Cost comparison of conventional and modern sanitation solutions*

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Abstract

The objective of the study is to investigate the cost effectiveness of Ecosan-solutions for rural villages in Austria. Three different scenarios have been compared, ranging from conventional to modern, reuse-oriented, solutions. For comparison a precondition for all solutions was the compliance with the applicable legislation. In the comparison a "model village", resembling a typical village in rural areas was used. Based on legal requirements due to small recipients – typical for these areas – higher then normal standards for effluents were assumed.

Three scenarios were compared, scenario A representing a conventional solution comprising sewer and treatment plant, scenario B considering urine diversion, separate storage and discharge to the treatment plant for reuse, and scenario C assuming in house measures for quantity reduction, storage and reuse respectively dry toilets and decentralised grey water treatment followed by infiltration. The cost estimations are based on actual costs of comparable systems and offers of suppliers. Necessary changes in the houses have been considered.

The results demonstrate clearly that, both with regard to construction and operation and maintenance, conventional systems for rural areas are the most expensive option but still encouraged through subsidising systems. It becomes clear that in addition to their sustainability reuse oriented systems are also definitely economically advantageous.

Introduction

The existence and enforcement of strict environmental legislation in Austria achieved significant improvements of the environmental situation; at least as far as the water compartment is concerned. Approximately 85 % of the population are connected to public sewers and consequently treated in biological treatment plants (BMLFUW, 2003a) with, depending on the size, advanced biological nutrient removal. Transferring this high tech end of pipe approach to less densely populated settlements resulted in the past in exorbitant increases both in investment and operational costs. Future trends regarding the possible developments of the water/wastewater industry (PWC, 2001) all focus on economic efficiency, mostly neglecting

*This paper has been peer reviewed by the symposium scientific committee presently un-served regions for cost reasons (BMLFUW, 2003b). All of these arguments assume the traditional non-prevention oriented strategy to be the only possible option to tackle the existing problems and could possibly result in a reduction of environmental standards for economic reasons.

For this study it is assumed that modern sanitation solutions, which focus on reduction of energy and material flows can assure the high environmental standards of Austria at acceptable cost for the population. The objective of this study therefore was to compare investment and operational costs for different solutions taking into account varying degrees of preventive measures in order to prove that applying different models of technical solutions for different settlement structures can be the option to achieve the requested environmental standards for rural and more remote locations at acceptable costs.

In addition such solutions are better suited to fulfil the legal requirements of Austria according to which reduction, prevention and recycling of wastewater and its compounds are prioritised against treatment of wastewater.

Frame conditions and problem description

The background of the study was the discussion in three rural villages on the solution of their immediate problems concerning wastewater. For the purpose of the study a "model-village" was created in order to objectify the discussion. The "model-village" is app. the average of the three villages in question and resembles a typical village of this region. It consists of 25 houses with a total of 100 inhabitants. The share of agriculture is still 30% meaning that 8 houses out of the total are active farms. Presently wastewater produced in these households is collected in septic tanks. Theoretically this would mean that wastewater is stored and reused in agriculture due to the fact that these septic tanks normally have an illegal overflow - in order to reduce the emptying frequency - mechanically treated wastewater (sedimentation only) is discharged either by an existing rainwater sewer or by means of drain pipes directly to the recipient.

The particular region is additionally marked by small receiving streams. Under certain circumstances this requires a significantly higher reduction of an emitted pollution load compared to the general standards. Therefore it is assumed that the pollution load of any water discharged from the households has to be less then 15mg/l BOD_5 and less then 5mg/l NH_4-N at an effluent temperature of 10°C.

Proposed scenarios

Three scenarios were considered only having one basic principle to fulfil was the legal compliance. This means that each technical solution has to fulfil the legal standards presently in force. Other criteria like for example whether one scenario would result in higher environmental benefits then requested were neglected.

Scenario A solves the problem in a conventional way by constructing a separate sewer system and a conventional biological treatment plant (Figure 1). Due to the strict standards a tertiary treatment step, e.g. a constructed wetland, is required.

Scenario B (Figure 2) assumes a conventional separate sewer system and treatment plant but toilets with urine separation and decentralised storage in each household. Automatically urine is collected separately by using the sewer system during night times with near to zero wastewater flow, stored separately and used as a fertilizer in agriculture (e.g. Lens *et al*., 2001). A tertiary treatment step is not necessary since no access of nitrogen has to be removed. The reason for including this scenario was that compared to Scenario C, which is presented below, still most of the responsibility for operation and maintenance of the whole system lies with the community and not the single households.

