SUMMARY OF RESEARCH

Regarding the Environmental Efficacy of Food Waste Disposers

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Table of Contents

Notes: Number in bracket [ ] refers to the study listed in the Reference Section. This document prepared for the convenience of researchers, municipal officials and others interested in this topic; complete copies of studies referenced are available upon request.

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1.0 Introduction

Food waste disposers were invented in the 1940's, initially as a convenience for residential kitchens and cooks. As interest developed in the post-WWII era's housing boom, disposers were thoroughly evaluated by municipalities to assess their efficacy with respect to local solid waste and wastewater collection and treatment systems.

By the end of the 20th century, disposers had become a standard appliance, installed in the majority of U.S. homes and nearly ubiquitous in new residential construction. The market for commercial food waste disposers – in a variety of food-serving establishments, such as restaurants, cafeterias, and markets – also has grown. International acceptance of food waste disposers also is growing, in response to significant concerns about diverting organic food waste from landfills and increasing the beneficial use of food waste for land application. Everything municipalities normally do with food waste is environmentally noxious: stored inside buildings (even refrigerated); piled in bags on sidewalks; collected in trucks; and shipped to distant landfills, where it generates leachate and greenhouse gases. This process is not cheap, hygienic, environmentally friendly, nor sustainable.

In sum, food waste disposers form an impressive part of an integrated modern waste management system in many parts of the world.

This document reviews eighteen (18) of the most recent studies conducted by universities, research institutions, and government agencies across the United States and in many countries that examine the efficacy of food waste disposers. It compiles and organizes the findings regarding all facets of the sewage collection, treatment, and disposal process. In sum, these studies have largely determined that the impacts of disposers are manageable, and that disposers provide a significant set of environmental benefits that merits their acceptance and use.

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2.0 Food Waste Disposer Usage Overview

2.1 Advantages

- ✓ Reduced transportation emissions and costs [5][10][18].
- ✓ Healthier Municipal Solid Waste (MSW) working environment [5].
- ✓ Renewable energy value of Wastewater Treatment Plant (WWTP) anaerobic digestion biogas [2][5][6][9][10][16][18].
- ✓ Less expensive and complicated than source-sorting food wastes [5].
- ✓ Removing kitchen waste from compost produces cleaner and better compost [6].
- ✓ Reduced incidence of disease-causing vector attraction in comparison to food waste storage/collection [6][9][11][14].
- ✓ Reduced truck collection, which blocks narrow streets [6][10].
- ✓ Reduced transportation noise [6].
- ✓ Reduced space concerns for food waste storage [6].
- ✓ Improved hygienic environment in comparison to food waste storage/collection [9][10][11][16].
- ✓ Ease of use [9].
- ✓ Reduced MSW garbage collection amount and frequency [3][4][9][14].
- ✓ WWTPs are equipped to treat food waste due to high water and organic content [9].
- ✓ High carbon content of food waste improves the overall WWTP nitrogen and phosphorus nutrient removal process [10][14][16].
- ✓ Most convenient and likely-used source selector of organic kitchen wastes [14].
- ✓ Natural selector of organic wastes, whereas, composting relies on the education and goodwill of the participants [12].
- ✓ Promotes nutrient recycling from organic wastes when WWTP biosolids are land-applied [14].
- ✓ Environmentally friendly and sustainable food waste disposal option [14].
- ✓ As food waste is 70% water, the WWTP is a more natural system of waste processing than hauling the waste to a “solid waste” facility [14].
- ✓ As food waste is 70% water, the WWTP system reduces leachate diverted from landfill and compost systems, which reduces potential contamination to groundwater [14].

- ✓ As food waste is 70% water, the WWTP system anaerobic digestion process will produce a viable energy source, whereas, incineration offers a very small net energy gain that also produces contaminated emissions requiring additional treatment [14].
- ✓ As food waste is 70% water, the WWTP system is a more natural method of waste processing than composting, which, although enhanced by the additional moisture, does require stricter operational control to avoid anaerobic conditions, and results in the loss of most nutrients to the extent that the final product is of low value [14].
- ✓ Reduces the potential of uncontrolled biochemical processes in landfills (i.e., leachate treatment) [16].

