INFLUENCES OF FOOD WASTE DISPOSERS ON SEWERAGE SYSTEM, WASTE WATER TREATMENT AND SLUDGE DIGESTION

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SUMMARY: As a consequence of changes within waste water treatment processes sludge compositions have changed and sludge ages have increased. Therefore many municipal digesters (in Germany) offer free capacities. Moreover many municipal waste water treatment plants (WWTP) lack of Carbon source for the biological nutrient removal. Due to high organic loads and high water contents food waste from households is generally more suitable for anaerobic than for aerobic treatment. Together with the often unsatisfying existing situation of bio-waste collection (and treatment) these facts were the motivation for a research project focussing on the treatment of food waste from households on municipal WWTP. Main interest was laid on the application of food waste disposers (FWD) and its influence on sewerage system, waste water and sludge treatment. This paper summarises the results of a literature study and lab scale batch-tests. Border conditions for a useful FWD-application are determined as well as advantages and disadvantages are named and discussed.

1. INTRODUCTION

Since the 1960ies many things have changed in Germany regarding waste and waste water treatment. Nutrient removal has been prescribed by limit values. Basic condition for the appropriate biological Nitrogen and Phosphorous removal is a sufficient supply with easily degradable substrate. Connected with the introduction of these treatment processes higher sludge ages occurred, which partially led to free capacities within the systems of anaerobic sludge treatment. The application of instrumentation (measuring, controlling, regulating, MCR) enabled an optimisation of the treatment processes. Likewise this meant partial free capacities in the aeration tanks. Beyond that biogas is nowadays seen as a regenerative energy source. The collection and treatment of wastes is practised over whole Germany and the problems of the waste management economy like low rates of source separation, high costs, increasing "garbage mountains", air pollution (odour emissions) and leachate treatment are well-known.
Concerning energy supply and usage expressions like “Green house effect” and “Global warming” led to an increasing pressure on politicians which - regarding Germany – among others resulted in a financial support for energy produced from regenerative energy resources. A new law guarantees that 0,09 and 0,10 €/kWh will be paid for electrical energy gained from

biodegradable waste. Biogas from municipal digesters and landfills can be sold for prices from 0,07 to 0,08 €/kWh.

Regarding the above named preconditions and referring to the existing process chain of drain system sewerage system and waste water treatment plant including sludge digestion, the application of food waste disposers generally offers an economically and ecologically interesting alternative for the source separated collection and treatment of food waste from households.

Using food waste disposers (FWD) for grinding, the pre-treated food waste will be transported to the local WWTP via the sewerage system. Most of the particulate food waste-fraction will settle in the primary clarifier while screens and grit chambers will only be affected to a small extend. Thus the majority of the food waste will reach the digester and cause an increase in gas production. The soluble food waste-fraction will lead to higher BOD respectively COD loads within the biological treatment steps which on the one hand can cause a higher oxygen demand but on the other hand can serve as a cheap and continuously available Carbon source.

2. CURRENT BIO-WASTE SITUATION IN GERMANY

The organic, biodegradable fraction of household waste (bio-waste) is about 40 % in weight, concerning the whole household waste. It mostly consists of garden waste (cutted gras and bushes, leaves), food waste, paper, cardboard and other materials (Fuhrmann et al. 1997). Basing on waste collection results from Gallenkemper et al. (1999) as well as Gallenkemper and Doedens (1994) the amount of organic household waste in Germany ranges between 55 and 180 kg moisty substance per capita and year, depending on the structure of the collection area (inner city district, suburban area, small town, village, country side). The amount and the constitution of biodegradable waste varies over the year. Meanwhile wintertime the food waste fraction dominates it consists mostly of cutted gras during summertime. Autumn is dominated by leaves and cutted branches and bushes, spring is a mixture with many cutted branches.