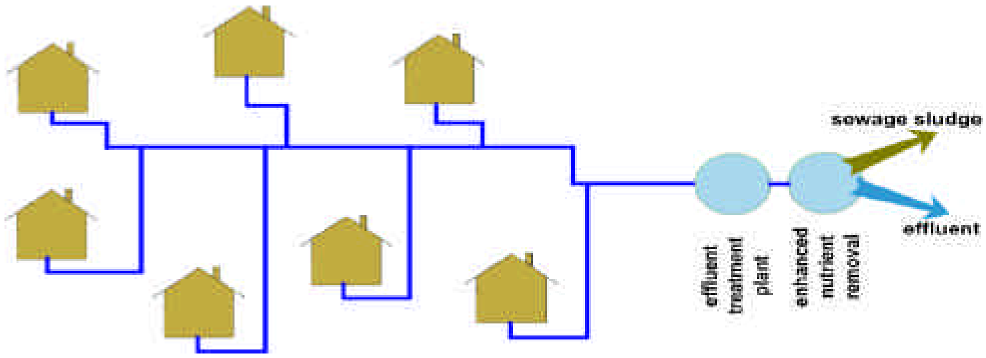

Figure 1: Schematic sketch of Scenario A.

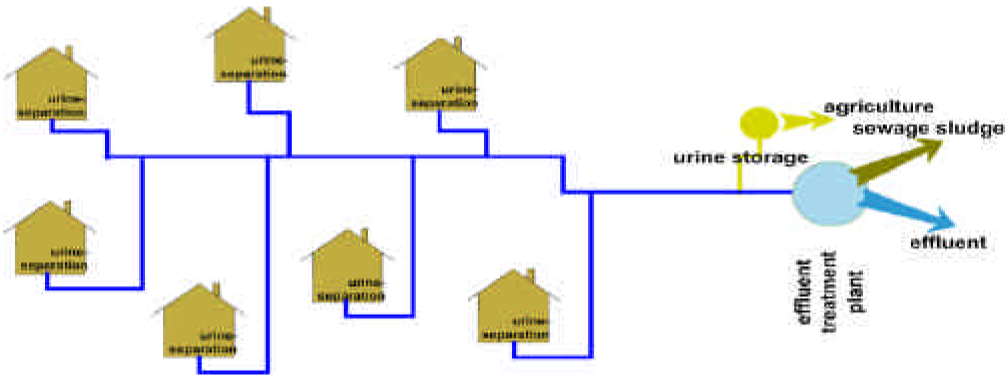

Figure 2: Schematic sketch of Scenario B.

Scenario C is assumed to be the option which fulfils the requirements of Ecosan-solutions best under the given conditions, i.e. to further sustainable development by closing nutrient and water cycles with as little loss of material (nutrients) and energy as possible. For those households which are active farms, in house measures for quantity reduction are assumed (i.e. low flush toilets), followed by storage in order to bridge those periods when use in agriculture is not allowed, e.g. during periods of frozen ground or snow, and subsequent use in agriculture together with manure.

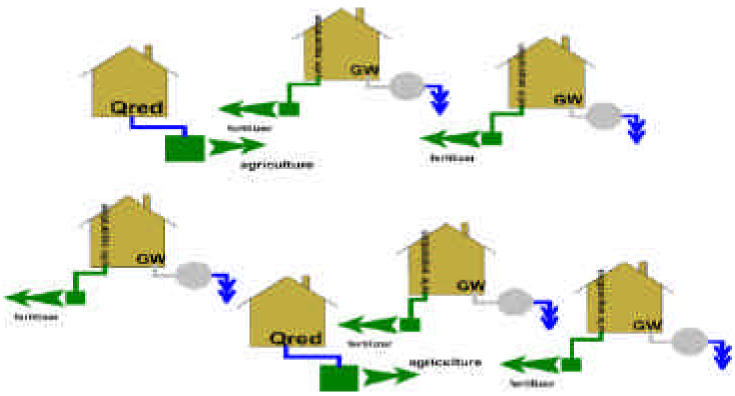

Figure 3: Schematic sketch of Scenario C.

For the remaining households reduction in wastewater quantity and quality is proposed by the application of dry toilets was foreseen. For the remaining greywater for each household a constructed wetland for treatment followed by infiltration is considered (Figure 3). It has to be stated that due to the particular situation in Austria regarding groundwater protection infiltration to the ground(water) is not forbidden as such but very strictly regulated. Nevertheless on the basis of average greywater quality (Laber and Haberl, 1999) after treatme nt no problems are assumed for the sage of this study.