2.2 Disadvantages

- ✓ Increased loadings of BOD and TSS to the WWTP [9].
- ✓ Increased water consumption [9][16].
- ✓ Increased WWTP biosolids generation and disposal costs [7][9][11][16][18].
- ✓ Potential grease/solids build-up in the sewer collection system, which increases maintenance costs [3][4][10].
- ✓ Increased potential loadings impact on combined sewer overflows [16].
- ✓ High initial costs for the user (not the municipality) [14][15][16][18].
- ✓ Increased energy consumption for both disposer use and WWTP aeration [16].

3.0 Food Waste Disposer Characteristics

3.1 Food Waste Composition

- Airport food waste sample analysis results were moisture 72.9%, Total Solids (TS) 27.1%, and Volatile Solids (VS) 94.9% [2].
- Lagerkvist & Karlson, 1983 and Nilsson et al, 1990 both indicate that about 20% of food waste suitable for composting is not suitable for disposer grinding [5].
- Olsson & Retzner, 1998 indicates that 75 kg/person/yr of food waste is generated [5].
- De Koning & Van der Graaf, 1996 assume that the total amount of food waste that can be ground through a disposer is 44 kg/person/yr [5].
- Nilsson et al, 1990 state that about 75% of food waste Biochemical Oxygen Demand (BOD) is in particle form and 25% in dissolved form [5].
- Food waste moisture content is 60% with a production of 0.08 wet kg/person/day (0.048 dry kg/person/day) [7].
- Daily person equivalent contributions due to organic food waste through disposers is 75 g/person/day for Chemical Oxygen Demand (COD), 50 g/person/day for Total Suspended Solids (TSS), 2.5 g/person/day for Total Kjeldahl Nitrogen (TKN), and 0.25 g/person/day for Total Phosphorus (P). This equates to a COD/TKN ratio of 30 [8].
- Typical organic waste composition is 25.6% TS (74.4% water), 96.5% VS, 3.2% TKN, 0.2% P, and 1,200 mg/L COD [8].
- Food waste is 64.3% water (35.7% solids) with 75.5 g/person/day generated through a disposer [9].
- Food waste generation is about 40-60 kg wet/person/yr [10].
- Average household food waste disposal is 260 g/person/day [11].
- Food waste is 30% dry solids (70% water) [11].
- Grindable food waste is about 35% of total household waste, which equates to 235 g/person/day (85 kg/person/yr) [12].
- The average person generates 0.29 lb/day of food waste with 0.21 lb/day (75%) able to be processed through a disposer [14].
- Food waste is 70% water and 30% solids [14].
- Typical food waste composition is 50.5% C, 6.72% H, 39.6% O, 2.74% N, and 0.44% S [14].

- Typical human waste composition is 59.7% C, 9.5% H, 23.8% O, 7.0% N, and 0% S [14].
- Average food waste generation is 182 kg/household/yr or 0.24 kg/person/day [15].
- Generated food waste is 76 kg/person/yr, with 67% able to be ground through a disposer (i.e., 50.9 kg/person/yr) [18].

3.2 Water Consumption

- Estimate 1 gal/capita/day with disposer use [3].
- Increased water demand from disposers is 0.02% at 3% market penetration, and 0.24% at 38% market penetration (assuming a 1% disposer market growth per year). Therefore, no significant impacts on the city water supply from disposers are expected [3].
- There is no statistical evidence that city water consumption has changed since the installation of disposers [4].
- Disposer water usage is 3-6 L/household/day [5].
- Nilsson et al, 1990 estimate that water consumption does not change because of disposer use [5].
- De Koning, 2003 reports the use of disposers does not result in a noticeable increase in the volume of wastewater [6].
- The average water consumption through disposer use is about 4.5 L/person/day (increase of 1.35%) [7].
- Disposer water consumption is 1.01 L/person/day [8].
- Disposer water consumption is 3-4.5 L/person/day [10].
- The average disposer water consumption is 4.48 L/person/day [11].
- Disposer water consumption is 3-4.5 L/person/day [12].
- Disposer water consumption is 4 L/person/day [13].
- Disposer water consumption is 2.95 L/person/day (6.2 L/household/day) [15].

3.3 Disposer Specifications

- A 1400 rpm rotating disk with a number of 3-4 mm holes [5].
- The energy requirement for use is 3-4 kW-h//household/yr [5].
- A Japanese study found food waste particle dispersion between 2-5 mm [5].
- Disposer energy consumption is 4.3 kW-h/yr [8].