In Germany the source separated collection and treatment of bio-waste is state of technology. The collection in special bins/containers ("Biotonne") followed by transportation via truck and connected with composting is the prevailing treatment. Within inner-city districts the collection of biodegradable waste, which in such areas mostly consists of food waste can be considered as being problematic. Some problems of the current system are:

- odour emissions during all process steps (collection, transport, treatment)
- increasing fraction of non-biodegradable waste in bio-bins,
- high water content of bio-waste => high weight => high costs for transport,
- No possibilities for home-composting
- lack of space for bio-waste bins,
- unsatisfying collection ration for bio-waste,
- uncontrolled biochemical processes in landfills => leachate => leachate treatment,
- unknown amount of food waste (bio-waste) flushed in toilets.

Most of the mentioned problems are caused by food waste, which generally can be characterised by high water contents and high organic loads. At least a reduction of food waste within the existing collection-transport-treatment-system for household waste would help to minimise these problems. The application of food waste disposers in general offers the possibility of a controlled, source separated food waste (pre-)treatment.

3. FOOD WASTE

3.1 Amount of food waste

Food waste or kitchen waste occurs during the whole year. Its amount only depends on peoples particular life and nutrition habits. Compared to the whole organic fraction of household waste the particular fraction of food waste is characterised by the following items: highest moisture content, best biodegradability, highest density, lowest heating value (due to highest water content). Basing on a literature study the national (German) and international amount of food waste (moisty) can be estimated to about 55 kg/(capita*a) (45 – 65 kg/(capita*a)) for Western Europe. This means a daily amount between 123 and 178 g/(capita*d). Table 1 gives a more detailed insight into the single values.

Table 1 - Amount of food waste in different Western countries

Author	**Food waste**			
	Amount (moisty)		**SS**	
	kg/(capita·a)	**g/(capita·d)**	**%**	**g/(capita·d)**
Nilsson et al. (1990), Sweden	88	235	-	-
Lagerkvist and Karlsson (1983), Sweden	90	245	27 (25 - 30)	67 (61 - 74)
De Koning and van der Graaf (1996), Netherlands	44	120	40	48
Hoffmann (1994), Germany	100	274	30	82
Karlberg and Norin (1999), Sweden	100	274	-	-
Diggelman and Ham (1998), USA	48	132	30	40
Strutz (1998), USA	48	132	-	-
Krogmann (1989), Germany	52	142	-	-
Schäfer (1995), Germany	22,5 (20 – 25)	82 (73 – 91)	-	-
Scheffold (1995), Germany	50	137	-	-
Doedens and Ketelsen (1992), Germany	65 50 - 80	179 137 – 220	-	-

3.2 Structure and constitution of food waste

Food waste mainly consist of less- or non-fibrous, mostly vegetable remainders which cooked or non-cooked are characterised by a high water content (70 % and more). Main constituents of food waste from households are

- vegetable waste,
- coffee ground,
- tea filters,
- remainder of prepared/cooked food.

The balanced C/N-ratio and the moisty consistency make that food waste is easily biodegradable whereby it is better suitable for anaerobic than for aerobic treatment.

Table 2 - Chemical constitution of different food waste fractions in percentage of suspended solids (SS) (De Koning and van der Graaf (1996))

	Vegetable and food waste	Remainders of oranges and lemons	Meat remainders	Fat/grease
C	49,1	49,0	59,6	73,1
H	6,6	5,7	9,5	11,6
O	37,6	41,7	24,6	14,8
N	1,7	1,1	1,0	0,4
S	0,2	0,1	0,2	0,1
Summation of VSS (= % of SS)	**95,2**	**97,6**	**94,9**	**100**
FSS	4,8	3,4	5,1	0,0
Summation of SS	100	100	100	100
C/N	**29,2**	**44,1**	**58,4**	**170,0**