Investment costs

The investment costs are based on the frame conditions described above, current data published (e.g. BMLFUW 2001, 2003c), information from suppliers (in particular regarding separation toilets, dry toilets, etc.) and own practical experiences from implementation of both conventional and alternative sanitation projects.

For Scenario A cost it is assumed that for the construction of the sewer lines no major hindrances due to underground conditions occur and costs are therefore comparatively low. The same applies for the treatment plant. Nevertheless due to the small size average costs of 1.000€ have been assumed per person equivalent. For tertiary treatment a vertical subsurface flow constructed wetland is assumed with relative cost – including all necessary pumps, structures and pipings – of approximately 125,-€ per person equivalent. The average length of the sewer line per house connection is based on an average length of the network in the village of 30m and a transport line to the nearest receiving stream of app. 1.000m. Table 1 summarises the assumptions and resulting total costs and costs per house connection respectively. The total investment costs are 14.650,-€ for each house connection.

Unit	Assumptions	Costs	Costs/house
sewer line	25 houses á 70m at 145 €/m	€ 253.750,00	€ 10.150,00
treatment plant	100pe at 1000€/pe	€ 100.000,00	€ 4.000,00
3rd step	100pe at 125€/pe	€ 12.500,00	€ 500,00
Total Scenario A		**€ 366.250,00**	**€ 14.650,00**

Table 1: Investment costs for Scenario A

Costs for the sewer line in Scenario B naturally have to be same as in scenario A while the cost of the treatment plant is assumed to be reduced significantly since enhanced nitrogen elimination is not required due to separate collection and storage of the urine. Operational problems of the treatment plant caused by a lack of nutrients could be solved by controlled dosage of urine from the storage tank. The storage tank was designed for a storage period sufficient to bridge the period during which no agricultural application of fertilizer is allowed. In addition to these costs also costs for the urine diversion toilet which is vital for the system to function are considered. It was assumed that on average two new toilets were required for each household.

Table 2 summarises the assumptions and the resulting total costs and costs per house connection respectively. The total investment costs of Scenario B (14.694,-€) are basically the same as for Scenario A. The advantage of reduced cost for the treatment plant is consumed by the urine storage tank and the urine diversion toilets.

Unit	Assumptions	Costs	Costs/house
sewer line	25 houses á 70m at 145€/m	€ 253.750,00	€ 10.150,00
treatment plant	100 pe at 500€/pe	€ 50.000,00	€ 2.000,00
urine diversion toilets	25x2 at 1.200€	€ 60.000,00	€ 2.400,00
urine storage	18m³ at 100€/m³	€ 3.600,00	€ 144,00
Total Scenario B		**€ 367.350,00**	**€ 14.694,00**

Table 2: Investment costs for Scenario B

Costs for Scenario C (Table 3), being the most "decentralised" solution, consider the different solutions for farmers and other households respectively. Cost for dry toilets for quantitative and qualitative prevention are calculated for 2/3 of all houses including cost not only for the toilet seat but also the required changes within the houses. For these houses treatment of greywater in constructed wetland systems followed by infiltration is calculated.

It is assumed that by application of vertical flow constructed wetland system a surface area of 2m² per person equivalent is sufficient at relative cost of 250,-€/m². For the remaining 1/3 of households use of the total wastewater in agriculture is assumed. Due to the unsatisfying state of most of the existing septic tanks costs for renovation (50% of new septic tanks) were considered. Since the required size of the tanks depends directly on the wastewater production reduction by installation of low flush toilets is included (2 new toilets per house). Thus a size of 58m³ for each tank is sufficient to achieve a six months storage period. The total investment costs for Scenario C per house connection is only app. 4.450,-€. The main difference compared to the other scenarios is the non-existence of a sewer line.

Unit	Assumptions	Costs	Costs/house
greywater treatment	17 houses at 500€/pe	€ 34.000,00	€ 1.360,00
dry toilets	17x2 at 1.500€	€ 51.000,00	€ 2.040,00
low flush toilets	8x2 at 600€	€ 9.600,00	€ 384,00
renovation septic tanks	50% of 58m³ per house	€ 16.240,00	€ 649,60
Total Scenario C		**€ 110.840,00**	**€ 4.433,60**

Table 3: Investment costs for Scenario C

Operational costs

The operational costs are based on the frame conditions described above, current data published (e.g. BMLFUW 2001, 2003c and own practical experiences from implementation of both conventional and alternative sanitation projects.

