FOOD WASTE DISPOSER

- Effects on wastewater treatment focused on additional production of biogas
- Food waste disposers versus "biobak" as system for collecting food waste

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Effects on wastewater treatment focused on additional production of biogas

INTRODUCTION

At the moment the use of food waste disposers is prohibited in the Netherlands [Sdu 2002, CECED 2003]. This prohibition originated from the 1960´s and was based on the fear for the obstruction of the sewer system and deteriorated treatment of wastewater. Several studies have already shown that obstruction of the sewer system is not very likely and that the deterioration of the treatment of wastewater is either very small or negligible. Most of the studies to the effects of the use of food waste disposers on the treatment of wastewater were case studies with pilot projects [e.g. Nilson *et al.* 1990, Karlberg *et al.* 1999]. However, a pilot project was never conducted in the Netherlands. For the Dutch situation only some desk studies have been carried out to the effects of the use of food waste disposers on the treatment of wastewater. In these studies the effects have been calculated based on the yearly loads for the Netherlands as a whole [de Koning 2003]. Research on the level of an individual wastewater treatment plant (wwtp) has not been carried out yet.
The former Minister of Spatial Planning, Housing and the Environment, Mrs. de Boer, has recognized already in 1998 "that a food waste disposer as such is not necessarily an environmental unfriendly device" [VROM 1998]. Previous research of the Delft University of Technology has concluded [de Koning 2003]:

- There is no proof for clogging of the sewer system caused by the use of food waste disposers.
- The use of food waste disposers does not lead to an increase of the hydraulic load of the sewer system.
- The increase of the load to the biological waste water treatment processes caused by the use of food waste disposers is negligible and therefore a deterioration of effluent quality is not expected (in the case of the installation of food waste disposers in 10% of Dutch households).
- The increase of the load to the final sludge treatment (drying, incineration and land fill) is approximately 5% (with installation in 10% of Dutch households). The existing sludge treatment capacity is high enough to treat this extra amount of sludge.

As mentioned before no research into the effects on the (biological) waste water treatment processes and sludge treatment of the use of food waste disposers at the level of an individual wwtp has been carried out in the Netherlands. In this paper the effect of the use of food waste disposers on a wwtp with a capacity of 100,000 population equivalents (p.e.) are calculated.

METHODOLOGY

WWTP

De effects of the use of food waste disposers has been calculated for a wwtp with a capacity of 100,000 p.e.. This wwtp is based on a low loaded activated sludge process with a primary sedimentation and biological nutrient removal. The primary sludge and surplus sludge is thickened, digested and dewatered together. The dewatered sludge is transported to a central sludge treatment plant. The scheme below gives an overview.

- water line:

  influent
  ↓ *bar screens*
  ↓ *primary sedimentation*
  ↓ *anaerobic biological P-removal*
  ↓ *oxidation ditch with nitrification and denitrification*
  ↓ *final clarifier*
  effluent

- sludge line:

  primary sludge (primary sedimentation) +
  surplus sludge (final clarifier)
  ↓ *pre-thickener*
  ↓ *digester*
  ↓ *post-thickener*
  ↓ *dewatering (filter belt press)*
  dewatered sludge (22% dry solids) at wwtp ↑

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  central sludge treatment ↓
  ↓ *(drying)*
  ↓ *incineration*
  ash → land fill

The biogas produced in the digester will be use for energy supply at the wwtp (electricity and heat).

Wastewater

For the composition of raw wastewater (without contribution from food waste disposers) has been taken the average composition in the Netherlands (see Table 1). The effluent fulfils in all cases the requirements also mentioned in Table 1.

Table 1 Wastewater composition and effluent requirements.

parameter	raw wastewater	after primary sedimentation		effluent
		efficientcy		
Chemical Oxygen Demand COD (mgO_2/l)	600	30%	420	50
• dissolved	180		180	38
• suspended	420		240	12
Biochemical Oxygen Demend BOD_5 (mgO_2/l)	220	20%	176	10
• dissolved	90		90	
• suspended	130		86	
Nitrogen as N (mgN/l)	55	5%	52	10
BZV_5/N	4		3.4	
Phosphorus as P (mgP/l)	9	10%	8	1
Suspended Solids (mg/l)	250	50%	125	10

Food waste disposer
The use of food waste disposers causes an additional load of suspended solids of 60 gram per person per day [de Koning 2003]. 90 % of the additional suspended solids is removed in the primary sedimentation [Nilsson 1990]. Table 2 gives an overview of the additional load of pollutants caused by the use of food waste disposers.