4. FOOD WASTE DISPOSERS

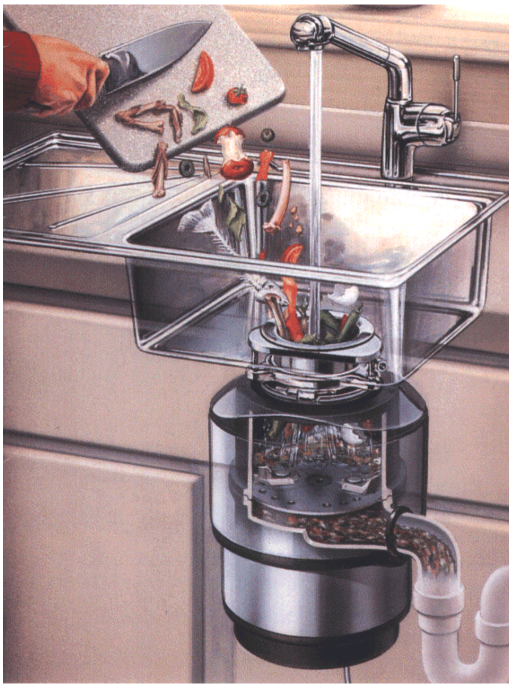
4.1 History of food waste disposers

The food waste disposer (FWD) was invented in 1927 by the American architect John Hammes. Nowadays there are approx. 8 manufacturers of food waste disposers world-wide. FWD have been installed in the United States (US) since over 60 years and can be found in 45 % of all US-households. In some states and in over 100 cities their use is even mandated. More than 80 % of all new homes in the US have a FWD. The attitude towards FWD has always been negative in Central and Western Europe over the past decades. The main reasons for that have been the additional amount of fresh water and electricity for FWD-application as well as the additional loads for the WWTP which then often were overloaded. Nowadays the most common argument against FWD is that the device works against the idea of source separated waste collection.

However due to positive research results in the past and referring to a holistic point of view FWD gain more and more interest in Europe (e.g. UK, Sweden, Norway, Italy, the Netherlands). The biggest penetration concerning Western Europe can be found in the UK where about 5 % of all households (more than 1 Mio.) already have a disposer. For the rest of the western European countries the penetration of FWD can be estimated to 1 %. Concerning Germany no explicit prohibition of FWD exists on the federal level. However leading/mixing waste into waste water is prohibited and thus indirectly the application of FWD. Regarding the municipal level, the German waste water association (Abwassertechnische Vereinigung, ATV-DVWK) recommends all communities not to allow FWD within their waste water directives.

4.2 Function of food waste disposers

The FWD is installed under the kitchen sink whereby the outlet is attached to the siphon of the sink. Frequently even the outlet of a dishwasher can be connected to the FWD so that even larger particles from this stream will be cut up before entering the drains. The device is equipped with a waterproof electrical or pneumatics switch. The FWD can rather be described as a mill, than a cutter as the organic, moisty wastes are ground on the rough external wall of the grinding chamber. This works with the help of a rotary disk, on which two hammer-cheeks mobile in horizontal direction are fastened. The disk is provided with 5 mm large holes, by those the suspension of water and ground kitchen waste finally is led into the drain- and sewerage system.



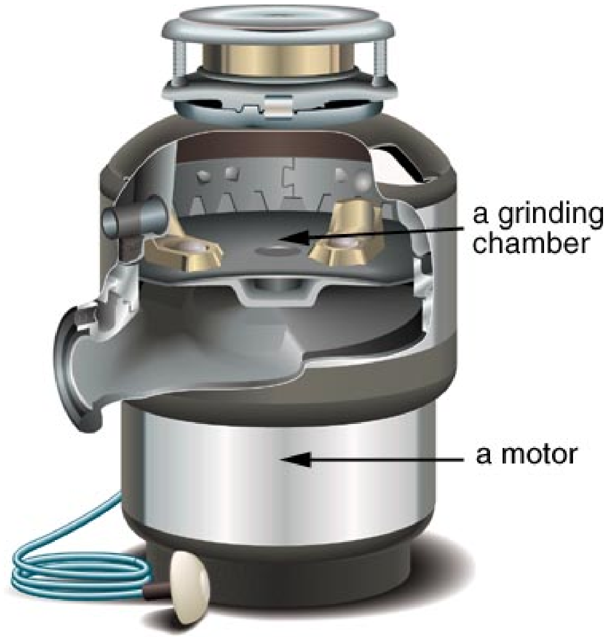


Figure 1. Food waste disposer a) in operation b) cross section (ISE, 1999)

Against frequent heard prejudices FWD do not contain rotating knifes. Regarding a FWD the danger of injury is small, compared to other kitchen appliances like e.g. electrical hand mixers or a hot stove. The operation of a FWD can be divided into the following steps: 1. let cold water run, 2. switch on FWD, 3. add food waste and meal remainders by portion, 4. let water run another 20 to 30 seconds after the disposal is finished.

