This kind of filter is called drained sand filter (Fig. 5b). Infiltration mounds are used in areas where groundwater level is close to the ground surface and consist of a sand filter placed over the existing ground (Fig. 6a). This system usually requires pretreated effluent pumping.

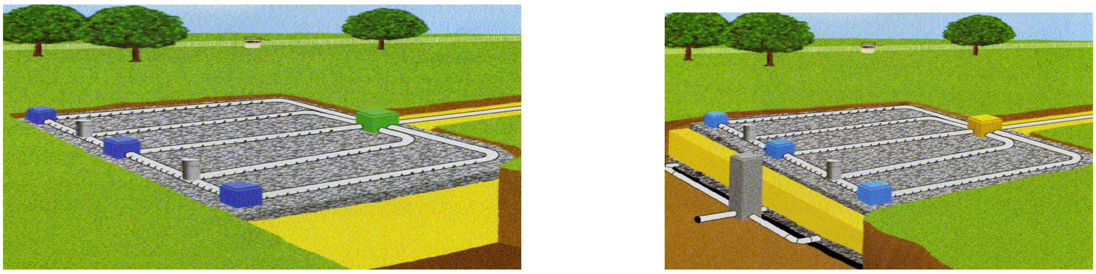


Figure 5: (a) Non drained and (b) drained sand filter [10]

3.4 Drained horizontal sand filters

Horizontal sand filters are designed for slowly permeable soils where it is not possible to use a vertical sand filter draining towards superficial water, due to insufficient slope. The wastewater percolates through layers of decreasing particle size materials. Drainage pipelines collect the treated effluent at the outflow of the filter and they discharge it into surface water. As a limitation, the quality of the horizontal sand filter effluent is not optimal, therefore usually they are not the preferable choice (Fig. 6b).

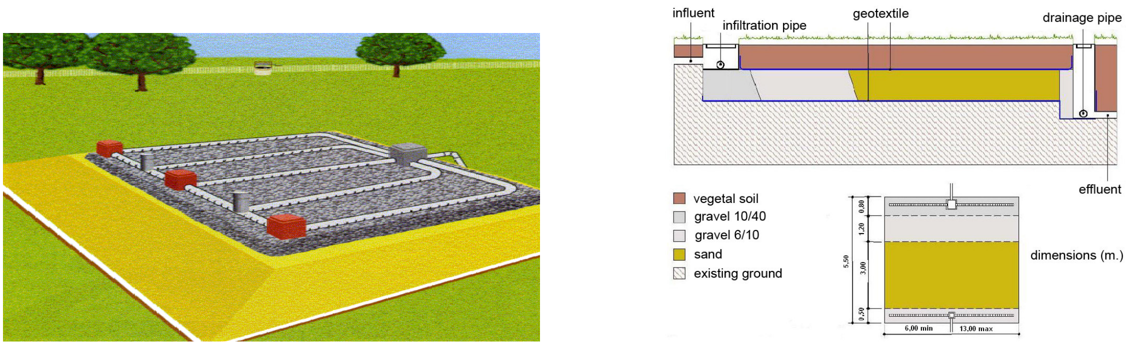


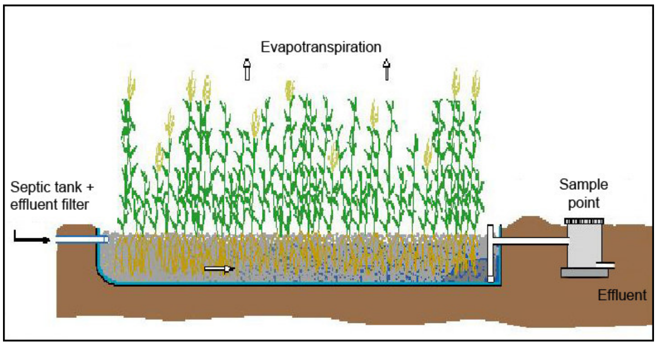
Figure 6: (a) Infiltration mound [10] and (b) Drained horizontal sand filter [12]

3.5 Constructed wetlands

A constructed wetland or reed bed is another option for the treatment of wastewater effluent from a septic tank and it could be used when conventional systems are not suitable. The main difference between a constructed wetland and other filtering systems is the planting of vegetation in the media. Such technology has been widely used for wastewater treatment in small communities and it is also adopted for individual sanitation. Constructed wetlands can be used for populations up to 50 inhabitants (from isolated buildings such as individual households to very small villages) and the effluent easily fulfills regulation requirements. Wastewater flows horizontally below the surface of the wetland media across the bed made of gravel (Fig. 7a). The reeds carry out several functions: assimilate nutrients (nitrates and phosphates) for their own growth; support the microorganisms involved in the treatment on its roots and rhizomes; provide the oxygen produced by photosynthesis to the aerobic bacteria placed in the rhizomes, which are the most effective pollutants removing microorganisms; and maintain the structure of the bed avoiding the risk of clogging and preferential movement.

3.6 Zeolite filter beds

Zeolite filter beds are packed-bed filter units and they are used in case of low permeability soils or low surface availability for other systems such as sand filters. The effluent is discharged into surface water. In spite of the low space requirement, this solution cannot be used for discharging in sensitive areas which require higher effluent quality. The zeolite filter bed consists of a filter media based on natural zeolite within a watertight compartment. The material is distributed in 2 layers of different particle sizes, whose global thickness must be at least 50 cm. Influent wastewater is spread on the entire surface of the zeolite bed by a pipeline distribution system and similarly a drainage system collects the effluent after its treatment at the bottom of the bed (Fig. 7b).



