Analysis of sludge management parameters resulting from the use of domestic garbage disposers

N.I. Galil and L. Yaakov
Department of Civil Engineering, Technion – Israel Institute of Technology, Haifa 32000, Israel
(E-mail: galilno@tx.technion.ac.il)

Abstract The use of domestic garbage disposers may reduce the amounts and improve the solid waste composition, by lowering putrid matter and water content and by raising the caloric potential. However, additional loading on the sewerage systems might require increased investments and operation costs of the wastewater treatment facilities. This project analyses additional amounts of solids, biosolids and process requirements connected with wastewater treatment facilities resulting from the domestic use of garbage disposers, as well as the additional production of biogas. It was found that the use of the domestic garbage disposers in 60% of the households in a given urban area, is expected to reduce the weight, volume and water content of the solid waste by 7.0%, 3.3% and 4.4% for garbage characterized by low organic content, and by 18.7%, 11.0% and 13.3% for high organic content, respectively. The additional amounts of sludge are expected to be the lowest in case of biological treatment only, 24 to 38 g/capita/day, and the highest in case of primary chemical sedimentation followed by biotreatment, 67 to 100 g/capita/day. In these conditions the energy potential from biogas obtained in anaerobic digestion of sludge from wastewater collected from the same area, will increase by 50% to 70%, depending on the wastewater treatment sequence. The investment in wastewater treatment is estimated to increase by 23% to 27% and the annual costs for operation and maintenance are expected to increase by 26% to 30%.

Keywords Additional wastewater sludge; domestic garbage disposer; improved solid waste characteristics

Introduction
The amounts of solid waste created in residential areas constantly rise as a result of the natural growth of the population and the standard of living increase. The conventional modes of treatment include recycling of different ingredients (metals, glass, etc.), ground burial, incineration and compostation. The stages of collection, transportation, treatment and removal of solid waste require constantly growing resources of space, energy, manpower and financing. In addition, the presence of waste in the area, even after the proper treatment is given, is hazardous to the quality of underground water, and may create bio-gas that spreads uncontrollably. One of the problems typical to domestic waste arises from its solid state, which makes it difficult to remove continuously (unlike liquid waste) and requires storage and removal according to apartment, house, neighborhood or urban portions. The physical nature of the domestic waste actually exposes the residents – and the entire urban environment – to various ingredients present in the waste, to smell, as well as to side effects such as undesirable and disease-spreading animals.

Another problem typical to countries where the habits of cooking and eating use plenty of vegetables, fruit and home cooking, is expressed by a relatively high content of organic-putrid ingredients and high content of water in the domestic waste. It especially worsens the environmental problems during the stages of collection, temporary storage, neighborhood removal, transportation and treatment – with hardly any dependence on the treatment and removal methods. When putrid ingredients and high wetness are present, the possibilities of categorization and recycling encounter serious difficulties.

The use of domestic garbage disposers is meant to enable the separation of all
food-waste ingredients out of the entire domestic garbage, its grinding by mechanic means in addition to tap water, and their flowing as liquid mixture to the sewage system. This way the domestic waste basket is left only with dry and very solid ingredients, so the continuation of their treatment does not form any particular problem environmental wise. On the other hand, the organic-putrid part of the domestic waste – which forms the problematic environmental factor – might find its way, in current flow, along with the rest of apartment and urban sewage, in the direction of the sewage treatment plants.

The transfer of organic waste, originating in domestic garbage, to the sewage system raises several significant questions regarding the amounts of additional water required for the transfer of particles; the hydraulic transfer capacity of the ground solids; the change of raw sewage nature in relation to the addition of suspended solids and organic substances; and the influence of additional loads on the sewage treatment plants. Shpiner (1997) referred to these questions and reported that the estimated addition of water is up to approximately 3% of the average specific consumption. In addition, the nature of the ground solids enables their transfer in gravitational sewers as long as they are planned according to conventional planning instructions.

The extent of garbage disposers’ influence is, at any rate, a function of their market penetration factor. This factor expresses the percent of family homes where garbage disposers are installed out of the entire number of families at a given urban environment. Wicke (1987) and Koning and Van der Graaf (1996) mention that after sixty years of marketing garbage disposers in the USA, their distribution reaches about 50%. From research conducted in Israel, Shpiner (1997) estimated that the maximal distribution of garbage disposers in residential areas will not exceed 60% in the near future.

The purposes of this paper were to evaluate the extent of decrease in solid waste amounts on the one hand, and on the other hand to examine the extent of increase in solid and organic pollutants in sewage, and the increase of sludge amounts expected to be created at the waste treatment plants. In addition, the paper examines the needs for enlargement of waste treatment plants and the addition in investment costs, when such plants also absorb ground substance from domestic garbage disposers.

**Domestic solid waste production**

The composition of domestic waste usually changes from district to district and from country to country. It depends on many factors such as standard of living, eating and cooking habits, etc. Meaningful differences can be indicated in the content of organic-putrid substance, the low level of which is around 8.4% of weight and 3.11% of volume according to Tchobanogluous et al. (1993), whereas the high level reaches 38.1% of weight and 15.4% of volume according to Biotech (1995). Figure 1 shows details of the weight and volume composition of two kinds of waste typical of low organic substance level as well as of high organic substance level.