Operational costs can only be assumed with a higher degree of uncertainty compared to the investment costs. One main reason is that only insufficient information on actual operational costs of sewer lines are available. In addition costs depend on the strategy applied in operation and maintenance of sewer lines, whether it is prevention or cure oriented. For the purpose of this study costs for a proper operation of sewer lines is assumed to be 1% of the investment costs annually. Another source of uncertainty is the cost for disposal of sewage sludge produced in Scenarios A and B and in a lesser extent in Scenario C. Depending on the chosen path of reuse respectively disposal the costs vary significantly. It was assumed that the quality of sewage sludge allows application in agriculture. In addition the idealistic value of work by all households in Scenario C regarding the emptying of the dry toilets and operation of the grey water treatment plants was neglected as well.

Depreciation of investment is considered on the bases of a fixed interest rate of 5% annually. The average life span of the mechanical equipment is assumed with 10 years while the average life span of all other investment is calculated with 50 years. Inflation is considered with 2% per year. For the purpose of this study a constant repayment rate was assumed. These assumptions are the same for all scenarios.

Table 4 shows the operational costs for Scenario A. For the treatment plant the costs comprise mainly costs for energy, material, personal and external supervision. Annual cost in Scenario A calculates to 1.300,-€ per house connection.

Unit	Assumptions	Costs	Costs/house
sewer line	1 % of investment annually	€ 2.500,00	€ 100,00
treatment plant	energy, material, personal, supervision	€ 10.000,00	€ 400,00
	sewage sludge (not considered)	€ 0,00	€ 0,00
depreciation	5 % over 10-50 a	€ 20.000,00	€ 800,00
Total operational costs Scenario A		**€ 32.500,00**	**€ 1.300,00**

Table 4: Operational costs for Scenario A

For Scenario B (Table 5) operational costs are nearly the same. A slight reduction in treatment plant operational costs – since the highest share in the cost is the personal – is compensated by the slightly higher investment costs of this option. The value of approximately 360kg of collected nitrogen per year is not calculated.

Unit	Assumptions	Costs	Costs/house
sewer line	1%	€ 2.500,00	€ 100,00
treatment plant	energy, material, personal, supervision	€ 9.000,00	€ 360,00
	sewage sludge (not considered)	€ 0,00	€ 0,00
depreciation	5 % over 10-50 a	€ 21.000,00	€ 840,00
Total operational costs Scenario B		**€ 32.500,00**	**€ 1.300,00**

Table 5: Operational costs for Scenario B

Operational costs for Scenario C are summarised in Table 6. In addition to the general assumptions the lifespan for dry toilets and low flush toilets was assumed to be 25 years in average. Therefore depreciation costs are high compared to the investment. As mentioned above both the idealistic value of work carried out by the households for operation of the units as well as the fertilizer value of the separately collected material are not included in the calculation. The total cost per household is with app. 410,-€ annually less then one third of the operation and maintenance cost of the first two scenarios.

Unit	Assumptions	Costs	Costs/house
grey water treatment	17x energy, supervision, etc.	€ 3.000,00	€ 120,00
	sewage sludge (not considered)	€ 0,00	€ 0,00
depreciation	5 % over 10-50 a	€ 7.293,17	€ 291,73
Total operational costs Scenario B		**€ 10.293,17**	**€ 411,73**

Table 6: Operational costs for Scenario C

Cost comparison

As mentioned above the main underlying principle of all scenarios presented was their compliance with the present legal situation with regard to discharge of wastewater to the environment. This means that the three solutions are comparable with regard to their performance in this sense.

In Figure 4 (left) the investment costs of the three options are compared. While the investment costs for Scenario A and B are similar, costs for Scenario C are significantly lower (app. 30%). The difference is mainly caused by the high costs of the sewer system.