Table 2 Additional load of pollutants caused by the food waste disposers [Nilsson 1990, de Koning 2003].

parameter	g/pers./day	parameter	g/pers./day
COD	95	Phosphorus (P)	0.30
• dissolved	22	• dissolved	0.19
• suspended	73	• suspended	0.11
BOD_5	66	Suspended Solids	60
• dissolved	24	• removed in primary sedimentation (%)	90
• suspended	42		
Nitrogen (N)	2.1		
• dissolved	1.6		
• suspended	0.5		

The use of food waste disposers doesn't result in a noticeable increase in the volume of wastewater [de Koning 2003].

The effect of the use food waste disposers has been calculated at a penetration[1] of 1%, 5% and 10%. The corresponding numbers of inhabitants are 1,000, 5,000 and 10,000 respectively.
With respect to the penetration the following remarks can be made. At the moment approximately 65,000 food waste disposers are installed in the Netherlands. Assuming all of these food waste disposers have been installed in households the penetration is nowadays less than 1%. In the case of a permission for food waste disposers to the Dutch market and considering the growth in the number of households [CBS 2004] and a sales of 5,000, 10,000 and 25,000 units per year the penetration in 2025 will be approximately 2.5%, 4.3% and 9.4% respectively.

Other design aspects
<u>Water line</u>
The average daily influent flow rate for the wwtp of 100,000 p.e. is set at 19,500 m^3 (Q_{day}).
The average hourly influent flow rates are:

- dry weather flow (DWF, Q_{dwf}): 1,000 m^3/hour
- storm weather flow (SWF, Q_{swf}): 3,000 m^3/hour

An overview of the design bases of the several parts of the water line is given in Table 3.

[1] penetration = [number of household with a food waste disposer] / [number of households without a food waste disposer] × 100%

Table 3 Design bases (range between brackets).

unit process	design parameter	reference
primary sedimentation	surface load at Q_{swf}: v_0 = 3 m³/m².hour (2 – 5)	Metcalf & Eddy 2003
anaerobic volume for biological P removal	residence time T at Q_{dwf} + $Q_{return\ sludge}$: T = 2 hours ($Q_{return\ sludge}$ = 1,000 m³/h)	STOWA 1998
oxidation ditch	sludge loading at Q_{day}: k = 0.06 kgBOD/kgMLSS.day (0.02 – 0.1) (sludge concentration = 4 gMLSS/l)	Metcalf & Eddy 2003
final clarifier	surface load at Q_{swf}: v_0 = 0.7 m³/m².uur (0.7 – 2.0)	Metcalf & Eddy 2003

The oxygen consumption in the oxidation ditch is calculated based on a yield Y with a value of 0.55 kgMLSS/kgCOD$_{removed}$ [van Nieuwenhuijzen 2002]. Furthermore for the calculation of the oxygen consumption has been assumed [van Nieuwenhuijzen 2002]:

- correction for reduced oxygen transfer in activated sludge compared to clean water: α = 0.7 [-].
- peak factor: p = 1.2 (1.1 – 1.5) [-].
- saturation concentration for oxygen at 14 °C: c_s = 10.2 mgO$_2$/l.
- oxygen concentration in aeration: c = 1.5 mgO$_2$/l.

<u>Sludge line</u>

The mixture of primary and surplus sludge is transported to the pre-thickeners with a dry solids content of 0.6% by weight. By the pre-thickeners the dry solids content is increased to 5% by weight. From the pre-thickeners the sludge is transported to the digester(s). Finally after dewatering the sludge is leaving the wwtp and transported to a central sludge treatment wit a dry solids content of 22% by weight. The total volume reduction after central sludge treatment is 98%.

In the digester(s) the organic matter in the sludge is partly degraded in anaerobic conditions. During the digesting biogas is produced. Out of the biogas energy (electricity and heat) is produced which can be used for the energy supply at the wwtp. For the production of energy a TE-installation (Total Energy) is applied. This TE-installation transforms 32% of the energy content of the biogas into electricity and 50% into applicable heat. The remaining part is lost.

The amount of biogas that can be produced out of sludge depends on percentage of organic matter in the sludge and of the nature of the organic matter. Out of the organic matter in primary sludge usually more biogas per kg can be produced. This means primary sludge is better to digest. Food waste (which for 90% ends up in the primary sludge) contains a high percentage of relatively easy digestible organic matter (see Table 4).