Grinding of the organic-putrid substance, its removal thereafter along with the rest of liquid waste through the domestic and public sewage systems, is expected to reduce the weight and volume of the remaining garbage to be removed as domestic solid waste. Since the organic-putrid substance, which can be removed by grinding, contains a relatively high content of water – about 70% – the use of domestic garbage disposers might also enable reduction of the average water content in the remaining solid waste. The calculations in this paper were performed under the assumption that the distribution of garbage disposers at a given residential area will not exceed 60% of family homes within the predictable period of time.

The weight of solid waste requiring removal in a residential area where the distribution of garbage disposers can reach 60% of family homes, might decrease at about 7% in case of...
low organic content and about 18.7% in case of high organic content waste – as described in Figure 2. Regarding the same garbage disposers’ distribution, reduction of the solid waste volume might decrease by 3.3% when the organic content is low, and by 11% in the case of high organic content – as described in Figure 3. It can be clearly observed that the higher the organic substance content in the domestic garbage, the higher the reduction in weight and volume of garbage to be removed in the framework of the district environment system. Such reduction might reach one-tenth of the volume and one-fifth of the entire weight, and therefore it is definitely meaningful.

In addition to the quantitative aspect, the qualitative aspect of waste remaining to be removed should be added. Reduction of the organic substance content turns this substance to a more stable one, makes it easy to be stored, removed and categorized, and reduces the leachate potential. Computational processing of the data also enabled us to estimate predictable changes in the wetness content of the garbage designated for removal. As can be observed in Figure 4, when a district garbage disposers’ distribution of 60% is concerned, the wetness content is expected to decrease by about 4.5% in case of low organic content.
and by about 13.3% in case of high organic content. The fact that the solid waste contains less water also increases its caloric capacity and improves the economic profitability considerations in case of removal by incineration while creating heat energy.

**Wastewater sludge production**

The ground organic substance is transferred, as aforesaid, through the apartment and public systems to the urban treatment institutes and here additional load is added beyond that which arrives with the liquid and sanitary waste. The first question to turn to is: What are the amounts of sludge expected to be created at the treatment plants? Three treatment process sequences have been taken into account, as the difference between them might be especially meaningful regarding the sludge issue. Aside from the main treatment processes of the incoming sewage flow, the sequences also include the treatment process of sludge, which is the byproduct of the main treatment processes. The treatment of sludge includes, for all cases: gravity thickening, stabilization by anaerobic digestion and dewatering by belt filtration.

The biological treatment only (BT) is based on activated sludge as an exclusive treatment process. The created sludge is entirely biological and contains mainly cells created from transformations undergone by the various organic substances, which are included in the sewage mixture and ground garbage solids.

Primary sedimentation followed by biological treatment (PS-BT) enables the process to receive two sludge flows: (a) sludge received by primary sedimentation, which mainly includes raw solids found in sewage and its sources, sanitary solids or ground garbage solids; (b) biological sludge received from the organic substance that has not been removed during the primary sedimentation process, and has undergone the activated sludge process when part of it is becoming biomass.
Primary chemically enhanced sedimentation and biological treatment (PCS-BT) is where the main flow is treated by chemical flocculation and sedimentation and then by an activated sludge process. In this research we assumed that the chemical flocculation is done by cationic polyelectrolyte at a dosage of 20 mg/l. This sequence is known to be extremely effective for the removal of suspended solids from the sewage and therefore it serves as a special protection to the following biological treatment. In this sequence two sludge flows are also received: (a) sludge from a primary chemical sedimentation – and here the highest amounts of sludge are expected to be received, due to the high effectiveness of the physico-chemical process; (b) biological sludge that is expected to be created here mainly from dissolved and colloidal organic substance which has not undergone sedimentation during the primary treatment stage.

All process calculations were based on specific sewage donation of 200 litre per capita per day (24 hours). The results described in Figures 5 and 6 are presented in specific values that express the amounts of sludge, which are expected to be obtained at the treatment plants – calculated in units of amounts per capita per day. In these Figures it can be observed that in a BT sequence the lowest amounts of raw sludge are expected to be received, 24 to 38 gram per capita per day as well as 0.10 to 0.14 litre per capita per day; whereas in a PCS-BT sequence the highest amounts of sludge are expected to be received, 67 to 100 gram per capita per day as well as 0.31 to 0.46 litre per capita per day.