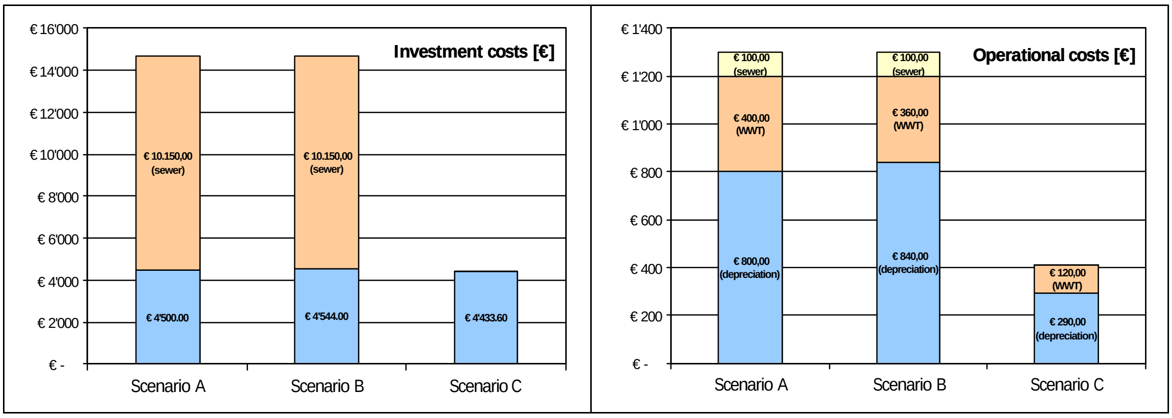

Figure 4: Comparison of investment costs (left) and operational costs (right) (wwt wastewater treatment).

Figure 4 (right) shows basically the same picture for the operational costs. In addition to the high depreciation costs, caused mainly by the high investment for the sewer lines also the operation of the wastewater treatment plants in Scenarios A and B is higher. The latter has to be qualified since, as mentioned above, the value of work carried out by the households themselves in Scenario C was not included. Nevertheless it is again obvious that both options with sewers cause approximately 3 times higher costs for operation and maintenance. Although if additionally the value of the nitrogen collected in Scenario B were considered still the level of costs achieved by Scenario C – were the same value is recovered – could not be reached.

Figure 4 compares absolute costs, not taking into account the present system of subsidising wastewater infrastructure in Austria. Generally all installations on private property (with the exception of long connecting sewers and main sewer lines) can not be subsidised. Taking into account average subsidy rates the pictures looks differently.

Figure 5 summarise both investment and operational costs taking into account present subsidising practices. Due to the nature of the subsidising system – normally only the minor part is a direct contribution to the investment but the rest contributes to the repayment of a loan – the effect becomes most obvious for the operation and maintenance costs which have to be financed by the households directly. Scenario B becomes the most expensive since the investment costs are nearly the same as for Scenario A but partly, since in house installations, not supported. Although Scenario A is still 50% more expensive then Scenario C it is obvious that an important incentive for alternative solutions is lost.

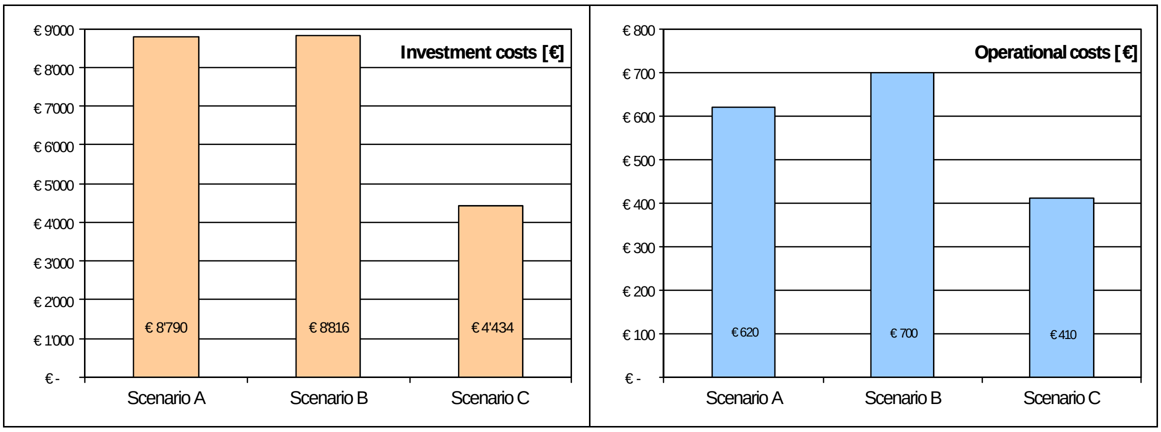

Figure 5: Investment costs (left) and operational costs (right) without subsidy.

Conclusions

The comparison of investment and operational costs of three different scenarios clearly shows that conventional systems for rural areas are the most expensive option (mainly due to the sewer lines needed) but still encouraged through the subsidising system. Neglecting subsidising issues the advantage of alternative sanitation solutions under the frame conditions described above becomes obvious. In addition to their sustainability reuse oriented systems are therefore also definitely economically advantageous.

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