The Recycling Fund (Industry Support Programme) ISP-1617-06-001

# Implementation of Food Waste Collection System for Catering Services – Project Summary

Submitted by
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March 2021

## Report Details

This Final Report is part of the submissions for funded project ISP-1617-06-001 under The Recycling Fund (Industry Support Programme):

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| **Application No.** | ISP-1617-06-001 |
| **Name of Grantee** | The Hong Kong Polytechnic University |
| **Project Title** | Implementation of Food Waste Collection System for Catering Services |
| **Project Period** | 27 February 2018 to 26 February 2021 |

## Team Members

The following are members involved in the funded project. All members are from the Department of Building Services Engineering, The Hong Kong Polytechnic University:

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| **Project Coordinator** | Dr. MUI Kwok Wai, Associate Professor |
| **Deputy Project Coordinator** | Dr. WONG Ling Tim, Associate Professor |
| **Research Assistants** | Mr. CHIU Yin Hei, Research Assistant |
| | Ms. BALACHANDRAN Anjana, Research Assistant |
| | Ms. TSANG Tsz Wun, Research Assistant |
| | Ms. KAO Ching Wah, Research Assistant |

## Amendment Record

| **No.** | **Date of approval** | **Summary of approved change requests** |
|---|---|---|
| 1 | 21/12/2017 | Change on location of implementation from Science Park to The Hong Kong Polytechnic University |
| 2 | 23/3/2020 | Project extension to 26/8/2020 |
| 3 | 24/7/2020 | Project extension to 26/11/2020 |
| 4 | 29/9/2020 | Project extension to 26/02/2021, reallocation of budgets of HK$34,200 for salary: HK$10,000 from Other expenses – seminar/conference; HK$2,000 from Equipment – Food waste System; HK$1,250 from Other expenses – printing materials; HK$8,000 from Other expenses – water sample testing; and HK$12,950 from Other expenses – filter. |
| 5 | 07/12/2020 | Change on budget item name from “Consumables and sample testing costs: filter” to “Consumables and sample testing costs: filters and consumables for lab experiments”. |

# Executive Summary

Hong Kong is facing an increasing challenge on food waste management due to limited landfill capacity. Food waste is the largest waste contributor among all MSW produced in Hong Kong and the commercial and industrial sector was responsible for 32% (about 1,100 tons per day) of the daily food waste produced in 2018. Despite efforts to promote the reduction and recycling of food waste, only 2% of the waste is recovered and recycled annually.

Given the situation, our team applied to the Recycling Fund in 2018 to study the feasibility and benefits of adopting a centralized food waste collection system at a catering complex at the Hong Kong Polytechnic University. The first small-scale automatic food waste collection system in Hong Kong and East Asia was installed and began its operation in July 2019 after approval of the study. The project aims to evaluate outcomes and the benefits resulted from the adaptation of a centralized food waste collection facility through lifecycle costing analysis, as well as to analyze behavioral changes of users due to change of food waste management practices. The project also reviews whether the system can serve as a replacement of the conventional waste handling process, and whether the system can be adopted in Hong Kong as an integral part of regional food waste management plan to maximize recycling rate of food waste and promote a cost-effective food waste recycling practice for local catering businesses.

System operation and monitoring were carried out to gather data on food waste quantities, dewatering performance of dewatering unit, electricity and water consumption of system, system utilization, wastewater quality and feedbacks and comments from system users. Results reported were analyzed in order to provide recommendations on adoption of system within the C&I sector in Hong Kong. In short, there are five areas that require careful consideration when adopting the system in catering facilities, namely system capacity and location, operation time, pest and hygiene, odor and waste bin collection practices.

Amount of food waste collected increased from 6,036 kg per month (199 kg per day) before system operation to 6,767 kg per month (217 kg per day) after system operation. Meanwhile, number of waste bins required for food waste collection decreased from 3.8 to 2.9 bins per day. Reduction of bin usage was due to the food processing feature of inlet units, which reduced volume of food

waste by about 60%. The dewatering process was able to reduce moisture content of food waste by about 12%. Average usage of all inlets was 9.4 times per day. Majority (70%) of the system faults during operation and monitoring period were contributed by issues with the dewatering unit (i.e. clogging of the unit by viscous food waste). Generally speaking, the number of system failure increased from once per month in summer semester to two to five times a month at the beginning of new academic year.

The 10-year cost estimation for manual collection is HK$19,499,677 and that for system collection is HK$16,951,542, which indicates that system collection will provide around 13% cost savings compared to manual collection. Collection charge from waste contractor contributed to the highest proportion of ongoing expenditure in both manual (98.8%) and system (86.5%) collection practices over a 10-year period. Thus, any reduction in daily bin usage (i.e. food waste compaction and volume reduction) will greatly reduce the cost of food waste collection in the long run. System collection becomes an economically viable option when waste collection charge is over HK$646 per bin. However, the system did not achieve its full cost-saving potential as system collection was not compulsory. Catering staff was free to dispose food waste manually or via system. In the ideal system usage scenario where all food waste is collected by system, it is estimated that daily bin usage would reduce to 1.5 bins due to 60% volume reduction of food waste from mincing process. In this system ideal case, 10-year cost is estimated to be HK$10,109,252 and system collection becomes economically viable when waste collection charge is over HK$245 per bin.

It is recommended that the collection system is installed in new catering facilities, such that the locations, power and water supply points, pipe layouts and drainage of the system can be planned and designed beforehand, and inlets can be placed close to food waste generation points or embedded in working benches, and wider 200mm pipes can be easily fitted within the building. Retrofitting the system in existing facilities is possible, but there will be difficulties in finding appropriate space for system placement and pipe layout, and additional drilling work and provision of power, water and drainage points. Dewatering unit of the system should also be replaced with an air-tight food waste collection tank since food waste generated from C&I sector is expected to be collected and transported to ORRCs for further energy recovery and composting. A food processing system at inlet unit will be sufficient to achieve compaction of food waste for cost-effective transportation. Lastly, regular flushing of inlet openings with hot water is useful in removing any food waste and scraps to avoid attracting pests, pesticide gels should regularly be applied around gaps and on back-panels of units to avoid pests inhabiting the inner layers of the units.

# Contents

## Figures and Tables

# 1. Introduction

Hong Kong is facing an increasing challenge on food waste management due to limited landfill capacity. Among all MSW produced in Hong Kong, food waste is the largest waste contributor, which accounted for around 34% (over 3,600 tons per day) of the total MSW disposed in 2017 (EPD, 2018). The commercial and industrial (C&I) sector was responsible for 35% (about 1,300 tons per day) of the daily food waste produced. Despite efforts to promote the reduction and recycling of food waste, only 2% of the waste is recovered and recycled annually. The green policy to enhance recycling capacity, efficiency and cost-effectiveness of food waste treatment plants is hindered by less effective collection practices.

The project team began in 2018 to study the feasibility of the adaptation of a centralized food waste collection facility for university canteens, and evaluates the benefits of employing such collection system. The system is expected to simplify food waste collection procedures in the canteens as the entire collection process is operated automatically to reduce labor input. The system is also expected to reduce the weight and volume of collected food waste through dewatering process, so as to reduce transportation costs to recycling facilities. The increase in cost-effectiveness of food waste collection may motivate users or businesses to enhance their willingness to adopt food waste recycling practices.