The differences in raw sludge amounts arise from the fact that in flows that include primary sedimentation, a significant part of the solids in the sewage is removed from the system and creates raw sludge as early as the primary treatment stage – prior to the biological treatment. On the other hand, in a flow that includes only biological treatment, a major part of the organic solids undergo some level of dissolution, they are partly used as internal energy sources and undergo transformation to biomass. The contribution of garbage

\[ \text{MARKET PENETRATION FACTOR (%)} \]

\[ \text{SLUDGE WEIGHT} \]

\[ \text{MARKET PENETRATION FACTOR (%)} \]

\[ \text{SLUDGE VOLUME} \]

\[ \text{MARKET PENETRATION FACTOR (%)} \]

**Figure 5** Dry weight specific production of row sludge (in gram/cap*day) by different treatment sequences versus market penetration factor for domestic garbage disposers

**Figure 6** Specific volume of row sludge production (in litre/cap*day) by different treatment sequences versus market penetration factor for domestic garbage disposers
disposers is felt in a way that when their distribution reaches 60% of the total family homes, they are expected to increase the weight of raw sludge by about 60% in case of a BT treatment sequence, and about 92% in case of a PCS-BT.

**Additional wastewater treatment requirements**

Increase of the sludge amounts that are expected to be created at each of the examined treatment sequences, might influence the size and cost of sewage and sludge treatment units. The influence of domestic garbage disposers on the biological treatment unit will be highly dependent on the process sequence according to which the sewage treatment plant will be planned and operated. The biological process forms a dominant economic ingredient – both regarding investments and regarding annual operation and maintenance costs. This process will be far less influenced by garbage disposers in the PS-B sequence, and especially the PCS-BT sequence, while a large part of the organic load is separated during the primary treatment stage.

Analysis of the costs has been based on economic data received from planning companies and municipalities in Israel, which have recently completed the establishment of sewage treatment plants. The various costs were calculated on the basis of relevant parameters as to which functional connections exist between the size of facilities, depending on the level of incoming pollutants, and the quality level of the final product. In order to enable a quick comparison between all outcomes, concentrated in Table 1, the evaluation was made in relative terms, while the costs required for treatment according to the BT flow were used as one cost unit, both regarding investments and regarding costs for operation and maintenance (O&M).

As can be seen in Table 1, the installation and operation of domestic garbage disposers might raise the price of investments in establishing sewage treatment facilities by 23% to 27%, and the annual O&M expenses by 26% to about 30%. The decrease in annual operation expenses – while moving from BT to PS-BT and PCS-BT – arises from a meaningful reduction in energy required for the biological treatment, while in the two last sequences a large part of the non-dissolved substance is removed prior to the biological process. The biological treatment forms a dominant ingredient in everything regarding sewage treatment costs. Tabasaran (1984) reports that at a garbage disposers’ distribution of 30%, an addition of 15% will be required for the biological reactor. Jones *et al.* (1994) report that at a garbage disposers’ distribution of 100% only a 16.5% increase of the biological reactor will be required. Cost calculations performed within the framework of this paper showed that the sludge stabilization stage through anaerobic digestion also forms an important ingredient in determining the costs – such as the biological treatment, and even more.

**Gas production**

Stabilization of the sludge through anaerobic digestion dissolves the organic substance including the solid substances while producing biogas. About 65% of this mixture includes methane gas and therefore it is conventional to use the energetic potential of the biogas in

**Table 1** Relative treatment costs for wastewater and sludge treatment facilities

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<th>Treatment sequence</th>
<th>Market penetration factor</th>
<th>Additional costs</th>
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<td></td>
<td>0%</td>
<td>60%</td>
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<tr>
<td>BT</td>
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<tr>
<td>PS-BT</td>
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<td>1.537</td>
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<tr>
<td>PCS-BT</td>
<td>1.364</td>
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projects where the techno-economic tests indicate that such exploitation is justified (Metcalf and Eddy, 1991; Quasim, 1999).

A comparative test of the energetic potential lying in sludge originating in sewage treatment was done on a relative basis, under the assumption that the amount of energy that can be produced from a BT sequence treatment plant – without any garbage disposers – is one unit. Based on the results appearing in Table 2, it can be observed that regarding all treatment sequences examined, the potential for creating energy from the biogas increases along with the installation of garbage disposers. An addition of over 50%, in case of the BT, and over 70% in case of PS-BT, might form a positive economic factor while planning and operating sewage treatment plants.

Conclusions

This project analyses the reduction in the amounts of solid waste, as well as additional amounts of sludge and wastewater treatment requirements, resulting from the domestic use of garbage disposers.

It was found that due to the use of domestic garbage disposers in 60% of the households in a given area, the following reductions of weight, volume and water content could be expected in the remaining solid waste: 7.0%, 3.3% and 4.4% for garbage characterised by low organic content, and 18.7%, 11.0 and 13.3% for high organic content, respectively.

The additional amounts of sludge are expected to be the lowest in the case of the BT wastewater treatment sequence, 24 to 38 g/capita/day and the highest for the PCS-BT sequence, 67 to 100 g/capita/day.

The energy potential of biogas obtained from the anaerobic sludge stabilization process will increase due to the use of garbage disposers by 50% to 70%, depending on the wastewater treatment sequence.

The use of domestic garbage disposers in 60% of the households is expected to increase the investment in wastewater treatment by 23% to 27% and the operation and maintenance by 26% to 30%.

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