- A grinding distribution of heaviest components show 62% of particles are <1.7 mm, 86% are <2.83 mm, and 94% are <3.36 mm [9].
- Approximately 98% of all particles pass through a 2 mm sieve [10].
- Disposer electrical consumption is <3 kW-h/household/yr [13].
- The food waste disposer can be described as a mill rather than a cutter. It works with a rotary disk in which two hammer-cheeks mobile in horizontal direction are fastened. The disk is provided with 5 mm holes. In opposition to frequently heard prejudices, a disposer does not contain rotating knives [16].
- Non-food wastes cannot be ground since the attempt will cause a resistance, which if it becomes excessive, will cause the resistor to switch off [16].
- The Plumbing Foundation City of New York, 2001 indicates that using the upper time limit for disposer usage of 2 min/day and the most common 0.5 hp motor, the disposer consumes less than a 75W light bulb uses in 10 minutes [17].
- Disposers have a 600W electric motor, used on average 2.4 times/day and 30 seconds each time [18].

4.0 Food Waste Disposer Usage Impact on the Sewer Collection System

- Disposers may cause increases in TSS and Oil & Grease (O&G) in the sewer system. There may be an increase in sewer maintenance costs estimated at 0.61% at a 3% market penetration and 7.6% at a 38% market penetration (assume 1% market penetration per year) [3].
- Videotaping done before and after the study detected no noticeable deposits of solids build-up. Therefore, no potential significant adverse impacts on the sewer system are expected from disposer use [3].
- In combined sewer systems built with an adequate self-cleaning velocity (ex., sanitary sewers 2.0-2.5 ft/sec and storm sewers 2.5-3.0 ft/sec), no additional deposits are expected due to ground food waste since its specific gravity of 1.01 is less than that of sewage (1.05), and much less than the suspended solids carried by storm runoff (specific gravity 2.65) [4].
- In combined sewer systems, the introduction of disposers will cause increases in suspended solids of about 20% on a per capita basis, and expected to increase O&G discharges. As a result, combined sewer systems with insufficient self-cleaning velocities will require routine cleaning, which will increase maintenance costs [4].
- In a 1993 apartment disposer use study, sewer pipes were flushed and videotaped with no differences observed (i.e., no additional particle, sludge, or grease accumulation) after both 1 and 3 years following installation [5].
- There is no literature example to prove that the use of disposers causes clogging or deposits in sewers. Most food solids have a density about equal to water and are easily suspended in water. Thus, it is unlikely that ground food waste contributes to sewer clogging [7].
- Discharged with cold water, any grease or fat found in food waste will congeal and attach itself to the other ground waste particles. Running cold water will prevent coating of the sewer with grease [7].
- Some trouble could arise from increased O&G discharge in sewers. However, studies have shown that no problems were caused [8].
- Sewage velocity is sufficient enough to maintain sewers clean. Generally, self-cleansing velocity is in the range of 0.5-1.6 m/s for sewers with a diameter of 200-2000 mm [8].
- Study results revealed that only 16.8% of TS (from ground organic wastes) settled in sewers, whereas, the residual 83.2% reached the

WWTP. Therefore, sewers should be considered a feasible way to transport food waste [8].

- Wicke, 1987 states that a concentration of less than 1% solids (10,000 mg/L) will not cause an increase in solid sedimentation, or for every 12 gal of water (45 L) there should be no more than 1 lb (454 g) of ground garbage [9].
- A daily minimum flow velocity of 0.5 m/s is seen as sufficient for food waste transport free of sedimentation. The density and settling velocities of food waste particles is very much less in comparison to mineral particles [10].
- Increased costs in sewer maintenance (from disposers) can not be ruled out. At 100% market penetration, a 20% increase could result [10].
- At a 50% market share, disposers contribute <0.1% flow to instantaneous maximum flow in sewer systems [15].
- At a 50% market share, disposers increase hydrogen sulfide generation in the sewerage system by 30% [15].
- Up to a 15% market penetration, the use of disposers in multi-unit dwellings would have a small impact on sewage collection systems [15].
- About 91% of solids in disposer effluent are <1 mm (0.25 in) in size, therefore, this small size would be unlikely to clog or become deposited in sewers or plumbing pipes [15].
- De Koning and Van der Graaf, 1996 state that the concern over grease and fats (from disposers) clogging sewers is invalid because the use of cold water causes grease and fat to congeal and attach to other food waste solids [15].
- There does not appear to be any sound evidence in literature to suggest that disposers cause clogging or deposits of solids in pipes [15].
- Nilsson, 1990 showed that a stimulated optimal usage of disposers for 15 years did not exhibit operational problems within the plumbing system. Regular inspection and videotaping of the piping system found a buildup of sewage was reported at water level with a width of 2-3 cm along the envelope surface at a thickness of 0.5-1.5 cm [17].
- Another aspect to consider is to avoid disposer installations in areas where blockages or hydrogen sulphide formation already are problems in the sewage system [18].

