Field performance assessment of onsite individual wastewater treatment systems

N. Moelants, G. Janssen, I. Smets and J. Van Impe

ABSTRACT

Onsite individual wastewater treatment systems can provide a financially attractive alternative to a sewer connection in locations far from the existing sewer network. These systems are, however, relatively new, and therefore, shortcomings in the design or operation problems still occur frequently. A previously performed survey revealed that most system owners neither carry out routine operation and maintenance tasks nor have a maintenance agreement with the manufacturer. This suggests that in reality, systems are often improperly managed and do not provide the level of treatment necessary to adequately protect surface and ground waters. To substantiate this statement, the field performance of 23 currently installed individual wastewater treatment systems in Belgium has been assessed.

The results of this study confirm that many installed individual systems do not perform well: 52% of them do not meet all the legal effluent standards (BOD, COD, SS). Activated sludge systems prove to be less efficient than biofilm-based systems and extensive systems perform better than compact systems. Maintenance problems and to a lesser extent improperly designed systems are indeed the main cause of unsatisfactory results through, e.g., wash out.

Key words | field performance assessment, individual wastewater treatment measurement campaign

N. Moelants
G. Janssen
I. Smets
J. Van Impe
Chemical Engineering Department,
BioTeC - (Bio) Chemical Process Technology and Control,
Katholieke Universiteit Leuven,
W. de Croylaan 46,
3001 Heverlee,
Belgium
Fax: +32-(0)16-32.29.91
E-mail: *nina.moelants@cit.kuleuven.be*;
ilse.smets@cit.kuleuven.be;
jan.vanimpe@cit.kuleuven.be

INTRODUCTION

In Europe, the European Wastewater Treatment Directive (91/271/EEG) forces the member states to treat all urban wastewater since 2005, and by 2015 all surface water should be of *good quality* (Directive 2000/60/EC). Currently, domestic wastewater treatment in Belgium is organised in a centralised way. Due to the scattered housing in some areas, it is, however, financially not feasible to connect all the houses to a sewer network. Onsite individual or single family wastewater treatment systems can provide a financially attractive alternative to a sewer connection in locations far from the existing sewer network (i.e., 10–20% of the population).

Individual wastewater treatment systems are relatively new in Belgium. Therefore, shortcomings in the design or operation problems still occur frequently and have an impact on the performance efficiency of the systems. A previously performed survey (Moelants *et al.* 2006*a*,*b*), focusing on the maintenance requirements and operation problems of individual wastewater treatment systems as well as on the financial aspect, revealed that most system owners do not carry out simple routine operation and maintenance tasks. Furthermore, a maintenance contract (between manufacturer and owner) for the more complicated tasks is not compulsory yet which suggests that in reality, systems are indeed often improperly managed and do not provide the level of treatment necessary to adequately protect surface and ground waters (Moelants *et al.* 2006*a*,*b*).

To substantiate this statement, the field performance of currently installed individual wastewater treatment systems in Belgium has been assessed. More specifically, 23 of

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the systems from the survey are studied, 17 in Flanders and 6 in the Walloon region. Both regions have a separate environmental policy and legislation.

METHODS

Between October 2006 and March 2007, the performance of 23 individual wastewater treatment systems, randomly selected from the 236 questionnaires that were filled out and returned by system owners, was evaluated. More specifically, 20 systems were of the compact type, including 8 sub merged aerated filters, 3 biorotors, 5 moving bed bioreactors and 4 activated sludge systems, and the remaining 3 were plant-based systems of the subsurface flow constructed wetland type. At three moments in the six months, one 1 L grab sample of the influent (or primary settling tank) and effluent (or secondary settling tank) of each treatment unit was taken and analysed. The samples were collected, spread over a period of time, in order to eliminate the high variation in influent load, typical for onsite individual treatment systems.