With the aid of a FWD all organic kitchen wastes such as vegetable and fruit peelings, coffee grounds, remainder of cooked dishes (vegetables, meat, fish), small bones (chicken), etc. can be ground. Non-food wastes like metal, glass, porcelain, leather, cotton, rubber, plastics and in addition hard organic material such as wood, fruit stones and large bones cannot be ground, since the mechanism of the device is not intended for such materials. The attempt to grind such materials will causes a resistance, which, if it becomes excessive, will cause a switch off of the engine (resistor). Additionally an intense noise is connected with the attempt of grinding hard materials which has an educational effect on the user.

5. RESULTS

Main focus was laid on the determination of border conditions for an economical and ecological application of FWD. Moreover informations about the numerable influences of ground kitchen waste on WWTP and sludge digestion were collected. At last the main advantages and disadvantages of FWD-application are listed.

5.1 Border conditions for a useful FWD-application

The projects motivation was to investigate about the influences of a FWD-application on the existing German system of waste, waste water and sludge treatment. As most of the Central- and Northern-European countries have about the same systems and standard of waste, waste water and sludge treatment, the border conditions mentioned in the following may to a large extend be transferred to these countries.

An introduction of FWD into existing waste (water) systems ought to fulfill some essential preconditions. First and most important of all is that there is no lack of drinking water in the area (city) where FWD will be used. Among others the application of FWD should be restricted to city districts with a separated sewerage system. The sewerage system ought to be in a good condition which means no fractures, no leakage, no sedimentations. The minimal gradient should not be below 2 ‰. Furthermore the concerned WWTP is to contain a primary clarifier and a sludge digestion and must offer free capacities regarding both waste water and sludge treatment. FWD should not be used in houses, connected to a dead-end sewerage as this includes a higher risk of sedimentation.

5.2 Additional loads due to FWD-application

Table 3 is a summary of all information gained from literature studies as well as from own batch-tests. The basic values of table 3 refer to the composition of German domestic waste water but will probably fit most of the Western European countries.

Table 3 - Main influences of FWD-application on waste water and sludge treatment (partially summarised, calculated and/or evaluated, basing on literature studies and own batch-test)

	Domestic waste water loads*	**Additional loads due to FWD-application**	
	g/(capita*d)	**g/(capita*d)**	**%**
Flow	128 L/(capita*d)	4,5 L/(capita*d)	3,5
Screenings	0,016	0,0008 – 0,0016	5 - 10
Grit	0,027	0,0014	5
$COD_{tot.}$	120	18 – 36	15 – 30
$BOD_{tot.}$	60	6 – 15	10 – 25
TKN	11	1,5	5 – 10
P_{tot}.	1,8	0,13 – 0,25	7 – 14
SS	70	28 – 40	40 – 60
C/N	2/1 – 5/1	25/1	+++
Primary sludge	45 - 54	20 - 40	50 - 70
Surplus sludge	10 – 35	5 – 20	10 – 40
Raw sludge	ca. 80	ca. 50	ca. 62
Digested sludge	48 - 60 (DS)	15 –18 (DS)	30 – 50
Biogas	16 - 25 L/(E*d)	16 – 25 L/(E*d)	90 - 100

* for Germany (after the German waste water associations working paper A 131 (ATV-DVWK, 2000))

5.3 Influence of FWD-Penetration

In order to estimate the real (theoretically possible) impact of FWD on the existing infrastructure the FWD-penetration (percentage of households that is equipped with a FWD) is of great importance. Going out from the penetration values mentioned in chapter 4.1, the annual penetration ratio can be estimated to a maximum of about 1 %. Presupposed a general permission of FWD this would mean very low actual loads for WWTP. Penetration ratios and consequently additional loads would even be lower if the permission was restricted to certain city districts. The percentage values of table 3 correspond to the actual additional loadings for a WWTP under the conditions of a 100 % FWD-penetration.