5.0 Food Waste Disposer Usage Impact on the WWTP

5.1 Pollutant Loading

- Additional pollutant loading due to disposer use is 66 g/person/day BOD, 60 g/person/day TSS, 2.1 g/person/day TKN, 0.3 g/person/day P, and 2.5-5% biosolids [6].
- The effect of disposers on WWTP processes is very limited [6].
- At a 15-20% disposer market share, loadings do not result in significant variations in the characteristics of sewage. At a 20-35% disposer market share, an increased WWTP system energy consumption is observed due to greater respiration of the active biomass and a larger production of excess biosolids. Beyond a 35-40% disposer market share, additional works must be done at the WWTP. European Union (EU) market levels will not exceed 15% in 25-30 years, thus, normal WWTP upgrades will allow for an accommodation of increased disposer loading [12].
- At a 100% disposer market share, flows would increase 0.4%, biosolids production would increase 18.1%, BOD would increase 16.5%, nutrients would increase 3.0% for TKN and 4.6% for P [13].
- At a 50% disposer market share, increases in sewage flows are very small (additional 0.5% to the mean average daily flow) [15].
- At a 15% disposer market share, no operational problems should be caused in terms of BOD, TSS, or O&G loadings [15].
- Up to a 15% disposer market share, the use of disposers in multi-unit dwellings would have a small impact on sewage treatment systems. Beyond this figure are increasing impacts, with potentially significant impacts at a 50% market share. However, this level of market share is unlikely in the near future [15].
- No operational problems are expected for market levels up to 15% in regard to BOD and O&G loadings, or up to 20% market for additional TSS loadings [15].
- Up to a 50% disposer market share, the transport and treatment of disposer effluent would require an additional 0.5% energy, and total WWTP costs would increase 0.5% [15].
- Up to a 50% disposer market share, additional loadings from disposers are <1% for TSS and nutrients, and <2% for BOD [15].

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- At 100% disposer market share, additional loadings from disposers are 3-5% for flow, 5-10% for screenings, 5% for grit, 10-25% for BOD, 40-60% for TSS, 5-10% for TKN, 7-14% for P, 50-70% for primary sludge, 10-40% for waste activated sludge, 30-50% for digested sludge, and 90-100% for biogas [16].
- The additional loads for wastewater treatment and sludge digestion can be estimated very well and, due to slow market penetration, will not lead to uncontrolled overloading to the WWTP "overnight" [16].
- Disposer discharge to a WWTP equates to 73 g/person/day dry matter, 25 g/person/day BOD, 0.25 g/person/day phosphorus, and 1.3 g/person/day nitrogen [18].

5.2 Preliminary Treatment

- It is expected that food waste will contain no grit [1].
- Screenings are not expected to be added by food waste disposers [4].
- Grit was assumed to be 5% of TSS. A method to evaluate scum or grit production impact could not be determined [4].
- With disposer usage, WWTP screens and grit chambers will only be affected to a small extent [16].

5.3 Primary Treatment

- The portion of BOD from disposer use that does not settle in primary treatment was determined using filtrate BOD. The portion of BOD from food waste that settled was 68.7% [4].
- Primary settling food waste removal is 20% BOD, 90% TSS, 5% TKN, and 10% P [6].
- The majority of additional BOD/COD and nutrient from disposer loading is concentrated in settled primary sludge [7].
- The average settling velocity of food waste is 13.2 m/hr (43.3 ft/hr) [8].
- According to literature, over 90% of food waste is removed in primary sedimentation [9].
- Brillet et al., 1986 reported that sedimentation removed 80% BOD and 90% TSS from disposer waste [9].

- Nilsson, 1990 reported that 75% of TS in wastewater and 90% of solids from disposer grinding are removed in primary sedimentation, thus, overall removal is 80% [9].
- Normal wastewater TSS removal is 58-64% and the food waste mixture TSS removal is 78-86% [9].
- Disposer solids settle readily under gravity. Sinclair Knight, 1990 state that the addition of disposer solids enhances the settling characteristics of sewage [15].
- With disposer usage, most of the particulate food waste fraction will settle in the WWTP primary clarifier [16].
- According to lab experiments, 75% (of disposer food waste) is assumed to be settled in the pre-sedimentation step [18].