## 1.1. Project Objectives

In this study, we aim to evaluate the outcomes and the benefits resulted from the adaptation of a centralized food waste collection facility through lifecycle costing analysis, as well as to analyze behavioral changes of users due to implementation of the system. The following are the objectives of this project:

1. To install the food waste collection system in a catering facility to investigate the problems and difficulties the user may be facing if they adopt the system. For example, space limitation, handling process, etc.
2. To evaluate the benefits resulted from the implementation of the food waste collection system.

3. To evaluate and compare the amount of odor, hygiene, wastewater and any form of by-product of food waste recycling process with and without the use of centralized waste collection system.
4. To evaluate the residue water quality and the need for additional treatment before disposal.
5. To evaluate the needs for modifying the waste collection system to fit for the unique features and the requirement of the catering service providers (middle and large scale) in Hong Kong.
6. To investigate the feasibility for a territory-wide implementation of the system to improve the overall performance food waste collection in Hong Kong.
7. To promote the food waste recycling among C&I sector and raise public awareness.

## 1.2. System Description

To facilitate cost-effective food waste collection on campus, a small-scale food waste collection system with dewatering feature, first in Hong Kong and East Asia, has been installed for the catering facilities at The Hong Kong Polytechnic University. The system began operation on 5 July 2019. The experimental food waste collection system is implemented at a catering, which has a total of 970 seats and is currently producing about 200kg of food waste per day. The system is divided into three components: (i) waste inlets, (ii) vacuum pump and (iii) dewatering unit. Table 1 shows the details of canteen and restaurants at the catering complex.

Food waste is first collected at inlet benches at kitchens (Fig 1). Food waste is broken down into smaller pieces by the internal mincing machine with water added before being transported by pipes. Each inlet can process up to 6L of food waste a time and has a processing capacity of 180L per hour. Suction force is then created by a vacuum pump to transport food waste from upper floors to the dewatering unit on ground floor. Finally, the dewatering unit reduces water content and volume of food waste by pressing it up against a screw chamber. The chamber rotates and press out wastewater through a screen. The dewatering unit can temporarily hold 20L of food waste and process up to 220kg of food waste per hour. The processed food waste is temporarily stored in collection bins with a 180L capacity (typically only filled to 90L, or half-full, as suggested by the food waste collector). The system is equipped with a level sensor, which will notify staff to replace the collection bin when it is over half full. Wastewater generated from the dewatering of food waste is drained to a nearby grease trap.

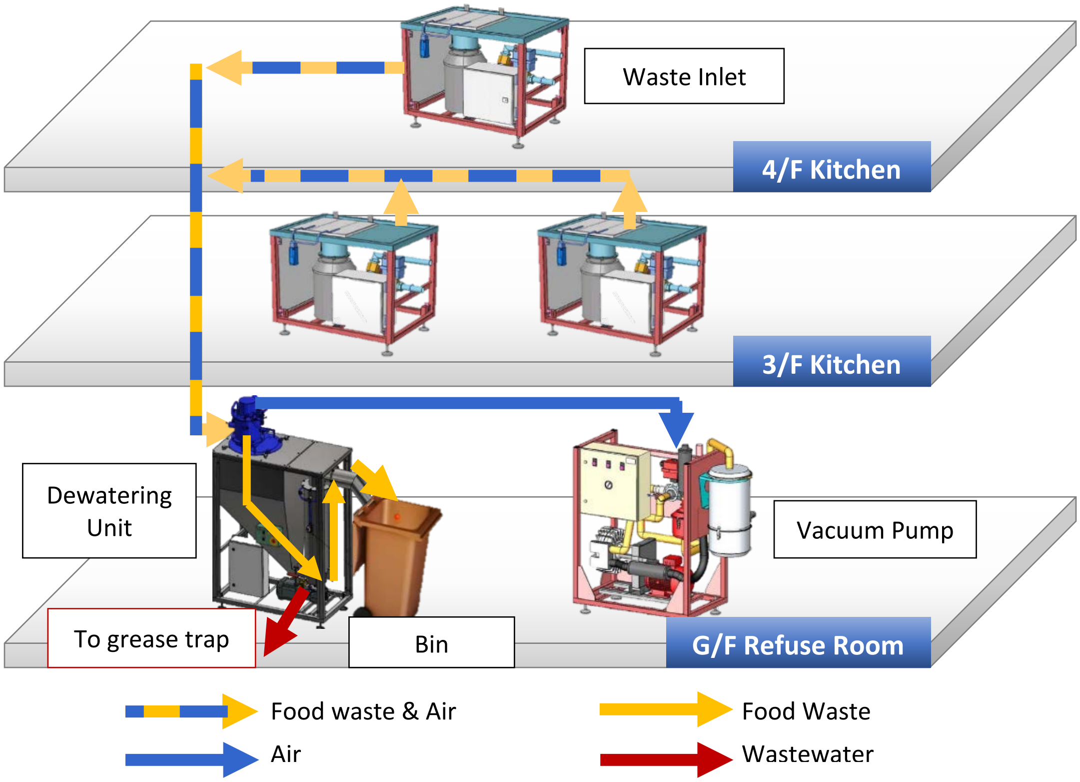



**Fig 1**. Schematic diagram of food waste collection system

**Table 1.** Restaurants and canteen at the catering complex of the project

| **Floor** | **Communal Building** | **Seats** | **Food Served** |
|---|---|---|---|
| 4/F | Communal Staff Restaurant | 250 | Dim sum, Northern dishes, home-style dishes |
| | Communal Student Restaurant | 200 | Noodles, congee, steamed rice and dim sum |
| 3/F | Communal Student Canteen | 520 | Fast-food items, bakery items, BBQ specialties |

1.3. System Installation, Training and Commissioning

The food waste collection system was procured from Envac Far East Ltd. from Sweden, including three inlet bench units, one vacuum pump unit and one dewatering unit. Envac is a Swedish environmental technology company establish in 1961. They are expert in automated waste collection systems with food waste collection project experience in China, Saudi Arabia, etc. They are also the sole and compliant offer received in the tendering period.

With the issuance of purchase order in June 2018, the project kickoff meeting was held in July. Site visits were held in August and September with the contractor to the catering complex. System requirements and design were finalized in October, which was followed by preparation and coordination of installation work with the University in November.

Regarding product delivery, pipe materials were delivered to the University in December 2018. The vacuum pump and three inlet bench units were delivered in January 2019. The dewatering unit arrived and installed in March. All installation work was completed in April 2019. System installation was delayed for ten months due to various delays in the manufacturing and delivery of system components from Sweden, including the Swedish manufacturer taking summer breaks, change in exterior designs and difficulties in the manufacturing of engine for the dewatering unit. Testing and commissioning of the system was conducted from May to June 2019 to tweak and optimize the system, including fixing faulty equipment assembly and enhancement of equipment design. For instance, the leakage of food waste into exhaust air pipe was found to be due to a mistake in system assemble and was subsequently fixed. Additional flushing device and level sensor were installed on the dewatering unit for more reliable system operation and control of system pressure and waste storage level.

