Combination of conventional and non-conventional technologies for wastewater treatment

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Abstract
Recent estimates suggest that around one million people will be making use of decentralised wastewater treatment in the Czech Republic in the near future, representing around 80 000 small and domestic wastewater treatment plants. As such, there is some economic justification for a decision-making paradigm shift from centralised to decentralised solutions. Moving sanitation services "as close as possible to the resources" should lead to a decrease in operating and/or investment costs and better utilisation of resources. In Germany, long-term sustainable 'novel sanitation systems' have been shown to work in combination with both decentralised systems and as part of low-energy building systems.

Keywords
Wastewater treatment, greywater, recycling, NASS

INTRODUCTION

Recent estimates suggest that around one million people will be making use of decentralised wastewater treatment in the Czech Republic in the near future. This represents around 80 000 small and domestic wastewater treatment plants, economically justifying a shift in the decision-making process away from centralised solutions to a decentralised system. Such a paradigm shift for sanitation services "as close as possible to the resources" should lead to a decrease in operating and/or investment costs and better utilisation of resources. In Germany, such technologies are termed Neuartige Sanitärsystemen (novel sanitation systems; NASS) and are typically based on separation of urine and greywater. Until recently, such methods had only been implemented by a relatively small number of 'enthusiasts'; however, it now appears that such methods could help solve many of the problems associated with maintaining increasingly stringent requirements for wastewater outlet quality. As regards long-term resource utilisation, NASS represent some of the most sustainable techniques available. Moreover, such methods work well in combination with both decentralised treatment systems and low-energy building construction.

The problems associated with effective management of wastewater from houses where connection of the wastewater outflow to a standard sewerage system is not possible have been the subject of discussion in Europe for some decades. In particular, there is concern over groundwater contamination issues, including contamination of underground water by nitrogen compounds. Czech wastewater treatment plants with infiltration systems of up to 50 PE (population equivalent) are now subject to new legislation (Government directive NV 57/2016 Sb.) requiring operators to implement denitrification systems (see Table 1 for maximum allowable concentrations under the new directive). This directive has led to operational problems for treatment systems that are not used continuously. As a result, there are increasing demands for technological solutions that address biomass in combination with wastewater separation.

Here, we examine a number of recent projects of the ASIO Company that have combined classic technologies with innovative techniques utilising septic tanks that include bifunctional biofilters, both in continuous and intermittent operation.

Example I - Technologies suitable for houses occupied only occasionally

Where houses are only occupied occasionally (over the year or week), extensive treatment solutions tend to be more suitable, such as anaerobic processes in combination with attached biomass and wastewater separation (e.g. septic tanks with bifunctional biofilters). As part of the ANASEP (Anaerobic Separator) project (funded by the Technology Agency of The Czech Republic), members of the ASIO Company developed and assessed a system (AS_ANAZON) comprising an innovative septic tank design (AS-ANASEP) and a bifunctional biofilter containing zeolite-gravel refill (AS-ZEON). According to Czech Regulation ČSN EN 12566-3+A2, the AS-ANASEP system meets all EN 12566-3+A2 water quality criteria (Table 2). Water retention time in the septic tank (which functions in a similar manner to an anaerobic reactor) was five days with a filter surface area of 1.2 m^2/PE (population equivalent), when the filter material reached 1 m.

Table 1. Emission standards for wastewater outlets under Government Decree no. 416/2010 [2]. * = population equivalent, 'maximum concentration' according to Czech Government Regulation no. NV 57/2016 Sb., COD = chemical oxygen demand, BOD_5 = biological oxygen demand (5 day), N_{ammon} = ammonium nitrogen, TSS = total suspended solids, N_{tot} = total nitrogen.

Size category*	maximum concentration (mg/l)				
	COD	BOD_5	N_{ammon}	TSS	N_{tot}
< 10	150	40	20	30	x
10 - 50	150	40	x	30	30
> 50	130	30	x	30	20

Table 2. Results of AS-ANAZON performance testing according to Czech Regulation ČSN EN 12566-3+A2. WTP = water treatment plant, COD = chemical oxygen demand, BOD_5 = biological oxygen demand (5 day), TSS = total suspended solids, N_{ammon} = ammonium nitrogen, N_{tot} = total nitrogen, P_{tot} = total phosphorous, $P\text{-}PO_4^{3-}$ = phosphates.