5.4 Secondary (Biological) Treatment

- After a decade of city-wide disposer distribution, costs would increase $4.1M for the most expensive N-control measure (a 0.27% increase). This represents a *de minimus* impact [3].
- At a 25% disposer market share, influent BOD would increase 12%, TKN and P would increase 2% [5].
- Increased loading to the biological processes from disposer usage is negligible (at 10% market share) [7].
- Brillet et al., 1986 reported that at a 100% disposer market share, biological treatment loading increased 9.5-16% BOD and 7.5-10% TSS [9].
- The additional soluble food waste fraction will lead to higher BOD/COD loading within the biological treatment steps, which on one hand will cause a higher oxygen demand, but on the other can serve as a cheap and continuously available carbon source (for nutrient reduction). A basic condition for the appropriate biological nitrogen and phosphorus removal is a sufficient supply of easily degradable substrate (i.e., carbon) [16].

5.5 Anaerobic Digestion

- Food waste Volatile Solids Destruction (VSD) is 83.7% (for thermophilic digestion at 55°C and food waste fruit and vegetables ground to a slurry) [1].

- The optimum digester operating temperature was found to be 55°C and 57°C (thermophilic digestion). As the temperature increased from that point, VSD and gas production decreased and volatile acids increased [2].
- Food waste (with 90% settling in primary treatment sludge) contains a high percentage of easily digestible organics (i.e., 80% VS) [6].
- As most of the food waste from disposers settles in the WWTP primary clarifier, the majority will reach the anaerobic digester and cause an increase in biogas production and a regenerative energy source [16].

5.6 Biosolids Handling and Disposal

- Disposer usage showed minimal to no impact on the WWTPs total biosolids production and handling processes as the high VSD from food waste yielded a minimum amount of solids in the residue [1].
- Bench-scale jar testing showed food waste dewaters easily and used less polymer than primary sludge/thickened waste activated sludge [1].
- Food waste appears to possess a natural settling capability [2].
- The Waste Management Research Unit at Griffith University, 1994 found that at a 25% disposer market share, sludge volume would increase 4% [5].
- Solids loading to thickening units and digester increases 5% at a 10% disposer market share [7].
- Ground food waste will significantly increase the quantity of biosolids, however, Nilsson, 1990 notes that these biosolids will decompose easier than regular wastewater biosolids and more gas can be produced [9].
- At a 100% disposer market share, food waste through sewage produces 50% more biosolids [11].
- At a 10% disposer market share, food waste through sewage produces 5% more biosolids [11].
- At a 25% disposer market share, disposers should not adversely affect sludge digesters, dewatering centrifuges, or biosolids hauling [15].
- At a 20% disposer market share, biosolids production will increase 12% [15].
- It is unlikely that biosolids produced by disposer usage would affect the contaminant level or reuse options of biosolids [15].

- Concerns about increased biosolids generation persist, and its potential environmental and economic implications may differ with location [17].
- In a scenario is which 50% of the households have disposers, the amount of WWTP sludge generated from food waste, expressed as dry matter, is calculated as 7.2% of the total sludge generated (or a 10% increase compared to the present situation without disposers) [18].
- Before disposers are installed in large scale a long-term solution for the use of sludge should be agreed, because disposers will increase sludge production [18].

5.7 Effluent Characteristics

- The BOD increase in the effluent due to disposer usage equates to a 0.01 mg/L dissolved oxygen decrease in New York Harbor in 10 years (*de minimus* impact) [3].
- Combined sewer overflow total stream BOD concentration increased 5% and TSS 2% over baseline from disposer usage. In the worst case area, the 4 mg/L minimum dissolved oxygen standard was exceeded by 1.5% over the baseline. This increase is considered to be *de minimus* [3].
- At a 20% disposer market share, effluent quality can be maintained through operative WWTP adjustment. A higher market share will necessitate plant expansion, but will take many years to occur [9].
- At a 50% disposer market share, disposers are unlikely to affect biosolids reuse, the marine environment, or energy consumption [15].
- The composting system does not impact the waterborne wastewater system, while the food waste disposer system is estimated to cause some minor increases in discharges of nutrients and heavy metals to water. All impacts in both systems are rather small [18].