Trainings were conducted to canteen kitchen staff on 5 July 2019. Kitchen staff were taught procedures for the daily operation of the system, including the steps and safety precautions of disposing food waste at inlets, the daily cleaning of inlet units and the change of waste bin at the refuse room when it is full. System operation began on the same day after training was completed. The following is a summary project timeline for the activities conducted during the project period (Table 2). The original project period was from 27 February 2018 to 26 May 2020. However, the extended project period was from 27 February 2018 to 26 February 2021 due to delays mainly from the delivery, installation and testing of the food waste collection system, unexpected campus closure and the pandemic of COVID-19. Operation and monitoring periods began in July 2019 and suspended starting from November 2019 due to unanticipated canteen and campus shutdown, as well as the COVID-19 epidemic. The canteen was never re-opened until the end of the project. Instead of further extending the project, only four-month system operation and monitoring data were used to ensure sufficient time for data analysis, reporting and project promotion. Review and analysis were carried out from April to July 2020 together with the drafting of final project report. Promotion of the project and collection system were carried out from November 2018 to February 2021, so as to promote the project and facilitate technology sharing to the academia, C&I sector and recycling industry. However, due to ongoing issues with COVID-19 and the temporary closure of catering complex for renovation in June 2020, site visits and promotion of the system could not be completed physically. Online promotions were done instead to promote the project outcome.

**Table 2.** Overall planned and actual project timeline

| | **2018** | | | | **2019** | | | | **2020** | | | | **2021** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 | Q1 |
| **Tasks/ Activities** | Jan | Apr | Jul | Oct | Jan | Apr | Jul | Oct | Jan | Apr | Jul | Oct | Jan |
| **Tender Invitation** | | | | | | | | | | | | | |
| Planned (Feb-May18) | | | | | | | | | | | | | |
| Actual (Apr-Jun18) | | | | | | | | | | | | | |
| **System Procurement, Installation & Staff Training** | | | | | | | | | | | | | |
| Planned (May-Aug18) | | | | | | | | | | | | | |
| Actual (Jun18-Jun19) | | | | | | | | | | | | | |
| **Operation & Monitoring** | | | | | | | | | | | | | |
| Planned (Aug18-Aug19) | | | | | | | | | | | | | |
| Actual (Jul19-Jul20)* | | | | | | | | | * | * | * | | |
| **Review & Analysis** | | | | | | | | | | | | | |
| Planned (Aug-Nov19) | | | | | | | | | | | | | |
| Actual (Apr-Jul20) | | | | | | | | | | | | | |
| **Report & Promotion** | | | | | | | | | | | | | |
| Planned (Feb19-May20) | | | | | | | | | | | | | |
| Actual (Nov18-Feb21) | | | | | | | | | | | | | |

*Remark: system operation was suspended in mid-November 2019 up until the end of this project due to campus closure and COVID-19 epidemic.

**Table 3.** Outcomes of project milestones

| **Milestone** | **Status** | **Implementation Details** |
|---|---|---|
| Purchase of Equipment (Tendering invitation was performed after funding confirmation.) | Completed | Six suppliers were invited to submit their offers, in which 1 returned an offer, 3 replied with no offer and 2 did not reply. Tender process carried out from 27 April to 15 May 2018. PO was confirmed and issued on 29 Jun 2018. Slippage from original schedule by around 1 month. |
| Onsite investigation and plan for system implementation were carried out.<br><br>System installation in catering facility, testing and commissioning were carried out.<br><br>Collection of data regarding the food waste collection practice before the use of the system was conducted through interviews with relevant canteen staff.<br><br>Training on food waste separation for system users (kitchen workers of the collaborating catering service providers) and proper operation of the system were conducted. | Completed | Kick-off meeting was held in July 2018 and site visits were held in August and September 2018 with the contractor to the catering complex. System requirements and design were finalised in October 2018 with the contractor, which was followed by preparation and coordination of installation work with the University in November 2018.<br><br>Installation began in December 2018 and was completed in April 2019.<br><br>Interviews were carried out on 7, 12 and 14 December 2018 to a total of eight canteen staff to gather data on food waste collection practices and behaviour from kitchen workers before system implementation.<br><br>Dewatering unit arrived and installed in March 2019. Testing and commissioning was conducted from April to June 2019.<br><br>Two trainings were conducted with a total of 15 canteen kitchen staff on 5 July 2019. System operation began on the same day after training was completed.<br><br>Slippage from original schedule was about 10 months. |
| Interview/ questionnaire survey on user's behavior were carried out.<br><br>Onsite monitoring of the system performance, environmental conditions, daily output of the system was done. | Partially Completed | One interview with canteen managers was conducted on 28 August 2019 to identify the issues and concerns encountered by the catering staff during system operation.<br><br>Collection of project data include:<br>- Quantity of food waste (total weight and number of bins) on a monthly basis<br>- Dewatering performance of system and moisture content of food waste on a weekly basis<br>- Wastewater sample testing on a monthly basis (by Hong Kong Wastewater Treatment Plant Management Co. Ltd.) |

| | | |
|---|---|---|
| Collection of data and water samples for testing were carried out. | | - System activity log on a weekly basis<br><br>One more round of interview/ questionnaire survey was originally planned to be conducted after the end of system operation period to collect change in user's behavior towards the system. As the system operation has been suspended since mid-November 2019 up until the end of this project due to campus closure and ongoing COVID-19 epidemic, data collection on system usage, performance and food waste output was suspended and eventually terminated. |
| Review and analysis of the collected results | Completed | Four-month system operation and monitoring data were reviewed and analyzed, which has been detailed in this report. |
| Project completion, report preparation and promotion, sharing of the study result were carried out. | Completed | - Attended HK Joint Symposium 2018 on 21 November 2018 and presented aim, design and expected outcomes of the project.<br>- Attended CIBW062 Symposium on Water Supply and Drainage for Buildings on 9 September 2019 and presented a study on the quantification of canteen plate waste and estimated effluent load of system.<br>- Published article on GreenNet@PolyU on 31 October 2019 to introduce features and expected benefits of the system.<br>- Attended Recycling Fund Technical Seminar on 22 November 2019 and presented preliminary outcomes of the project.<br>- Attended the Smart Way of Waste Collection and Enhanced Food Waste Collection technical seminar on 8 June 2020<br>- Conducted food waste lecture with University students on 25 November 2020<br>- Attended HKIE technical seminar and presented preliminary outcomes of the project on 29 December 2020<br>- Conducted food waste seminar with University students on 23 January 2021<br>- Conducted webinar about final project outcome on 24 February 2021 |

1.4. Project Methods

Monitoring of the food waste collection system was carried out from 5 July to 12 November 2019. The monitoring period encompassed a summer and first semester in order to record the performance and usage patterns of the system in a typical academic year. The system was monitored in order to investigate the effects of changes in food waste collection practice on the quantity of food waste collected and the behavior and attitude of catering staff managers towards the new system and food waste management practices. In addition, data on system performance, namely dewatering performance (i.e. moisture content of dewatered food waste), electricity and water consumption, system activity patterns and wastewater quality, will also be collected to evaluate the cost-effectiveness and utilization rate of the system. Items monitored are grouped into four categories, namely (i) waste quantities and dewatering performance, (ii) wastewater quality, (iii) system utilization and (iv) users' behavior.

**(i) Waste Quantity and Dewatering Performance**

To quantify the amount of food waste collected at the catering outlets, monthly waste data was obtained from the University's waste contractor, which reports on the weight of food waste collected to the University at the end of each month. The number of bins collected per day was obtained from the food waste collection logbook located at the refuse collection point (Figure 2).