	COD (mg/L)	BOD_5 (mg/L)	TSS (mg/L)	N_{ammon} (mg/L)	N_{tot} (mg/L)	P_{tot} (mg/L)	$P\text{-}PO_4^{3-}$ (mg/L)
Inflow	718	230	382	48.4	57.4	14.2	8.72
Outflow (septic tank)	127	51	19	33.6	36.5	7.27	6.56
Outflow (biofilter)	32	4.0	4.9	3.19	34.9	5.29	5.00
Treatment efficiency (%)	**95**	**98**	**99**	**94**	**38**	**62**	
Outflow of WTP with activated sludge	52	7.1	15	4.52	30.7	3.81	-

These results suggest that bifunctional biofilters not only display considerable stability but also significant removal efficiency for ammonia nitrogen and total nitrogen, even during unequal loading. These nitrogen removal efficiency results could potentially be improved further with the application of NASS technologies; including, for example, removal of urine from men’s toilets and subsequent separate treatment. Note, however, that inclusion of such techniques will increase both investment and operating costs.

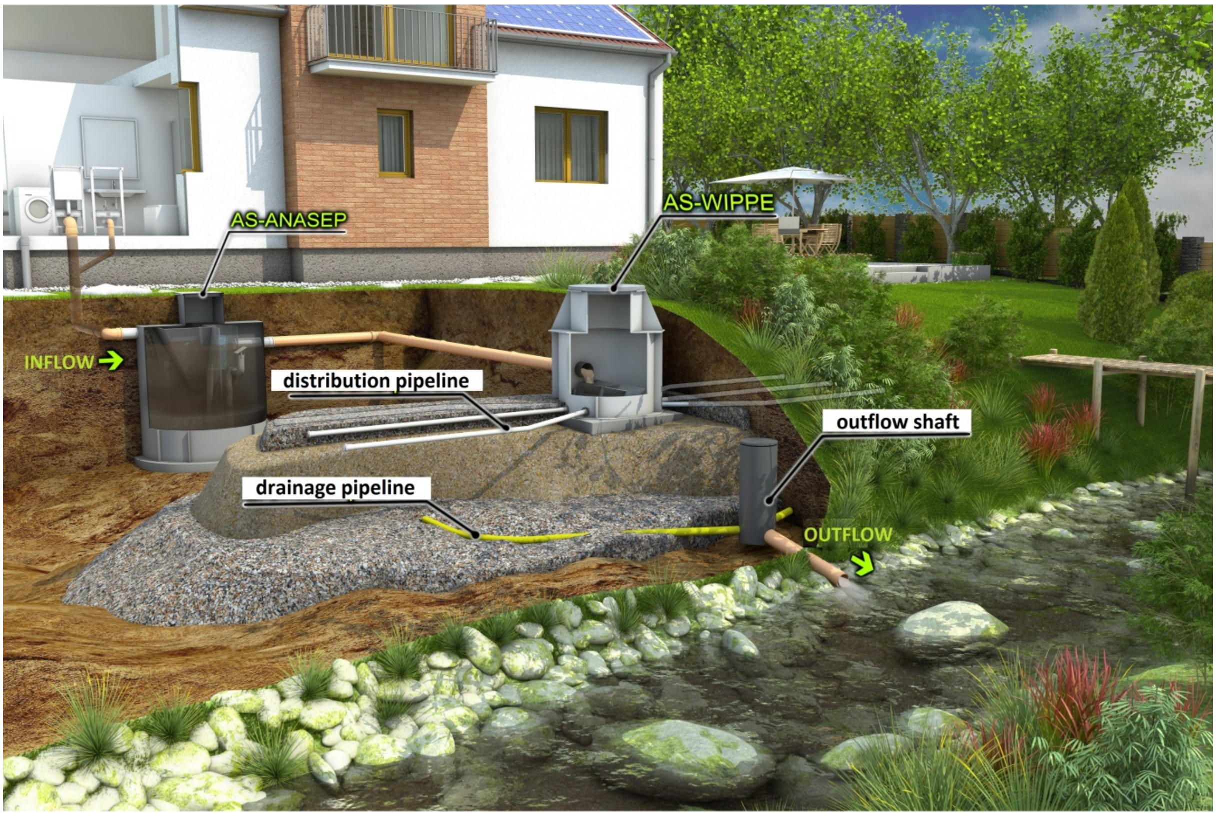

Figure 1. An example of a septic tank with a bifunctional biofilter in position.

Below, we present five further variants of NASS solutions proposed by the ASIO team in response to specific customer requests (variants a-e), along with calculations of investment and operating costs (Figure 3).

Variant a)
Construction of comfortable flushing toilets with no water separation and application of high-technology treatment solutions (including substrate dosing and a membrane bioreactor in combination with a subsequent infiltration system).

Variant b)
Construction of flushing toilets for ladies, with separation of urine and water-free urinals in combination with urine reservoirs. Waste-water control is via an AS-ANASEP septic tank and AS-ZEON bifunctional filter.