5.8 Food Waste Energy Recovery

- The value of the biogas produced from food waste anaerobic digestion appears to exceed the cost of processing the food waste and disposing of the residual biosolids (based on a LAX Airport proposal to divert 8,000 tons/year of bulk food waste) [1].
- Methane gas generated in the anaerobic digesters is transported to a city-owned power generation steam plant, which is used as a

supplemental fuel and burned in the production of steam and electrical energy (15 scf of digester gas produced per lb of VS destroyed). In digesting fruits and vegetables only, the value of the biogas appears to exceed the cost of processing the food waste and disposing of the biosolids [2].

- Additional gas production is generated from the volatile portion of food waste loading (7 ft^3 of gas is produced per lb of VS that enter the digester) [4].
- Anaerobic digester gas production averaged 346 m^3/day before disposer usage and 417 m^3/day after disposer usage for an increase of 20.2% (at 65% methane, this equates to 160,000 kW-h/yr) [5].
- Biogas production from food waste is 1.15 m^3/day of digested organics with a content of 22,000 kJ/m^3 of biogas [6].
- The use of disposers will increase electric self-supply from 72% (at 0% disposer market share) to 82% (at 10% market share). Profits gained in electrical supply will cancel out additional biosolids treatment costs [6].
- At a 60% disposer market share, an increase of additional energy potential due to anaerobic digestion in the range of 54-73% was observed [8].
- Food waste fermentation (anaerobic digestion) has an energy potential of 300 MJ/person/yr, contributing about 25 kW-h/person/yr to electric supply (which is about the electrical usage of 1 WWTP) [10].
- As most of the food waste settles in the WWTP primary treatment process, the majority will reach the anaerobic digester and cause an increase in biogas production and a regenerative energy source [16].
- The potential energy value from food waste by anaerobic digestion was assumed insignificant [17].
- The food waste disposer system generates more energy than consumed through the digestion (biogas) [18].

6.0 Food Waste Disposer Usage Impact on Municipal Solid Waste

- At a 38% disposer market share, grinding 50% of the food waste through disposers will save $4 M in solid waste export costs [3].
- The Department of Sanitation recognizes the potential of disposers to make a positive impact in New York City residential waste management. Benefits include reduced odors and pest attraction, and better separation of recyclables [4].
- Most people are unwilling to separate food scrap for Department of Sanitation pickup [4].
- The organic, biodegradable fraction of household waste is about 40% in weight [16].
- The application of disposers offers the possibility of a controlled, source-separated food waste pretreatment [16].
- Compared to the whole fraction of household waste, the food waste fraction is characterized by a high moisture content (70% +), best biodegradability, and lowest heating value [16].
- In this study, the introduction of food disposers into the waste and wastewater management systems led to net economic benefits that ranged between 7.2% and 44.0% of the current solid waste management cost. Food waste disposers can constitute a viable option (economically and environmentally) that could reduce the load on the solid waste stream and minimize the amount of end waste requiring landfilling. [17].
- The food waste disposer system appears to be slightly less costly than central composting when only the costs for water and refuge handling are considered, and the user pays for the purchase and installation of the disposer themselves [18].

7.0 Food Waste Disposer Usage Impact on the Environment

- Potential disposer concerns are reduced WWTP biological effluent quality, congestion, hydrogen sulfide production in the sewage system, utilization of a bad principle to mix food waste with water and then separate the useful matter, and cost increases at the WWTP [5].
- The Netherlands has prohibited disposers since the 1960s due to fears of sewer blockages and the deterioration of WWTP biological treatment [6].
- The food waste disposer has to be considered an addition rather than a competitor to the current system for the collection of kitchen, food, and garden waste [6].
- Food waste collection followed by anaerobic digestion and biogas utilization in power plants has been judged more positive than separate collection followed by composting [6].
- In a comparison of costs and environmental effects of food waste disposal, anaerobic digestion is the best option, followed by composting and finally disposal through disposers to the WWTP (Note: The WWTP in this study utilized thermal drying of biosolids through incineration instead of anaerobic digestion, which is inefficient due to the high water content in food waste) [11].
- The recycling of food waste through the re-application of sewage sludge to soil is a method in full line with European Union (EU) environmental goals: improve soil quality; increase recovery of organic waste to ensure it is not landfilled or incinerated; and improve the quality of sewage sludge. The disposer is an integral tool to turn food waste into sludge that can undergo anaerobic digestion [12].
- The most common argument against food waste disposers is that the capacity of WWTPs is not sufficient. In none of the EU countries (cited in the reference) are restrictions based on empirical research and evidence, but rather on the application of the precautionary principle [12].
- The food waste disposer is designed to grind only food waste. Materials other than food waste (ex., bottle caps, textiles, etc.) will lead to device jamming. Thus, the disposer is a natural selector of food waste. In contrast, composting largely depends upon the education and goodwill of participants as to the quality of collection [12].