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Location/QTY./WT. | Date | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| 2 | Quantity Delivered To EPD'S ORRC | | | | | | | | | | | | | | | | | | | |
| 3 | 1. 理工大學(S座) | Barrels | 0 | 2 | 2 | 2 | 3 | 0 | 0 | 3 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 3 | 3 |
| 4 | | Kg | 0 | 142 | 199 | 178 | 297 | 0 | 0 | 255 | 151 | 152 | 184 | 133 | 50.5 | 71.5 | 93 | 130 | 180 | 205 |
| 5 | Quantity for South China Processing | | | | | | | | | | | | | | | | | | | |
| 6 | 1. 理工大學(S座) | Barrels | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| 7 | | Kg | 126 | 135 | 93 | 101 | 115 | 84 | 0 | 88 | 125 | 109 | 98 | 84 | 117 | 80.5 | 112 | 121 | 0 | 106 |
| 8 | Contaminated food waste | | | | | | | | | | | | | | | | | | | |
| 9 | 1. 理工大學(S座) | Barrels | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | | Kg | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | Total Quantity | | | | | | | | | | | | | | | | | | | |
| 12 | 1. 理工大學(S座) | Barrels | 1 | 3 | 3 | 3 | 4 | 1 | 0 | 4 | 3 | 3 | 3 | 3 | 2 | 2 | 3 | 3 | 3 | 4 |
| 13 | | Kg | 126 | 277 | 292 | 279 | 412 | 84 | 0 | 343 | 276 | 261 | 282 | 217 | 168 | 152 | 205 | 251 | 180 | 311 |

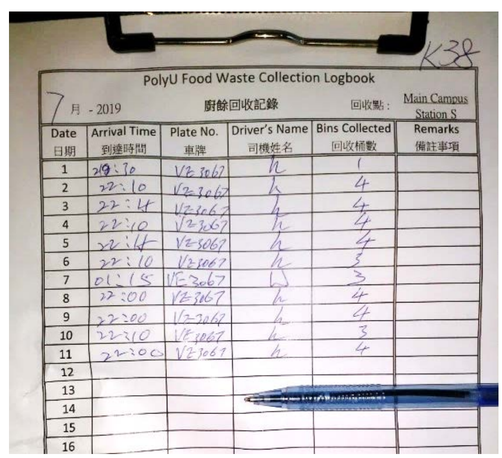



**Fig 2.** Monthly quantity of food waste collected (right) and food waste collection logbook (left)

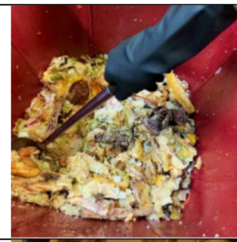
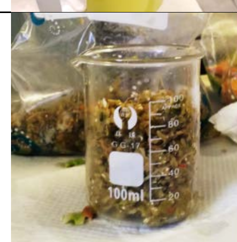
Kitchen food waste survey was conducted to quantify the weight and volume of food waste produced from the canteen during food preparation. Canteen staff were informed to keep all preparation waste for the project team on the day of survey. The volume and weight of food waste were measured. Samples were also collected for the dry weight experiment to measure water contents of the waste. The procedure of kitchen food waste survey is detailed in Table 4. Results from kitchen surveys were used to estimate the quantity of food waste generated and disposed by the catering facilities, which were then compared with the waste data provided by the contractor for the purpose of data accuracy and cross checking.

Since the weight and volume of input food waste would be reduced by the dewatering unit, dewatering performance of the system was determined by comparing the water content and density of food waste before and after dewatering through the dry weight experiment. The dry weight experiment was conducted according to the standard method from AOAC international (Ahn et al., 2014) on a weekly basis to obtain an average dewatering performance of the unit. Experimental procedure of determining dry weight and water content of food waste is listed out in Table 5.

**Table 4.** Kitchen food waste survey procedures

| Step | Description | Photos |
|---|---|---|
| 1 | Collect food waste from kitchen. |  |
| 2 | Measure volume of food waste with measuring jug. |  |
| 3 | Measure weight of food waste on scale. |  |

**Table 5.** Dry weight experiment procedures

| Step | Description | Photos |
|---|---|---|
| 1 | Take food waste sample from kitchen and put sample into a zip lock bag. |   |
| 2 | Measure the weight of the container before filling it with sample. |  |
| 3 | Break food waste sample into small pieces with a food processor. |  |
| 4 | Measure 100ml of sample in a beaker and place the sample in tray. Measure the total weight. |   |
| 5 | Place sample in oven. Heat the sample at 135ºC ± 5 ºC for 2 hours. |  |
| 6 | Remove sample from oven and measure final weight. |  |

### (ii) Wastewater Sampling

Wastewater samples were collected from the residue water each month for water quality tests conducted by an external waster testing agency. Oil and grease (O&G) content, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and total suspended solids (TSS) were examined. The testing laboratory selected, Hong Kong Wastewater Treatment Plant Management Co., Ltd., was recognised under The Hong Kong Laboratory Accreditation Scheme by the Hong Kong Accreditation Service. Standard method APHA 22e 5210B and 5220B were used for the testing. Wastewater samples were collected from the discharge valve located inside the dewatering unit (Fig 3).

**Fig 3.** Wastewater sampling at the discharge point of the dewatering unit

### (iii) System Utilization

To study the utilization and failure rates of the system, activity and maintenance logs were obtained from the system and contractor, which included the number of operations for inlet, pump and dewatering units, as well as emergency stops and faults of various system components. Electricity and water consumptions of the inlet, vacuum and dewatering units were also recorded from meter readings for the consideration in cost analysis.

System activity log, including the number of daily operations of inlet, dewatering and vacuum pump units, were collected from the control box of the system (Table 6). The data log is stored in a USB flash drive, which can be transferred to computer for analysis (Fig 4). System faults and failures were recorded by the contractor in the system maintenance logbook.

**Table 4.** Activity log components

| Component | Data Log |
|---|---|
| Inlet Bench | No. of operations |
| | Emergency stop |
| | Discharge valve fault |
| | Miner fault |
| Pump | Emergency Stop |
| | Pump fault |
| Dewatering | Level sensor Fault |
| | Pump and screw fault |