Full scale studies in Sweden have shown that penetrations between 5 and 10 % did not have any noticeably influence on the WWTP-operation except for the estimated production of biogas (Nilsson et al., 1990).

Besides general and limited permission there two more political instruments which allow to influence the FWD-penetration. The first possibility which could be combined with a limited permission would be "politically wanted". This for example could be controlled by lowering the waste tax for those households, installing a disposer. The most offensive instrument is to mandate FWD as practised in about 80 cities in the US.

5.4 Advantages and disadvantages of FWD-application

The advantages of FWD-application are:

- Improvement of hygienic conditions regarding households and waste collection,
- Reduction of uncontrolled bio-chemical processes within landfills,
- utilisation of existing infrastructure,
- reduction of uncontrolled addition of ungrounded food waste into waste water,
- additional Carbon source for denitrification and biological Phosphorous removal,
- utilisation of energetic potential of organic wastes,
- higher rates of VSS-degradation.

Presupposed an observance of the border conditions named above the probability of problems like

- sedimentation,
- odour (H_2S) emissions,
- increase of rodents populations,
- additional loads for the aquatic system due to discharge events,
- soil and groundwater pollution due to leaky drains etc.

can be classified as small and therefore are not listed in the following.

The main disadvantages of FWD-application are:

- Higher amounts of digested sludge,
- additional sludge liquor,
- (high) initial costs for the user (not for the community),
- additional fresh water and energy requirement (FWD-application, aeration).

6. CONCLUSIONS

The current waste, waste water and energy situation makes it useful, to use free capacities in municipal waste water treatment plants (WWTP) and municipal digesters for the treatment of easily biodegradable food wastes from households. Presupposed the observance of border conditions the application of food waste disposers (FWD) together with an existing infrastructure of sewerage system and WWTP (incl. digestion) offers an economical and ecological interesting solution for an alternative treatment of food waste, especially in cities.

Research studies from different western countries have shown that the additional loads for waste water treatment and sludge digestion can be estimated very well and due to slow penetration processes will not lead to an uncontrolled overloading of WWTP "over night". On the contrary, going out from penetration ratios of less than 1% of all households per year (tolerating of FWD), the additional loads can be implemented in the operation, extension and development of waste water and sludge treatment facilities. Despite of all positive aspects one always has to keep in mind, that the main purpose of a WWTP is to clean waste water and to treat the different kinds of sludge which occur during the single process steps of water treatment. This purpose must not be influenced in a negative way by the application of FWD at any time. Therefore a determination of free capacities as well as an evaluation of the sewerage and the observance of border conditions is essential.

Further fields of research could be the possibilities of reducing the water consumption for FWD or the replacement of drinking water by rainwater. Moreover there are still several questions concerning FWD's impact on sewerage systems.

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REFERENCES

ATV-DVWK (2000) Bemessung von einstufigen Belebungsanlagen. Abwassertechnische Vereinigung (ATV-DVWK). Arbeitsblatt ATV-DVWK-A 131, p. 15, 2000.

Austermann-Haun, U.; Rosenwinkel, K.-H.; Wendler, D. (2000) Verwertung organischer Substrate aus Gewerbe- und Industriebetrieben in kommunalen Faulbehältern - Ergebnisse einer bundesweiten Umfrage. In: *Anaerobe biologische Abfallbehandlung. Beiträge zur Abfallwirtschaft, Technische Universität Dresden.* Band 12, pp. 1-11, 2000.

de Koning, J., van der Graaf, J. H. J. M. (1996). Kitchen food waste disposers – effects on sewer system and waste water treatment, study by request of In-Sink-Erator. Delft University of Technology, Faculty of Civil Engineering, Department of Water Management, Environmental & Sanitary Engineering, 1996.