For all the samples, BOD_5, COD, filtrated COD (COD_{fil}), SS (suspended solids), TN (total nitrogen), NO_3-N and NH_4-N were determined (*Standard Methods* 1998 and Spectroquant test kits, VWR). Since nitrogen standards are not yet included in the legislation, effluents are only compared with the standards for BOD_5, COD and SS, as depicted in Table 1, and only the graphs concerning BOD_5, COD and SS removal are presented in the results. As no Flemish COD standard exists, the Flemish treatment units will be compared with the Walloon COD norm. In contrast to the (very few) previous studies (e.g., DGRNE 2006), also the percentage of removal from influent to effluent is determined.

The performance of the plant-based systems is compared with that of the compact systems, and activated sludge systems are compared with attached-growth (i.e., biofilm-based) systems. The influence of maintenance and certification on the performance efficiency of individual systems is studied.

Table 1 | Discharge standards for wastewater coming form households (Vlarem II, art. 4.2.7.1.1.)

	COD (mg/L)	BOD_5 (mg/L)	SS (mg/L)
Flanders	/	50	60
Walloon region	180	70	60

RESULTS

Variability of influent quality

The quality and amount of influent pumped into the individual treatment units exhibits large variation. This is to be expected because of its dependency on various and varying household activities (Neralla *et al.* 2000). Moreover, the systems are directly connected to a home with a minimum of piping, and therefore, the wastewater is not modified by the various processes taking place when transported in the sewers. In order to have a representative view of the systems' performance, as mentioned before, in total, three grab samples of the influent (and effluent) of each system were taken and analysed.

Figure 1 illustrates the high variation in influent COD concentration, not only between the samples of the same system, but also between the different systems/households.

Global treatment performance

As depicted in Figure 2, 5 of the 23 systems do not comply with the (locally valid) BOD standard.

No less than 12 systems, or 52%, do not meet the Walloon COD standard (Figure 3), and 9 systems are unable to adequately remove the suspended solids (Figure 4). The average removal percentages of BOD, COD and SS are, respectively, 77%, 62% and 39%.

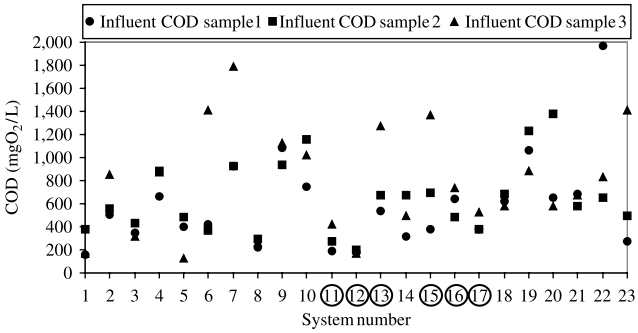

Figure 1 | Variability of the COD of the influent samples. The circled system numbers 11, 12, 13, 15, 16 and 17 are situated in the Walloon region, the others are situated in Flanders.

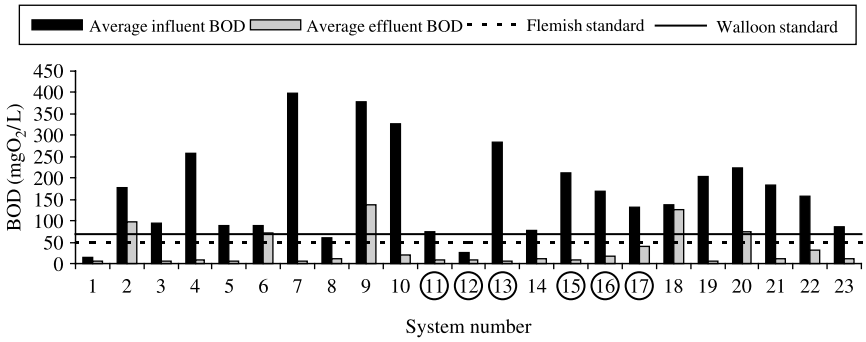

Figure 2 | Average BOD of influent (dark bars) and effluent (light bars) of the 23 systems, accompanied by the Flemish and Walloon standard. The circled system numbers 11, 12, 13, 15, 16 and 17 are situated in the Walloon region, the others are situated in Flanders.