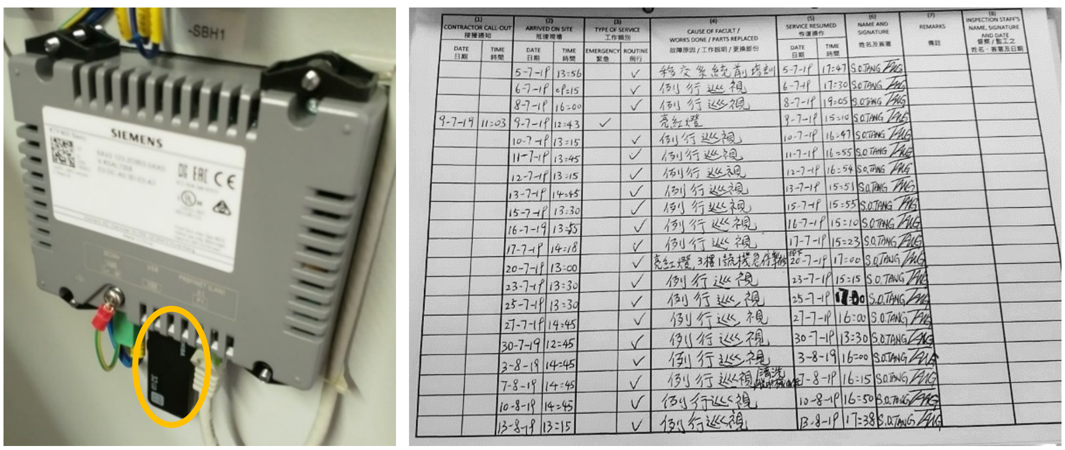



**Fig 4.** System data log stored in USB flash drive (left) and maintenance log (right)

### (iv) Users' Behavior

User behavior towards the system was monitored, surveyed and analyzed for any change with the implementation of the system. Users' personal experience, attitude and comments were collected through interviews for analyzing whether the system can successfully improve food waste collection procedures at the catering facility, such as the location, capacity and labor inputs required for daily operations. Direct system users and managers of the canteen were interviewed to gather their attitudes and personal experiences towards the implementation of a food waste collection system. Changes in user behavior towards the system will be monitored, surveyed and analyzed prior to and following system commission. A summary of data collection carried out during system operation and monitoring period is presented in Table 7.

**Table 5.** Summary of data collected

| | **Data** | **Method of collection** | **Frequency** |
|---|---|---|---|
| 1. Waste quantity & dewatering performance | Waste collected per month and number of bins per day | Waste contractor | Weekly/ Monthly |
| | Input and output weight estimation | Kitchen Survey | |
| | Moisture content and dewatering performance | Dry weight experiment | |
| 2. Wastewater quality | Wastewater sample | Wastewater analyst | Monthly |
| 3. System utilization | System activity and maintenance | Control panel reading and maintenance log | Weekly |
| | Electricity and water consumption | Meter reading | |
| 4. Users' behavior | Opinions on system | Interview and meeting | Once before and after project |

## 2. Project Outcomes

This section presents the data gathered during the project period. The results are grouped into four aspects similar to those described in Section 1.3 Project Methods, namely waste quantify and dewatering performance, wastewater quality, system utilization and user's behavior. Results reported in this section will form part of the basis in providing recommendations in Section 4, including investigation of problems and difficulties direct users may face when using the system, and how food waste collection practices, system setup and cost-effectiveness can be improved.

### 2.1. Waste Quantity and Dewatering Performance

Monthly quantities of food waste disposed were recorded for twelve months prior to (June 2018 to May 2019) system implementation, and four months after (5 July 2019 to 12 November 2019) the implementation of the collection system. System testing and commissioning was carried out from May to June 2019 and therefore the monthly data was excluded from record. In addition to the monthly waste quantities, daily averages of the number of food waste bins used for disposal were also recorded from January to April 2019 and from July to November 2019.

The amount of food waste collected has increased from 6,036 kg per month (199 kg per day) before system operation to 6,767 kg per month (217 kg per day) after system operation (Appendix i). Monthly quantity of source separated and collected food waste has increased by 12%. Meanwhile, the number of waste bins required for food waste collection has decreased by 24% from about 3.8 bins per day before system operation to 2.9 after system operation (Appendix ii). It should be pointed out that the collection of food waste by system was not made compulsory to the catering staff, so as to reduce the impact of change in waste collection practices on the daily operation of the canteens, and to provide catering staff the opportunity to compare and choose manual and automatic food waste collection practices. As such, of the daily 217 kg of food waste collected after system operation, about 199 kg was collected manually and 18 kg was collected by the system (see Section 2.3. for details on system utilization). The low utilization of system collection was mainly due to inlet location and processing capacities as reflected by catering staff (see Section 2.4. for comments from users and Section 4 for recommendations). The anticipated food waste compaction feature of miner at inlet and screw press at dewatering unit was reflected from the reduction of daily bin usage. However, the relatively larger drop in bin usage (24%) compared to the proportion of food waste collected by system (8%) was partially due to the fact that bin removal and replacement at dewatering unit was not performed consistently on a daily basis by the catering staff, as some of the food waste was held up by the dewatering unit at the temporary storage tank and compacted food waste would fill up collection bin more slowly. In addition, catering staff would sometimes forget to replace collection bin at dewatering unit at the beginning months of system operation.  Reminders were given by the project team to the staff on bin replacement whenever such issue was found.

The dewatering performance of the system was evaluated by comparing moisture content of waste samples from the dry weight experiment. Average moisture content of unprocessed food waste was around 76% (range 69-83%) and for dewatered food waste was 64% (range 54-73%), leading to around 12% moisture content reduction from dewatering process (Fig 5). In terms of waste compaction, the mincing process was able to reduce volume of food waste by about 60% (range 49-69%), which in turn increased the density of processed food waste from 308 to 481 g/L, or by about 56%. Table 8 shows the summary of waste quantity, dry weight and kitchen survey results before and after system operation. Detailed results of kitchen survey and dry weight experiment are shown in Appendix iii and iv.

**Table 6.** Summary of waste quantity, dry weight and kitchen survey results

| | Before System Operation | After System Operation |
|---|---|---|
| Waste quantity | | |
| Average quantity per day (kg) | 198.8 | 217.2* |
| Average bin usage per day | 3.8 | 2.9 |
| Average quantity per bin (kg) | 52.0 | 74.1 |
| Dry weight experiment | | |
| Moisture content (%) | 76.3% | 64.4% |
| Kitchen Survey | | |
| Density before system processing (g/L) | N/A | 307.6 |
| Density after system processing (g/L) | N/A | 481.0 |
| Weight of food waste per inlet usage (g) | N/A | 1,388 |
| Volume of food waste per inlet usage (L) | N/A | 4.54 |

*Usage of system not compulsory, daily manual collection: 199 kg; system collection: 18 kg