Diggelman, C., Ham, R. K. (1998) Life-cycle-comparison of five engineered systems for managing food waste, executive summary to the final report to the National Association of Plumbing-Heating-Cooling Contractors, University of Madison, Wisconsin-Madison, Department of Civil and Environmental Engineering, 1998.

Doedens, H., Ketelsen, K. (1992) Konzepte zur Entlastung des Hausmülls von organischen Abfällen. *MÜLL und ABFALL*, Heft 7/92, 1992.

Fuhrmann, K., Schilling, B., Schmidt, W., Valentin, L. (1997) Stand der Kompostierung von Grün- und Bioabfall in NRW: Behandlungsverfahren, Kosten, Belastung durch Keime, 30. Essener Tagung für Wasser- und Abfallwirtschaft vom 19.3.1997-21.3.1997 in Aachen, GWA Nr. 158, 1997.

Gallenkemper, B., Doedens, H. (1994) Getrennte Sammlung von Wertstoffen des Hausmülls. In: *Abfallwirtschaft in Forschung und Praxis.* Band 65, 2. Auflage, Erich Schmidt Verlag Berlin, 1994.

Gallenkemper, B. et al. (1999) Bioabfallsammlung und Kompostverwertung in Nordrhein-Westfalen. Ministerium für Umwelt, Raumordnung und Landwirtschaft NRW, 1999.

Hoffmann, E. (1994) Niederthermische Verfahren – Gemeinsame Vergärung von Biomüll und Klärschlamm. In: Klärschlamm - Ressource oder kostenintensiver Abfall, Tagungsband der 8. Karlsruher Flockungstage. *Schriftenreihe des ISWW.* pp.105–121, 1994.

ISE (1999) Homepage of the company In-Sink-Erator. http://www.insinkerator.com/International/51/51.htm. 1999.

Karlberg, T., Norin, E. (1999) Köksavfallskvarnar – effekter på avloppsreningsverk – en studie från Surahammar. *VA-Forsk Rapport.* Nr. 9, VAV AB, Sweden, 1999.

KTBL (2000). Kofermentation. Kuratorium für Technik und Bauwesen in der Landwirtschaft e.V., Darmstadt. *KTBL-Schriften-Vertrieb im Landwirtschaftsverlag GmbH , Münster-Hiltrup.* Arbeitspapier 249, pp. 20-21, 1998.

Krogmann, U. (1989) Menge und Zusammensetzung der erfaßten Bioabfälle. In: *Stoffliche Abfallverwertung - getrennte Sammlung – Vermarktung – Bioabfall*. Berichte der Fachhochschule Münster, Eigenverlag, pp. 167-181, 1989.

Lagerkvist, A., Karlsson, B. (1983) Integrerat transportsystem för källsorterat hushållsavfall. Lulea Tekniska Högskola, Avdelningen för Restproduktteknik, Forskingsrapport Nr. 1, 1983.

Nilsson, P., Hallin, P.-O., Johansson, J., Karlén, L., Lilja, G., Petersson, B. A., Pettersson, J. (1990) Källsortering med Avfallskvarnar i hushållen – En fallstudie i Staffanstorp (Sweden). Finial report. *Bulletin serie VA.* Nr. 56, University of Lund, Department of Water and Environmental Engineering, 1990.

Schäfer, B. (1995) Feldversuch Biotonne. In: Abfall Wirtschaft – Neues aus Forschung und Technik - Biologische Abfallbehandlung II – Kompostierung, Anaerobtechnik, MBA, Klärschlammverwertung. M.I.C. Beaza Verlag, p. 303, 1995.

Scheffold, K. (1995) Bioabfall eine relevante Gebührengröße. In: *Müll und Abfall.* Nr. 4, pp. 217-223, 1995.

Strutz, B. (1999) Life Cycle Comparison of five engineered systems for managing food waste. Brief summary and interpretation. University of Wisconsin, 1998.