As evidenced by the substantial difference between the effluent COD and the filtered effluent COD (Figure 5), wash out is in 7 cases the reason for the elevated effluent COD and SS values. Wash out occurs when sludge and settled solids accumulate, due to flaws in the design or a lack of maintenance, and leave the system with the effluent.

Nitrification occurs in most systems with an average ammonium removal of 50%, but denitrification is not significant, which means that the nitrates leave the system and end up in surface and ground waters. The individual systems are not yet designed to remove nitrogen (a total average nitrogen removal percentage of only 24%), but since effluent standards are becoming more and more stringent, nitrogen standards for individual systems will probably be implemented in the near future, and design adjustments will be required.

Extensive systems (#3) vs. compact systems (#20)

Extensive systems perform considerably better on all the measured parameters in this study. In Figure 6, a comparison between the average effluent BOD, COD and SS of the compact and extensive systems is made.

Possible explanations are that extensive systems are already being used for a very long time, have few or none mechanical parts and require very little maintenance compared to compact systems. Constructed wetlands thus prove to be very efficient and well performing systems. A disadvantage of these systems is, however, apart from their high installation cost, that they require a high surface area (3–5 m^2/population equivalent) and, therefore, are not suitable in all circumstances. One needs to keep in mind that only 3 extensive systems are compared with 20 compact systems.

Activated sludge systems (#4) vs. attached-growth systems (#16)

The activated sludge systems exceed every effluent standard (Figure 7). Although these systems are generally expected to have a high performance efficiency, poor field results are also reported by other authors (e.g., Hanna *et al.* 1995).

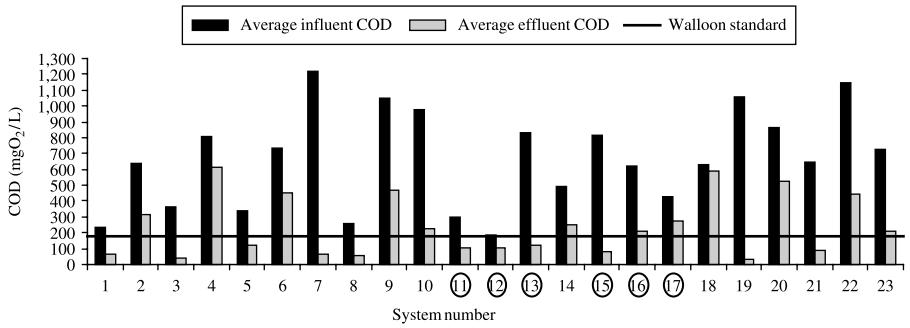

Figure 3 | Average COD of influent (dark bars) and effluent (light bars) of the 23 systems, accompanied by the Walloon standard. The circled system numbers 11, 12, 13, 15, 16 and 17 are situated in the Walloon region, the others are situated in Flanders.

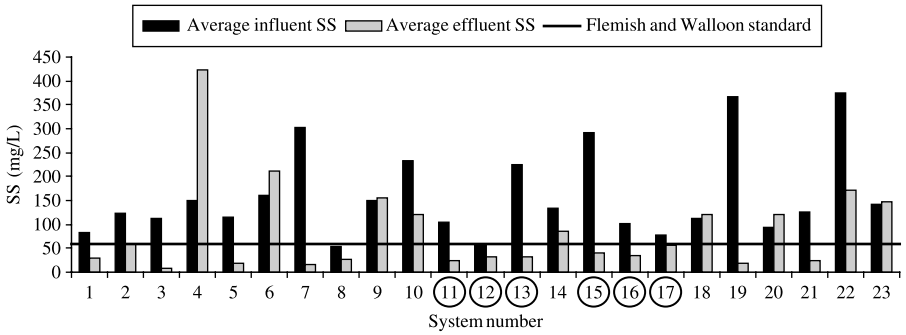

Figure 4 | Average SS of influent (dark bars) and effluent (light bars) of the 23 systems, accompanied by the Flemish and Walloon standard. The circled system numbers 11, 12, 13, 15, 16 and 17 are situated in the Walloon region, the others are situated in Flanders.