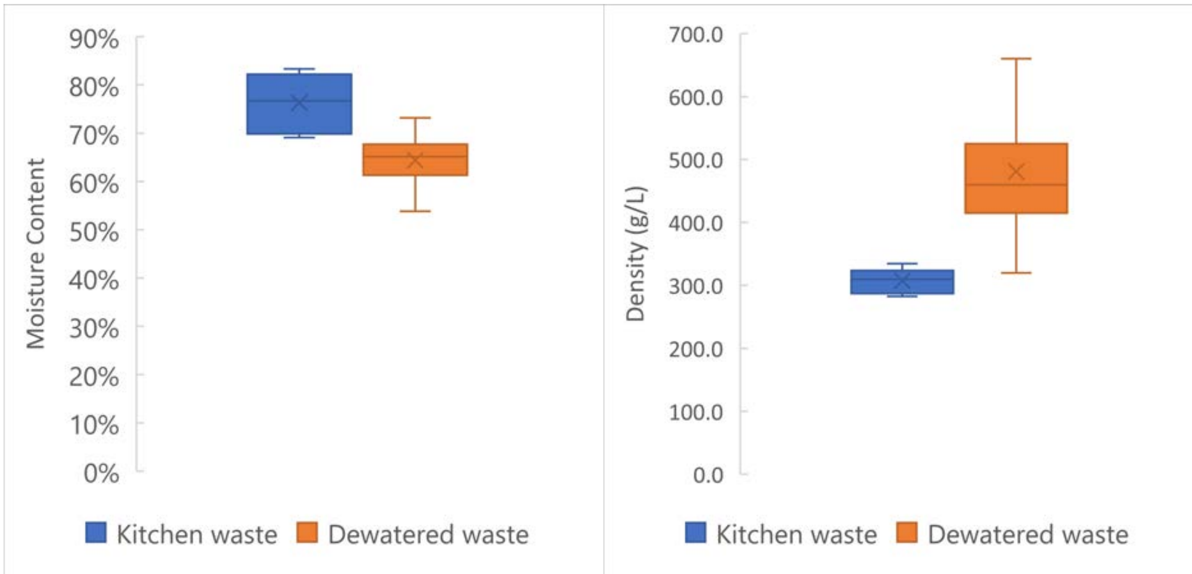



**Fig 5.** Food waste moisture content (left) and density (right) before and after system processing and dewatering

2.2. Wastewater Quality

Wastewater samples were collected once a month for six months. Oil and grease (O&G) content, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD) and total suspended solids (TSS) were tested by Hong Kong Wastewater Treatment Plant Management Co., Ltd. The wastewater generated from the dewatering process had high BOD, COD and TSS. O&G content was occasionally high depending on the type of food waste processed. According to the standards for effluents discharged into foul sewers by EPD, the limits set for BOD, COD, O&G and TSS are 1,200, 3,000, 100 and 1,200 mg/L for flow rate of less than 10 $m^3$/day respectively.

Average effluent discharge rate of the system is about 0.1$m^3$ (100L) per day. Effluent from organic food waste was observed to have high BOD, COD and TSS contents, indicating that the wastewater generated from dewatering process is in small quantities and has high level of organic contents, and should be discharged into grease traps instead of direct discharge. The discharge should also be connected to the foul drain of the premise and discharged with other effluents (e.g. from kitchen and toilets) to the sewage treatment plant for processing. Results of water tests are presented in Table 9.

**Table 7.** Monthly results of wastewater tests

| Sampling Date | BOD (mg/L) | COD (mg/L) | Oil & Grease (mg/L) | Total Suspended Solids (mg/L) |
|---|---|---|---|---|
| 25-Jul-19 | 6,450 | 7,440 | 9 | 1,080 |
| 01-Aug-19 | 7,770 | 13,700 | 585 | 5,510 |
| 05-Sep-19 | 2,100 | 5,770 | 28 | 2,670 |
| 03-Oct-19 | 9,440 | 24,600 | 189 | 5,380 |
| 07-Nov-19 | 1,280 | 2,280 | 9 | 548 |
| 07-May-20 | 2,410 | 7,290 | 49 | 1,570 |
| **Average** | **4,908** | **10,180** | **145** | **2,793** |

## 2.3. System Utilization

System activity, electricity and water consumption were recorded to better understand usage patterns and operation costs of the system. Usage patterns were recorded from 5 July to 8 November 2019. Usage pattern was determined by the frequency of inlet operations each day. Electricity and water consumptions of the inlet, vacuum and dewatering units were also recorded to determine operation cost of the system (Appendix v and vi).

The average electricity and water consumption of the system as gathered from meter readings were 7.36 kWh/ day and 0.096 $m^3$/ day, the system consumes 0.74 kWh and 0.011 $m^3$ of electricity and water per inlet operation (Table 10). Average usage of all inlets were 9.4 times per day, in which Inlet 1 has the highest usage and Inlet 3 the lowest. Inlet 1 is located at the food preparation area of the 3/F canteen kitchen and is responsible for collecting all preparation wash generated from the kitchen. Inlet 2 is installed at the dish washing area of the 3/F kitchen, which mostly receives food waste from the dining and beverage area. Inlet 3 is located at the dish washing area of the 4/F kitchen and collects food waste generated from the Chinese restaurants. The relatively higher usage of Inlet 1 is mainly due to preparation waste generated from the peeling and cutting of vegetables and meat. Since the Chinese restaurants on 4/F has less customers and part of their food items (e.g. dim sum and pastry) were premade by a food factory, the kitchen produced less preparation and plate waste than the 3/F canteen. Moreover, the catering staff preferred disposing all unserved rice and cooked dishes manually to waste collection bins at close of business each day, simply due to the fact that it is more convenient and less time-consuming to dispose the large amount of unserved food into collection bins manually than to have it processed in batches by the food waste system, especially after large events and banquets. Full inlet usage is shown in Appendix vii. System maintenance and breakdown incidents were recorded in the contractor's maintenance logbook, detailing the dates and time of routine checking and reparation work performed (Table 11). Generally speaking, the number of system failure increased from once per month in the beginning (from July to August 2019 of the summer semester) to two to five times a month at the beginning of the new academic year (September to October 2019). Majority (70%) of the system errors during operation and monitoring period were contributed by issues with the dewatering unit, namely the clogging of the temporary storage tank by viscous food waste. As a result, food waste within the tank could not be dewatered and discharged out of the system, which led to over accumulation of waste that triggered shut down of the system. In light of the identified shortcoming of the system, the project team requested the contractor to ensure proper emptying of the food waste to collection bin and separation of wastewater from the waste by the dewatering unit through more frequent cleaning of its temporary storage tank and screw press.

The transport pipe connecting Inlet 1 came off loose when the canteen and system resumed operation after four months of idling. The project team took note that proper flushing of the system is required after system idling so as to ensure transport pipes are unclogged and any food residues are cleared from pipes to prevent backflow of food waste back to the inlets. Inlets and dewatering unit should also be flushed and cleaned if the system is anticipated to idle for an extended period of time, and power and water supply to the system should also be cut off.

Other faults included clogging of inlet units and accidental pressing of emergency stop buttons. Both of the faults occurred at the beginning of the monitoring period as the canteen staff were likely still familiarizing the operation of the system. Such incidents did not occur again in the remainder of the monitoring period.

**Table 8.** Average daily electricity, water consumption and inlet usages

| | Average Daily Electricity Consumption (kWh) | Average Daily Water Consumption ($m^3$) | Average Daily Inlet Usage (no. of times) |
|---|---|---|---|
| Inlet 1 (3/F) | 0.35 | 0.016 | 6.0 |
| Inlet 2 (3/F) | 0.31 | 0.0057 | 2.9 |
| Inlet 3 (4/F) | 0.29 | 0.0014 | 0.5 |
| Dewatering Unit | 0.69 | 0.073 | N/A |
| Vacuum Pump | 5.72 | N/A | N/A |
| **Daily Total** | **7.36** | **0.096** | **9.4** |

**Table 9.** Summary of system faults during monitoring period

| Month | No. of fault(s) | Description of fault |
|---|---|---|
| Jul-19 | 2 | Clogging of one of the inlet units (once) and emergency button accidentally pressed by staff (once). |
| Sep-19 | 5 | Dewatering unit clogged, leading to high levels of food waste in temporary storage tank. |
| Oct-19 | 2 | Dewatering unit clogged, leading to high levels of food waste in temporary storage tank. |
| Mar-20 | 1 | Transport pipe connecting inlet Unit 1 on 3/F kitchen came off loose. |

2.4. Users' behavior

Direct system users and mangers of the canteen were interviewed to gather their attitudes and personal experiences towards the implementation of a food waste collection system. Changes in user behavior towards the system will be monitored, surveyed and analyzed prior to and following system commission.