- Home composting produces a high strength (BOD) leachate when food waste is present. There is no readily available mechanism to manage this leachate [13].
- Methane has a much greater greenhouse effect (on the environment) than the equivalent of carbon dioxide. Environmentally, therefore, it is desirable to minimize methane release. There is no readily available mechanism for achieving this with household composting. In contrast, landfills and sewage treatment works can be constructed to maximize methane recovery as a fuel [13].
- Diverting food waste through a disposer to a WWTP should be encouraged when solids handling systems are adequate, methane is combusted (through anaerobic digestion) to produce energy, and effluent and/or sludge (biosolids) are returned to soil. Food waste is effectively being recycled [14].
- The Food Waste Disposer/WWTP system provides other municipal solid waste (MSW) management systems benefits by transferring putrescible food waste, which reduces regulatory requirements for MSW collection (frequency), landfill systems (daily cover), compost systems (more stringent management), and incineration (reduced solids handling) [14].
- The digestion of organic waste by bacteria and mold starts in the kitchen. There is often a significant increase of bacteria and mold growth in organic waste buckets and bins. Therefore, organic waste can be an important source of microbiological exposure in the household and the working environment. Microbiological exposure includes visible mold and bacteria, as well as dead micro-organisms. However, investigations with regard to potential impacts in human health are rare. Measured concentrations of microbiological agents are significantly higher in households with separate organic waste collection (1.6-3.0 times higher/m^2 for plain floors and 50-300 times higher/m^2 for textile floors) than without separate collection. The concentration of microbial agents also depends upon the frequency of emptying the food waste bucket. In houses where the bucket is emptied once/week or less, the concentration is 1.3-3.5 times higher than in houses where the bucket is emptied more than once/week. In addition, an increased concentration of mold and bacteria occurs during the opening and emptying of the separate food waste bucket.

Exposure to mold spores is 10 times higher upon opening (which disappears 15 minutes after emptying) [15].

- It can be concluded that there is a measurable exposure to microbiological agents during the collection of garbage. The exposure is considerably smaller than other industrial sectors because most of the activities take place outdoors. It cannot be excluded that long standing exposure to the endotoxins will affect human health. However, it cannot be concluded that separate collection of organic food waste will lead to an increase in microbiological exposure compared with mixed waste collection. The neuslavage study shows increased upper respiratory infections for garbage collectors than supervisors related to microbiological exposure during work. The same pattern was exhibited in an older study analyzing human health effects on compost plant workers [15].
- The introduction of food waste disposers should fulfill some essential preconditions, including no lack of drinking water in the area; a separated sewerage system; the sewerage system should be in good condition (i.e., no leaks, fractures, or sedimentation) with a minimal 2% gradient; and the WWTP should contain a primary clarifier, sludge digestion, and free capacity [16].
- Further fields of research could be the possibilities of reducing the water consumption for food waste disposer use, or the replacement of drinking water by rainwater. Moreover, there are still questions concerning food waste disposers impact on sewerage systems [16].
- The Integrated Solid Waste Management system has failed to achieve target with more than 80% of total wastes routed to landfills, raising into question the purpose of sorting-processing-composting facilities, as well as the recycling program. Apparently, the market demand for compost and recyclables may be either less than the generation rate or not environmentally competitive. Current waste management activities, particularly source separation and recycling have not measured favorably. Also, locating and approving suitable landfill sites is increasingly difficult [17].
- The food waste disposer alternative causes 3 times less global warming than the composting alternative, due to the reduction of truck transport [18].