Table 4 Organic matter and digestibility of sludge and food waste.

kind of sludge or food waste	organic matter (% by weight)	degradation in digester (% by weight of organic matter) residence time in digester 20 days	reference
primary sludge	65	50	STOWA 1998, Metcalf & Eddy 2003
surplus sludge	73.5	30	STOWA 1998, Metcalf & Eddy 2003
food waste	80	60	Nilsson 1990

Energy
The major part of the electricity consumption of a wwtp is caused by the aeration. In the Netherlands the average electricity consumption by aeration is 65% of the total electricity consumption [CBS 2004]. Besides electricity also heat is consumed at a wwtp especially to keep a constant temperature in the digester(s) of approximately 30 °C. Expressed in kWh the heat consumption of the digester(s) is almost equal to the electricity consumption of the aeration (for a wwtp of 100,000 p.e.).
The bases for the energy balance calculations are given in Table 5.

Table 5 Parameters of energy balance.

parameter	value	bron
biogas production	1.15 m³/kg digested organic matter (0.75 – 1.15)	Metcalf & Eddy 2003
energy content of biogas	22,000 kJ/m³ biogas	STOWA 1998
TE-installation • transformation to electricity • transformation to heat	 32 % 50 %	STOWA 1998
electricity consumption of aeration	0.4 kWh/kg O_2	STOWA 1998
heating of sludge inflow (digester)	100,000 kJ/m³ sludge	STOWA 1998
price of electricity	€ 0.068 per kWh	STOWA 1998

Central sludge treatment
For the unit costs of central sludge treatment (including transport) € 400 per ton dry solids has been assumed.

RESULTS AND DISCUSSION
It should be mentioned here that the accuracy of the results of the calculations, based on the above mentioned values, is plus and minus 10%.
The discussion of the results of the calculations is focussed on the energy balance, the costs for central sludge treatment and total costs per p.e. respectively (see Table 6). The determination of the costs per p.e. has been based on the assumption of the average wastewater treatment fee in the Netherlands. In 2000 the average wastewater treatment fee was € 42.40 per p.e. [CBS 2004]. The increase of treatment costs due to the use of food waste disposers is distributed over all p.e.´s.

Base on the calculations it has been concluded that the effect of the use of the food waste disposer on the processes at the wwtp (water and sludge line) is very limited. This confirms the conclusions of other studies [Karlberg *et al.* 1999, de Koning 2003].

Table 6 Effect of food waste disposer on energy balance, costs of central sludge treatment and costs per p.e. (between brackets % in-/decrease compared to penetration = 0%).

	penetration (%)			
	0	1	5	10
biogas production (m^3/dag)	1917	1951 (1.8)	2088 (8.9)	2262 (18)
electricity:				
• self supply* (%)	72	73 (1.4)	77 (6.9)	82 (14)
• costs for buying shortage (€/year)	35,900	34.700 (-3.3)	30,000 (-17)	24,200 (-33)
central sludge treatment:				
• amount (ton dry solids/year)	1,859	1,875 (0.9)	1,940 (4.4)	2,026 (9.0)
• costs (€/year)	743,700	750,100 (0.9)	776,100 (4.4)	810.500 (9.0)
costs per p.e. (€/year)				
• extra due to food waste disposer:				
o electricity	-	-0.012	-0.059	-0.120
o central sludge treatment	-	0.064	0.324	0.667
• total yearly costs	42.40	42.45 (0.12)	42.67 (0.63)	42,95 (1.3)

* For the calculation of the self supply in electricity is a 100% use of the produced biogas assumed.

The energy consumption for heating the digester(s) has been left out of Table 6 because the heat produced out of biogas is more than enough to heat the digester(s). At a penetration of 0% the surplus is 774 kWh/year. The surplus increases to 1,005 kWh/year for a penetration of 10%. However, it will not be easy to apply this surplus usefully.
From Table 6 it can be concluded that due to the use of food waste disposers the self supply for electricity will increase from 72% to 82% at a penetration of 10%. Due to the increase of the self supply the costs for the electricity consumption will decrease. However, at the same time the costs for central sludge treatment will increase and the profits in the electricity supply will be cancelled out. In total the increase in costs per p.e. caused by the use of food waste disposer will be minimal and is within the accuracy of the calculations (± 10%).

To assess whether a change in the bases for the calculations has an effect on the outcome or not a sensitivity analysis is done for some important parameters. In this sensitivity analysis the effect of a change in the value of these parameters on the additional costs per p.e. (electricity and central sludge treatment) is investigated. The investigated parameters have on one hand of a process technological nature and on the other hand an economical nature:

- parameters with a process technological nature:
    - *Yield (Y)*. The organic matter in the primary effluent is utilized by the micro-organisms in the biological treatment processes for:
        1. the production of new cell material (sludge growth).
        2. the energy supply for the biological processes. During this CO_2 and water is produced out of organic matter and oxygen (aeration) is consumed.