Mechanical problems as well as a too short or too long hydraulic retention time (leading to, respectively, wash out or a too low activated sludge concentration), and the lack of regular sludge removal, can decrease the performance to unacceptable levels. Even though also 7 biofilm-based systems do not meet the Walloon COD standard, most likely also caused by a lack of maintenance, a better removal is consistently achieved in the attached-growth systems for all the parameters. This is probably due to their better resistance to high variations in influent quality and quantity, as the micro-organisms are fixed into a biofilm.

Maintenance

Only 5 of the studied treatment units have a maintenance contract. These systems perform significantly better than the others (Figure 8).

Of the remaining 18 systems, 6 have been subjected to a minimum of maintenance, consisting mainly of sludge removal and/or the replacement of a pump, a motor or another mechanical part. The results reveal that their performance is not better than that of the systems without maintenance. Clearly, only a maintenance contract can really ensure the treatment efficiency. Unfortunately, because of the substantial average yearly cost of 200 €, few owners have such a maintenance agreement with their manufacturer (Moelants *et al.* 2006*a*,*b*).

Certification (#5 systems)

The Flemish BENOR quality mark can be obtained after a thorough certification procedure. This procedure is much more strict than the European CE mark, and does not only assess the structural stability, but also the water tightness, the nominal capacity, the performance efficiency and the manufacturing process. The results of this study illustrate that a BENOR certificate alone is not sufficient to guarantee a sustainable performance. Indeed, the performance of certified compact systems without a maintenance contract is not better than other systems. A certificate can only underwrite

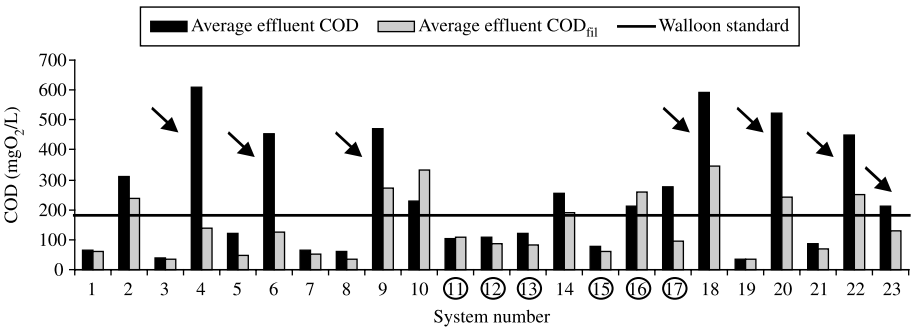

Figure 5 | Average COD (dark bars) and COD_{fil} (light bars) of the effluent of the 23 systems, accompanied by the Walloon standard. The circled system numbers 11, 12, 13, 15, 16 and 17 are situated in the Walloon region, the others are situated in Flanders. The arrows point out the great difference between the COD and COD_{fil}, possibly induced by a wash out situation.

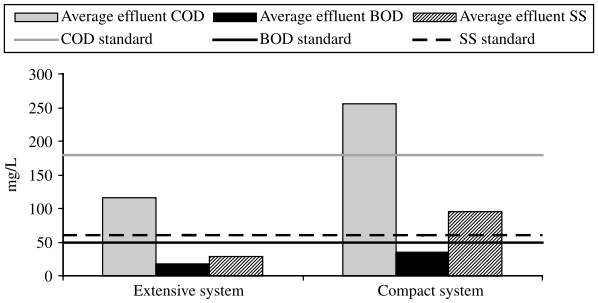

Figure 6 | Comparison of the average effluent BOD, COD and SS values of compact and extensive systems. The lines represent the different standards.

a high treatment efficiency if it is combined with regular and proper maintenance through a maintenance contract.