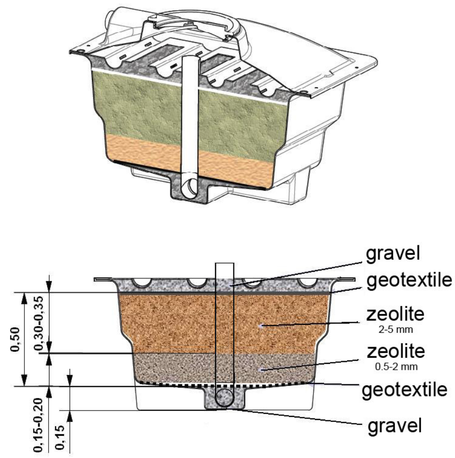
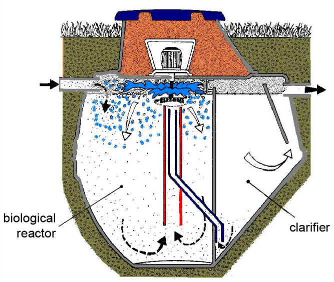


Figure 7: (a) Longitudinal section of a constructed wetland [13] and (b) Zeolite vertical filter [12]

3.7 Compact technologies

Conventional wastewater treatment technologies, packed in compact units, can be used in case of limited available surface or non appropriate soil conditions for the above mentioned alternative on-site treatments. Activated sludge treatment and biofilm processes are very well known (Fig. 8).



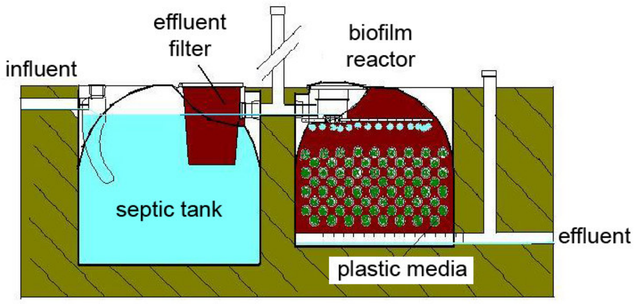


Figure 8: (a) Activated sludge system [12] and (b) Biofilm process system [14]

4 Selection criteria

Each of the presented systems should be assessed for the selection, in a case by case basis. Selection criteria are: soil type and slope; groundwater level; surface availability; discharge area; disposal fate, etc., which are synthesized in Table 1. The Fig. 9 indicates surface requirements of each system for individual households, based on soil permeability.

Table 1: Soil type and disposal fate for each system [12]

Treatment system	Soil type	Disposal fate
Infiltration trench and chamber	High permeability; slope < 10%; existing soil	Ground
Infiltration bed	Sandy; flat; existing soil	Ground
Non drained sand filter	Cracked rock or high permeability; soil replaced by sand	Ground
Drained sand filter	Low permeability; drop between in and outlet > 1,5 m; soil replaced by sand	Superficial
Infiltration mound	High groundwater level; soil replaced by sand	Ground
Drained horizontal sand filter	Low permeability; high groundwater level; drop between in and outlet < 0,5 m; soil replaced by granular material	Superficial
Constructed wetland, Zeolite filter	Low permeability; soil replaced by gravel or zeolite	Superficial

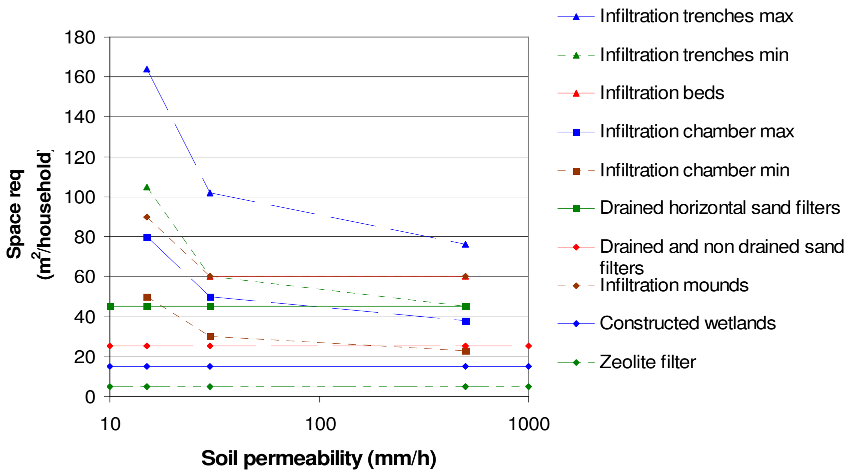


Figure 9: Space requirement based on soil permeability and treatment system [15]

5 Conclusions

Individual on-site sanitation provides complete treatment system, able to meet the legislation requirements. It is the main option for households or building away from the conventional sewage of a collective sanitation system. There is a wide range of possibilities for individual treatment systems, which consist of a pre-treatment such as a septic tank, followed by soil infiltration in case of satisfactory permeability and replaced soil (sand, gravel or zeolite) infiltration otherwise. The effluent of the individual treatment system can be discharged into the ground or to superficial water, depending on the case. The typical on-site treatment systems are: infiltration trenches, infiltration beds, infiltration chambers, drained and non drained sand filters, infiltration mounds, drained horizontal sand filters, constructed wetlands and zeolite filters. Soil infiltration systems discharging into groundwater present higher surface requirements than those discharging into superficial water. The soil type (slope, permeability, ground thickness, groundwater level, etc.) as well as the surface availability are the main factors to be considered in the selection of the most appropriate system.

Acknowledgements

The study presented in this paper was carried out in the framework of the Bilbao-Bizkaia Water Consortium – University of Cantabria Agreement and it was supported by the Spanish Ministry of Education and Science through the NOVEDAR_Consolider project CSD2007-00055, "Conception of the Sewage Treatment Plant of the XXI Century".

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