      The yield gives the amount (in kg) of organic material (sludge) produced per 1 kg of removed COD. A change is the yield has an effect on two values: sludge growth and oxygen consumption. An increase of the yield does lead to an increase of the sludge growth rate and therefore to an increased production of surplus sludge. A higher sludge production leads to a higher biogas production. In the same time the oxygen consumption decreases because less COD is used for the energy supply of the biological processes. So, an increase of the yield leads to lower costs for electricity and to higher costs for central sludge treatment. With a decrease of the yield the effect is opposite.

    - *Specific biogas production*. The specific biogas production gives the number of m³ biogas produced out of 1 kg of digested organic material. A decrease of the specific biogas production leads to smaller amount of biogas and therefore to higher costs for electricity.
- parameters with an economical nature:
    - *Price of electricity in € per kWh.*
    - *Unit costs of central sludge treatment in € per ton dry solids.*

The results of the sensitivity analysis are given in Table 7.

Table 7 Sensitivity analysis.

		effect on:		
parameter	variation	costs for electricity	costs for central sludge treatment	additional costs per p.e.
Yield	+/- 10 %	-/+ 51 %	+/- 6.5 %	+/- 4 %
Spec. biogas production	- 10 %	+ 26 %	--	+ 1.2 %
Price of electricity	+/- 10 %	+/- 10 %	--	+/- 0.5 %
Unit costs of central sludge treatment	+/- 10 %	--	+/- 10 %	+/- 9.5 %

--: no effect

It can be concluded from Table 7 that especially the costs for central sludge treatment has an effect on the additional costs per p.e. caused by the use of food waste disposers. The level of penetration does not have an influence on the percentage of increase or decrease of the additional costs per p.e.. Obviously, it has an influence on the absolute increase or decrease of the additional costs per p.e.. At the same time it can be mentioned that the effect of changes in the price of electricity and the specific biogas production is limited.

CONCLUSION

With respect to the use of food waste disposers the following can be concluded:
- The production of biogas will increase and therefore also the self supply in electricity will increase. This can be considered as an advantage.
- The advantage of the increase in self supply in electricity partly compensates for the increase in the costs for central sludge treatment.
- The increase in costs per p.e. will be minimal or negligible.

The calculations in this paper do confirm the conclusions of former studies with respect to the increase of the load to the wwtp caused by the use of food waste disposers.

Food waste disposer versus "biobak" as system for collecting food waste

Food waste disposers are supposed to be a competitor for the current system for collecting Kitchen, Food and Garden waste (KFG). With respect to the garden waste this proposition is wrong; a food waste disposer cannot process garden waste. With respect to kitchen and food waste a food waste disposer has to be considered more as an addition than as a competitor for the current system for the collection of kitchen, food and garden waste.

CONSIDERATIONS WITH RESPECT TO THE CURRENT COLLECTION SYSTEM FOR KFG-WASTE

The current system of KFG-collection exists in the Netherlands approximately 10 years. A good moment for an evaluation. The collected amount of KFG-waste is already constant for years. Approximately 1,500 kilotons per year is collected and composted [de Jonge *et al.* 2003]. The collected amount of KFG-waste is approximately 50% of the amount produced in households [VROM, 2001, 2002b].

Not every fraction of the KFG-waste is suitable for composting. Composting of only garden waste gives a cleaner and better compost than the compost produced out of all fraction of KFG-waste together. In areas with no (big) gardens, areas with a high density of high-rise buildings and in city centres, the KFG-waste contains hardly any garden waste. Furthermore the quality of the collected KFG-waste is so low that composting is nearly impossible. As a consequence the KFG-waste is processed together with the non-KFG-waste. Due to the small amounts and low quality of the KFG-waste collected in high-rise building areas and city centres the costs for separate collection are disproportionately high [AOO 2002, de Jonge *et al.* 2003].

The space for storing KF(G)-waste without any nuisance from odour, flies etc. is usually lacking in high-rise buildings and houses in city centres. Therefore the motivation of residents in these areas to separate their waste is under pressure.

In the Environmental Impact Assessment report [AOO 2002] of the National Waste Management plan 2002-2012 [VROM 2002b] separate collecting of KFG-waste followed by digesting and utilization of the produced biogas in power plants is judged more positive than separate collection flowed by composting.

Some municipalities are searching for alternatives for the separate collection of KFG-waste in which only the collection of garden waste is continued. Examples are the municipalities of Hoogezand-Sappemeer and Horst [VROM 2002a, de Jonge *et al.* 2003].