8.0 Food Waste Disposer Life Cycle Analysis

8.1 University of Wisconsin [14]

The Life Cycle Analysis (LCA) is a comparison of five systems for the processing of 100 kg of food waste. The five systems are:

1. Food Waste Disposer/Wastewater Treatment Plant (FWD/WWTP)
2. Municipal Solid Waste Collection/Landfill (MSW/L)
3. Municipal Solid Waste Collection/Compost (MSW/C)
4. Municipal Solid Waste Collection/Incineration (MSW/I)
5. Food Waste Disposer/On-Site Septic System (FWD/OSS)

The LCA analyzed land requirements, total system energy, total system materials, total emission to the environment, and total system cost for each method. The ranking for these areas were:

Total land requirements: FWD/WWTP < MSW/I < MSW/L < MSW/C < FWD/OSS
Total system energy requirements: FWD/WWTP < MSW/L < MSW/C < MSW/I < FWD/OSS
Total system materials: MSW/C < MSW/I < FWD/WWTP < MSW/L < FWD/OSS
Total flows to environment: MSW/C < MSW/L < MSW/L < FWD/WWTP < FWD/OSS
Total system costs: MSW/L < MSW/C < FWD/WWTP < MSW/I < FWD/OSS

Overall, of the five systems, the FWD/WWTP has the lowest municipality cost (system cost due to disposer cost, which is paid by the homeowner); least air emissions; converts food waste to a recycled resource; is the most convenient system of food waste disposal; is the most likely system for organic source separation; and overall is the most environmentally friendly and sustainable option.

8.2 Sydney, Australia [15]

The Life Cycle Analysis (LCA) is a comparison of four systems for the processing of 182 wet kg of food waste. The four systems are:

1. Food Waste Disposer/Wastewater Treatment Plant (FWD/WWTP)

2. Home Composting (HC)
3. Co-Disposal or Municipal Solid Waste Collection/Landfill (MSW/L)
4. Centralized Composting or Municipal Solid Waste Collection/Compost (MSW/C)

The research was undertaken as five separate but interlinked studies examining technical and operational, environmental, economic, social acceptance, and microbial risk impacts. [Note: The beneficial use of by-products (i.e., compost and biosolids) was not part of the study. Also, the amount of recovered energy is uncertain should biogas be used for energy recovery. Electricity generation from biogas can lead to high environmental improvements for the FWD/WWTP and Co-Disposal (MSW/Landfill) systems. However, little biogas was being recovered at the WWTP (Bondi STP) that was used in the study. In addition, the Bondi STP is a "high rate primary" plant, thus, nutrients (nitrogen and phosphorus) are released to treated effluent, which caused a poor eutrophication rating for the FWD/WWTP system.]

Environmental Impacts: Home Composting has the smallest environmental impacts. The FWD/WWTP system ranked second in terms of energy consumption, global warming potential, and eutrophication potential; but fourth in terms of human, aquatic and terrestrial toxicity potential. Co-Disposal ranked second highest in toxicity potential and eutrophication potential; ranked slightly behind FWD/WWTP for energy consumption and acidification; and had the lowest ranking for global warming potential. Centralized Composting has a relatively poor environmental performance due to its energy intense collection activities, ranking fourth for energy and acidification; and third in the remaining categories.

System Cost Comparison: Home Composting is the least expensive option for multi-unit residents; then Centralized Composting; Co-disposal; and FWD/WWTP is the most expensive (due to a high initial unit and installation cost paid by homeowner). From a system point-of-view, the FWD/WWTP system was again the most expensive; Co-Disposal (the current system utilized by Sydney) has landfill space and does not require capital investment; Centralized Composting would necessitate capital investment. The FWD/WWTP system may require capital investment beyond a 25% market share.

Health Risk Comparison: The FWD/WWTP system may only marginally increase the rate of sanitary sewer overflows during periods when the sewer is flowing at 100%. Home Composting without pet fecal waste or meat products addition should result in acceptably low infection rates for all pathogen groups. Centralized Composting (including human fecal waste) should be satisfactory from the point of no significant pathogen risks. Overall vector-based diseases were not considered significantly different due to the operation of food waste disposal units and domestic composting containers.

Social Impact Comparison: Disposal of food with municipal waste was judged as the least satisfactory option (current Sydney system). Home Composting was judged impractical for multi-unit dwellings. FWD/WWTP and food waste collection with Centralized Composting were much more appropriate, provisional on the level of treatment that would enable reuse of the waste residuals (which was not studied).

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Notes: Number in bracket [ ] refers to the study listed in the Reference Section. This document prepared for the convenience of researchers, municipal officials and others interested in this topic; complete copies of studies referenced are available upon request.

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