DISCUSSION AND CONCLUSIONS

Although the number of tested systems is limited, this study illustrates that many installed individual systems do not perform well: 52% of them do not meet all the legal effluent standards. A similar study by the Walloon government reports analogue results (62.5% do not meet all the standards) (DGRNE, Walloon region 2006). Although the performed survey reveals that 74% of the owners are satisfied with their system (Moelants *et al.* 2006*a*,*b*), the performance results demonstrate that this satisfaction does not correspond with an adequate treatment performance; it seems that malfunctioning is just not noticed. Activated sludge systems prove to be less efficient than biofilm-based installations, which corroborates the higher robustness of the latter systems with respect to the highly varying influent quality and quantity, typical for small scale wastewater treatment

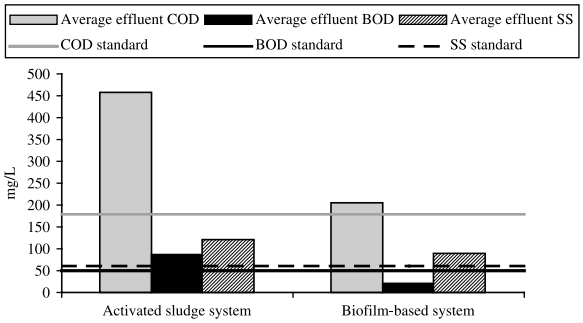

Figure 7 | Comparison of the average effluent BOD, COD and SS values of suspended growth and attached-growth systems. The lines represent the different standards.

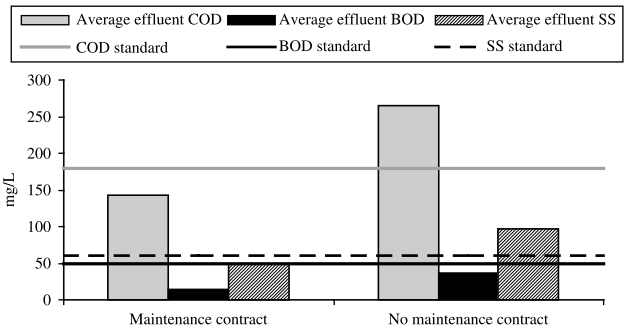

Figure 8 | Comparison of the average effluent BOD, COD and SS values of systems with and without a maintenance contract. The lines represent the different standards.

systems. Extensive systems perform better than compact systems. The fact that they have few or none mechanical parts and require very little maintenance compared to compact systems possibly results in the higher treatment efficiency.

Wash out of sludge comes out as the most frequently occurring sign of malfunctioning. In some cases this is the result of an improper design of the system (e.g., positioning of the effluent opening, or the depth of the final part of the secondary settling tank) but in most systems it is merely a lack of (regular) maintenance. To alleviate these (maintenance) problems and to come to a successful wastewater treatment management, increased public involvement and education are critical. It is proven that onsite system owners are often uninformed about how their systems function and what the consequences of poorly functioning systems can be (Moelants *et al.* 2006*a*,*b*). Educational activities directed at increasing general awareness and knowledge of onsite management efforts can improve the probability that simple routine operation and maintenance tasks are carried out by system owners.

For the more complicated maintenance tasks, there are two possible approaches: (i) through a centralised maintenance and supervision management of decentralised systems by local water authorities (Willetts *et al.* 2007), or (ii) through the enforcement of a maintenance contract between the manufacturer or a subcontractor and the owner, possibly combined with a BENOR certificate. Such a contract should not only include an annual control of the sludge levels and the control and maintenance of electromechanical parts but also the analysis of an effluent sample and the control of the architectural state of the system. At this moment, the financing of a maintenance contract is,

however, entirely the owner's responsibility, which explains why only a minority has such a contract.

Two important aspects that are not yet included in the current contracts are the correct installation and the follow-up of the start-up of the systems. The manufacturer must have the necessary expertise to install the systems properly, taking into account, e.g., the level of the ground water table. Furthermore, individual systems may need several months before their operation is stable (Moelants *et al.* 2008). In the first weeks of operation, it is important to check the system regularly for unexpected problems or complications. Seeding the system with activated sludge from other wastewater treatment installations can be helpful in order to decrease the start-up period.

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