FOOD WASTE DISPOSER AS AN ADDITION AND IMPROVEMENT

The above-mentioned considerations show the usefulness of a search for improvements and additions to the current system for the collection of KFG-waste. Costs considerations as well as environmental consideration can be mentioned as the motivation for this search. The collection in areas with high-rise buildings and in city centres is disproportionately expensive. Furthermore the trucks used for collection cause quite often nuisance from odour, noise and blocking of streets.

So, the search has to be aimed on a system that is easy to use by residents and that gives no nuisance during collection and transport. In this sense the food waste disposer could be considered as an improvement of and a useful addition to the current system for the collection of KFG-waste. With the food waste disposer a resident can easily get rid if his or her kitchen and food (GF-) waste. A storage is not longer needed. The transport of GF-waste through the sewer system to the wwtp is to a large extent by gravity without any energy input. The calculations in this paper has already shown that the effects of the use of food waste disposers on the biological wastewater treatment processes and sludge treatment are limited.

Garden waste still has to be collected. For this collection of garden waste one can choose for an adapted frequency of collection in those periods in which a lot of garden waste is produced (spring and autumn). For large quantities collecting on request can be organized. This is already common practice in some municipalities.

CONCLUSION
It can be concluded that the use of the food waste disposer might lead to an improvement of the current system for the collection of KFG-waste. In areas in which for environmental and/or economical reasons the separate collection is abandoned the food waste disposer might replace the current system on a voluntarily basis. In areas in which separate collection is feasible the choice for the use of food waste disposers can be given to the residents. The use of the food waste disposer improves the living comfort and has no adverse effects to the environment.
It is conceivable that the effect of food waste disposers on the environment is smaller than the effect of the current system for KFG-collection. However, this is difficult to quantify. The collection of garden waste has always to be continued. Composting of garden waste only gives a better compost than the integral composting of Kitchen, Food and Garden waste.

References

AOO (2002), *Milieueffectrapport Landelijk Afvalbeheerplan 2002-2012*, Afval Overleg Orgaan, Utrecht, januari 2002.

CBS (2004), *CBS-Statline*, http://statline.cbs.nl.

CECED (2003), *Food waste disposers*, CECED – European Committee of Manufacturers of Domestic Appliances, Spring 2003.

Geel, van P.L.B.A. - Staatssecretaris van VROM (2003), *Speech Conferentie toekomstig afvalbeleid*, Den Haag, september 2003.

Jonge, J.A. de, Beeck, J.C.W. van (2003), *Tien jaar gescheiden GFT-inzameling: tijd voor maatwerk*, Afval!, nummer 6, augustus 2003.

Karlberg, T., Norin, E. (1999) *Food waste disposers – effects on wastewater treatment plants. A study from the town of Surahammar*, VA-VORSK Report 1999-9, Sweden, 1999.

Koning, J. de (2003), *Afval het riool in!*, Afvalwaterwetenschap, jaargang 2, nr. 2, april 2003.

Metcalf & Eddy 2003, *Wastewater Engineering – Treatment and Reuse*, fourth edition, McGraw-Hill Higher Education, 2003.

Nieuwenhuijzen, A.F. van (2002), *Scenario studies into advanced particle removal in the physical-chemical pre-treatment of wastewater*, PhD-thesis, Delft University Press, Delft, 2002.

Nilsson, P., Hallin, P.O., Johansson, J., Karlén, L., Lilja, G., Petersson, B.Å, Pettersson, J., (1990), *Waste management at the source utilizing food* waste *disposers in the home - a case study in the town of Staffanstorp - final report,* University of Lund, september 1990.

Sdu (2002), *Besluit lozingsvoorschriften niet-inrichtingen milieu beheer*, versie geldig vanaf 08-05-2002.

STOWA (1998), *Fysisch/chemische voorzuivering van afvalwater*, STOWA-rapport 98-19, Utrecht, september 1998.

VROM (1998), *Brief (DWL98025100) van de Minister van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer aan de heer J.S. Ferrara, In-Sink-Erator Continental Europe*, april 1998.

VROM (2001), *Afval in Nederland – Groente-, Fruit- en Tuinafval (GFT-afval)*, Informatieblad Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, juni 2001.

VROM (2002a), *Brief (SAS/2002098250) van de Staatssecretaris van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer aan de Tweede Kamer*, Den Haag november 2002.

VROM (2002b), *Landelijk Afvalbeheerplan 2002-2012*, Ministerie van Volkshuisvesting, Ruimtelijke Ordening en Milieubeheer, 2002.