**(i) Before System Implementation**

Individual interviews were conducted on 7, 12, 14 December 2018 to ask canteen managers and staff on existing management practices on food waste sorting and collection, and their attitudes towards food waste collection. Three staff on 3/F canteen and two managers and three staff on 4/F restaurants were interviewed (Table 12).

Overall, the managers and staff were satisfied with the manual food waste collection practices. They have noted that source separation and collection of food waste was already part of their day to day job, and did not see the work as time consuming or causing extra workload. However, extra walking might be required to transfer the food waste due to the placement of the food waste collection bins in the kitchens. The interviewees also agreed that the collection practice had little health and safety concerns, as no injuries, health issues and odor problems had occurred from the collection of food waste and manual transportation of waste bins to the waste stations. When asked about their opinions towards the installation of an automatic food waste collection system, some interviewees raised concerned over the size and working mechanism of the system. After explaining the general working principles of the system, the interviewees were hoping that the system would bring convenience to their daily food waste collection practices. Lastly, the staff were generally positive towards the idea of food waste collection and recycling.

**Table 10.** Summary of interview outcomes before system implementation

| Categories | 3/F Student Canteen | 4/F Staff and Student Restaurants |
|---|---|---|
| Management Practice | Not inconvenient<br>• Part of day to day work when collecting and washing plates | Not inconvenient<br>• Part of day to day work when collecting and washing plates |
| | Little workload<br>• Bins carried once or twice per day (5 minutes per trip) | Little workload<br>• One staff carrying a bin once per day (5 to 6 minutes per trip)<br>• A bit more walking required to dispose food waste to collection bin |
| | Not time consuming<br>• Manageable within working hours | Not time consuming<br>• Manageable within working hours |
| Quantity of Food Waste | About one bin per kitchen area | About half a bin per day, generally little leftover from diners (except from banquets) |
| Health and Safety | Little health and safety concerns<br>• No injuries or health issues related to food waste collection<br>• Little odor as waste is removed daily | Little health and safety concerns<br>• Trays filled with food waste can be heavy and harder to handle, will ask others to help to carry trays if needed<br>• Careful in transporting food waste<br>• Little odor as waste is removed daily |
| Food Waste Collection System | Concerns over size and working mechanism of system | Concerns over size and working mechanism of system |
| Views on Food Waste Collection | Improvement needed<br>• More convenient to require less walking around<br>Positive attitudes<br>• Support food waste collection and recycling<br>• Government should promote more on food waste recycling | Positive views<br>• Food waste sorting could lead to lighter waste bins<br>• Government should be proactive in promoting food waste collection |

### (ii) After System Implementation

A meeting was held on 28 August 2019 with the canteen managers, contactor and relevant University staff to discuss operation issues and concerns encountered by the cantering staff during system operation. Issues on (i) inlet capacity and location, (ii) operation time, (iii) pest and hygiene, (iv) odor and (v) waste bin collection were identified and discussed for future improvements and optimization of the system.

**Inlet capacity and location**

- The caterer has raised concerns over the size and capacity of the inlet unit as some food items, such as whole chicken and goose carcasses, cannot be fitted in the inlet. Thus, additional time was required for the staff to sort out waste suitable for disposal at the inlet. It was also mentioned that the distance of some inlet from food waste generation points were too far and inconvenient for the transportation of food waste.

**Inlet operation time**

- The contractor has stated that, according to system specifications, the disposal of food waste by each inlet bench unit requires about 2 minutes for each cycle. Catering staff has reflected that they would not have additional staff and time for the disposal procedure during peak service hours, especially when the new semester starts.

**Pest and hygiene issue**

- Flies and cockroaches have been found around the inlet bench units at kitchens and around the collection bin at the refuse room. The pest was likely to be attracted by the odour of food waste and the warm interior of the machines, which raised hygiene concerns.

**Odor issue**

- Processed food waste gathered by the collection bin has created odour problem while the waste bin was waiting to be collected by the waste contractor every night. In addition, since detergents cannot be used when cleaning the inlet units to avoid food waste contamination, only hot water can be used. Oil and grease could not fully be removed by cleaning with hot water, and the use of hot water by staff has raised safety concerns.

**Waste bin collection**

- The catering company has reported that the change of waste bins at the refuse room after the implementation of the system was inconvenient, since staff had to access the ground floor refuse room for the replacement of full bin.

2.5. Promotion

In order to promote the collection system and share study outcomes with the C&I sector, and to raise public awareness on food waste recycling, the project team has attended a number of seminars and conferences, and organized a number of site visits and workshops throughout the project period (Table13).

In November 2018, the team presented the conference paper titled “Feasibility of Automatic Food Waste Collection for a University Catering Complex” at the Hong Kong Joint Symposium to attendees from ASHARE, HKIE and CIBSE. The paper was an introduction of the project’s aim, design, method and expected outcomes. In November 2019, the team also attended the CIBW062 Symposium for the building and construction industry with another conference paper titled “Quantification for Food Wastes of University Canteens”. The paper analyzed food wastes generated in one of the canteens of the project, and determined the collectable food waste, its composition and generation patterns, and the probable amount of wastewater produced from dewatering process.

As the technology of the collection system is open to the industry, the team has promoted the system to the C&I sector, caterers and recycling service providers at a number of occasions. The team attended the “Recycling Fund Technical Seminar” organized by HKPC on 22 Nov 2019 and seminar on “The Smart Way of Waste Collection and Enhanced Food Waste Collection” organized by EVD, CAD and AMC on 8 Jun 2020 to present project aim, system design and preliminary outcomes to the recycling industry including recyclers and food waste collectors, restaurant operators from C&I sector, HKIE members and the general public. The team also organized an online seminar with ASHRAE Hong Kong Chapter and HKIE on 29 December 2020 to present the technical aspect of the system, project outcomes and analyzed data to recycling industry including recyclers and food waste collectors, restaurant operators from C&I sector, engineer and general public. To present to final project outcomes to registered food waste collectors, C&I parties who have expressed interest in delivering food waste to ORRC and the public, the team organized a webinar about food waste collection practice and final outcome of this project with WGO on 24 February 2021.

The project team has also introduced the system to students and staff on campus through site visits, lectures and newsletters. An article was published on 31 Oct 2019 on the GreenNet@Polyu newsletter (https://www.polyu.edu.hk/greencampus/GreenNet/issue/21/campus-article03.php) to introduce system functions and its expected benefits. A lecture and a seminar were conducted on 25 November 2020 and 23 January 2021 with engineering and multi-disciplinary university students.