Variant c)
Construction of dry toilets for tourists and flushing toilets for staff. Tourist toilets include tanks for faecal storage. Staff toilets utilise an AS ANASEP septic tank and an AS-ZEON bifunctional biofilter, along with building a storage tank for urine.

Variant d)
Comfortable flush toilets with a septic tank in combination with a bifunctional biofilter and sorption filter. This setup was not completed due to unrealistic demands on the filter surface, resulting in low total nitrogen removal efficiency (20 mg/l).

Variant e)
Flush toilets with minimal water consumption, completed using a septic tank and bifunctional biofilter (Figure 2).

In each case, the decision-making process involved a compromise between the demand for comfort and overall cost (investment + operation). The variants above all utilise a system with urine separation toilets for women and water-free urinals for men, with subsequent transport of urine to the wastewater treatment plant. The possibility also exists for dosing of urine through a biofilter during low operation (traffic); a subject that will be discussed in the future.

Figure 2. An example of tourist toilets in Australia.

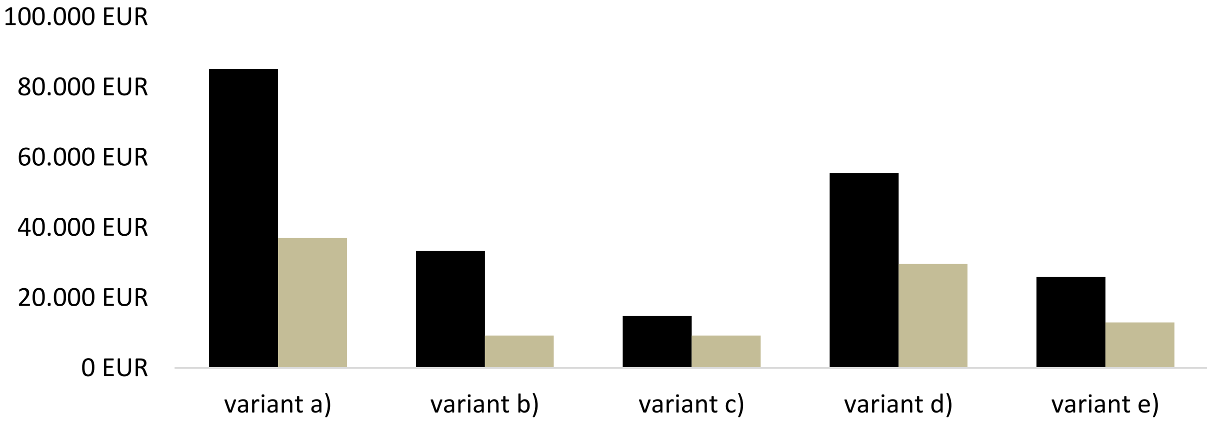

Figure 3. Evaluation of investment and operating costs over a 10-year operating period for the five customer solutions (variants a-e) prepared by ASIO (black bars represent investment costs; grey bars represent operating costs).

Example II - Investment and operating costs in houses with no sewage system connection and no infiltration
In a separate project, ASIO was asked to design a treatment system for a classic Czech house that had no connection to the sewerage system and where infiltration was impossible in the

locality. Once again, NASS was suggested as an appropriate solution. We also compared investment and operating costs and payback period in the case of yellow-water separation.

In most cases, NASS are used to separate grey-water from showers, etc. After treatment, this water can safely be used for the flushing of toilets. Under conditions prevalent in the Czech Republic, this can represent a 50% cost saving in comparison with transporting all water away. Overall savings can reach around 500 Euro for a four-member family, with payback at around five years. A further possibility is the use of reverse osmosis for rain-water and grey-water treatment, though this is only really suitable in localities a lack of drinking water is an acute problem. Where drinking water is sufficient, the payback period for this system can be more than 20 years.

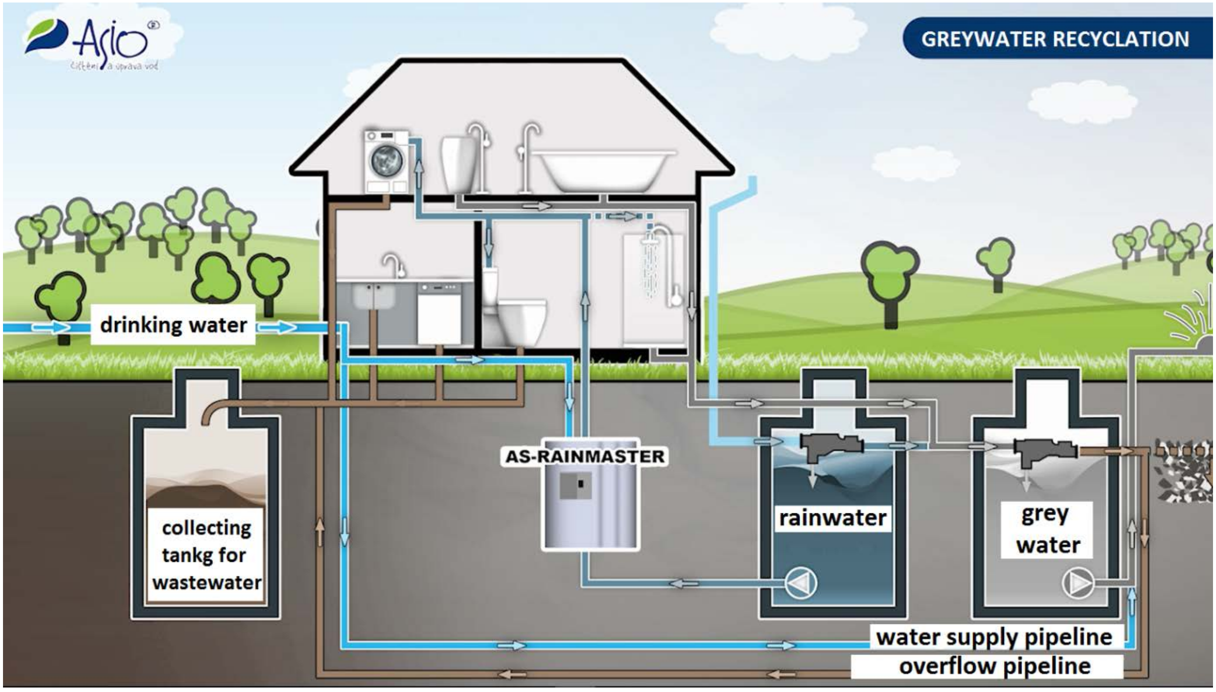

Figure 4. Water treatment arrangement for a house located in an area lacking drinking water.

Example III - Use of NASS in low-energy building projects

Automatic application of NASS technology in every case can lead to high economic costs. In cases where cost-effective water treatment is required alongside energy-saving building technology, a reduction in overall water consumption alongside the separation of wastewater for recycling may be the best option (see Figure 4). The most frequently used techniques for saving water are a) the use of ‘water savers’ and b) detection (and treatment) of water leakage in toilets or sinks. A suitable solution where low-energy treatment is required, e.g. where solar energy is used as an energy-source, would be the use of a septic tank with an appropriate filter. Water savers (Figure 5) and leakage detectors are usually very simple devices that are able to reduce production of wasted water, thereby lowering operating costs dramatically, especially in public buildings. Such savings may be especially important in cases where wastewater must be transported out.

Other possibilities for minimising energy consumption include the previously mentioned septic tank in combination with a bifunctional filter. Where required, it would be possible to install such a set-up where the pump’s electrical supply came from photovoltaic panels (Figure 6). Unfortunately, the investment costs for this type of solution are relatively high (a

domestic water treatment plant using intensive technology such as sequencing batch reactors can be purchased for half the price) and the payback period is approximately 20 years. Similarly, while heat recycling from water is theoretically possible in small buildings, realistic payback periods are only obtainable in larger buildings.
Water recycling is especially suitable for grey-water, which can be re-used for flushing toilets and heaters that use non-potable water (Figure 7). Many sophisticated solutions presently exist for grey-water recycling, including use of membrane technologies (Figure 8). Low-cost alternatives are also available, including water flushing, handwashing up to toilets, etc.
As an example of grey-water recycling, ASIO undertook a case-study in a recreational building serving as an education centre for children and teenagers. The overall capacity of the building was around 30 people. After calculating the operating costs, the payback period was approximately seven years.

Figure 5. A drinking water distribution system utilising a water saver and a device for detecting water leakage.

Figure 6. An example of device using photovoltaic cells as its energy source.

 

Figure 7. An example of devices for grey water recycling – treatment plant for grey water and spiral heat exchanger

Figure 8. An example of a desk heat exchanger for heat recycling from grey water.

CONCLUSIONS

Thanks to new legislation (e.g. restrictions on release of wastewater to underground water systems) and the savings possible, NASS are slowly starting to be implemented as practical working systems, even in countries and localities where water deficiency is not a problem. Full acceptance of these solutions by the general public may take some time, though urine separation and grey-water recycling may is clearly appropriate where ecological approaches and sustainable development are important. It is clear that, while NASS are likely to undergo further changes over the coming years, the approach is the right one and the process of NASS implementation is nor irreversible.

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