**Table 11.** Summary of activities

| Date | Activity | Description | Targeted Group(s) | Number of participants |
|---|---|---|---|---|
| 21 Nov 2018 | Attended Hong Kong Joint Symposium 2018, organized by ASHARE Hong Kong Chapter, HKIE, and CIBSE (KPI 4) | Presented aim, design and expected outcomes and benefits of the project | Academics, members of ASHARE, HKIE and CIBSE | More than 100 |
| 9 Sep 2019 | Attended CIBW062 Symposium on Water Supply and Drainage for Buildings (Melbourne, Australia) (KPI 4) | Presented study on the quantification of canteen plate waste, estimation of effluent load from dewatering of food waste | Academics, building and construction industry | More than 100 |
| 31 Oct 2019 | Published article on GreenNet@PolyU (KPI 6) | Sharing of system function and features, and expected benefits | PolyU students and staff | NA |
| 31 Oct 2019 | Technical visit from EPD | Sharing project's progress update and introduction to system operation and components | EPD and HKPC | NA |
| 22 Nov 2019 | Presented project details /Attended Recycling Fund Technical Seminar (HKPC) (KPI 3) | Sharing of project aim, system design and preliminary outcomes | Recycling industry including recyclers and food waste collectors, restaurant operators from C&I sector | 66 |
| 8 Jun 2020 | Presented project details/Attended Technical Seminar: The Smart Way of Waste Collection and Enhanced Food Waste Collection, organized by EVD, CAD and AMC (KPI 3) | Sharing of project and system design, and outcomes and recommendations of the project | Invitation was sent to all members of HKIE including members from the Environmental Division. Public announcement of the seminar was also made on HKIE website. Recyclers and food waste collectors, restaurant operators from C&I sector and general public were all targeted. | About 50 |

| | | | | |
|---|---|---|---|---|
| 25 Nov 2020 | Conduct lecture at university (KPI 6) | Sharing of technical aspect of the system, project outcomes and analyzed data | Engineering students | About 80 |
| 29 Dec 2020 | Organized ASHRAE and HKIE technical seminar (KPI 3) | Sharing of technical aspect of the system, project outcomes and analyzed data | Recycling industry including recyclers and food waste collectors, restaurant operators from C&I sector, engineer and general public | About 50 |
| 23 Jan 2021 | Conducted food waste seminar at university (KPI 6) | Sharing of food waste recycling, project outcomes, data and technical issues | Students from multi-disciplines | About 40 |
| 24 Feb 2021 | Organized webinar about final project outcome with WGO (KPI 7) | Sharing of final project outcome | Invitation was sent to all recyclers, food waste collectors, and restaurant operators who have expressed interest in food waste recycling. Public announcement of the webinar was also made on WGO website for public participation. | About 50 |

# 3. Life Cycle Cost Analysis

This section will evaluate the benefits resulted from the implementation of the food waste collection system. In particular, the space requirement, installation and operation costs for manual and automatic food waste collection management practices will be compared. Since manual collection of food waste does not require any machinery, the space requirement will be equal to the number of waste bins placed in the kitchen or refuse area. In the case of the catering complex, five food waste bins are required for their daily operation, which adds up to 1.7m$^2$ of the area (Table 14), whereas the total area required for automatic collection of food waste is 5.7m$^2$ with the addition of the system (i.e. 3 inlet units, one vacuum pump and dewatering unit).

**Table 12.** Space requirement for manual and system collection methods

| | **Manual** | **System** | **Remarks** |
|---|---|---|---|
| Bin area (unit space: 0.34 m$^2$) | 1.7 | 1.7 | 5 waste bins (180L) for both methods. |
| System area (3 inlet, 1 vacuum, 1 dewatering units) | N/A | 4.03 | Inlet unit: 1020(L) x 700(W) x 1520(H) mm<br>Vacuum unit: 1400(L) x 600(W) x 1370(H) mm<br>Dewatering unit: 1610(L) x 650(W) x 1935(H) mm |
| **Total area (m$^2$)** | **1.7** | **5.73** | |

For cost analysis, a 10-year operation period is assumed for the food waste collection system. The system purchase, installation and retrofitting costs totaled HK$1,751,900. The waste bin cost for both manual and automatic collection is assumed to be HK$6,857 for five 180L food waste collection bins with replacement period of 3.5 years. It can be seen from Table 16 that the initial investment cost of the system is higher than manual collection method. However, when taking operation costs into account, it can be seen that system collection is more cost-effective compared with manual collection. The system operation and maintenance costs of HK$34,675 and HK$268,300 are offset by the lower waste collection charge due to lower daily bin usage. System operation cost is calculated from the average electricity and water consumption in each system cycle (i.e. each time system is activated), which is about HK$1 per cycle (HK$0.9 electricity cost and HK$0.1 water cost). Daily system usage was 9.5 cycles per day, which is taken from the average number of usages from the catering staff recorded in the monitoring period. Meanwhile, labor cost of both collection methods is the same as the source separation and disposal processes require similar labor input (e.g. 1 hour per day) from the catering staff. Since collection fee of waste contractor is charged by bin, the reduced bin usage of 2.9 bins per day (compared with 3.8 bins per day in manual collection) greatly helped to save costs in the long-term. Bin usage reduction is achieved by the mincing and dewatering processes of the inlet and dewatering units, which compact and reduce the volume of food waste. Overall, the 10-year cost for manual collection was estimated to be HK$19.5 million (HK$26.8/ kg) and that for system collection was HK$17.0 million (HK$21.4/ kg), indicating an overall 12.8% cost saving (20.1% per unit saving) for the adoption of collection system (Table 15).

With the above values as reference, the overall costs of manual and system collection are compared with various food waste collection charge to better understand at what level of collection charge from private food waste collection services the automatic collection option will be a more cost-effective option. Collection charge is studied as it contributes to the highest proportion of ongoing expenditure in manual (98.8%) system (86.5%) and system ideal case (75.1%) collection practices over a 10-year period. Thus, any reduction in daily bin usage (i.e. reduction in volume of food waste through mincing and compaction processes) will greatly reduce the cost of food waste collection in the long run. From the analysis, system collection becomes an economically viable option when waste collection charge is over HK$646 per bin for a 10-year period (Fig 6). Automatic system collection would not be a cost-effective option if unit waste collection costs from contractors are lower than the value according to the studied system configuration.

However, system usage during monitoring period may not reflect full cost-saving potential as system collection was not compulsory, catering staff was free to dispose food waste manually or via system. Thus, maximum volume reduction by system collection and bin usage cost reduction were not realized. In the ideal system usage scenario where all food waste is collected by system, the project team estimated that daily bin usage would reduce from 3.8 bins to 1.5 bins compared with manual collection due to 60% volume reduction of food waste from mincing process. Average number of inlet operations would increase to 75.3 times per day for the collection of around 200kg food waste, assuming each inlet can process 4.54L of waste per operation and around 342L of food waste (3.8 bins filled with 90L of waste each from manual collection data before system implementation) is generated each day at the premise. In this case, 10-year cost is reduced to HK$10.1 million (HK$13.9/ kg) and system collection becomes economically viable when waste collection charge is over HK$245 per bin. Net present value (NPV) for system collection was calculated to compare payback periods of system collection and system ideal case. Payback period for system collection was 7.0 and 11.4 years for discount rates of 0% and 10%, while that for the system ideal case was 1.9 and 3.1 years. The results showed that system collection may not be beneficial in the studied case when caterers were provided with the option to dispose food waste manually or via system.

**Table 13.** 10-year cost estimation for manual and system collection methods

| **Cost (HK$)** | **Manual Collection** | **System Collection** | **System Ideal Case** | **Remarks** |
|---|---|---|---|---|
| Storage bin | 6,857 | 6,857 | 6,857 | HK$480/ bin; replaced once every 3.5 years |
| System | N/A | 1,070,800 | 1,070,800 | Inlet, vacuum, dewatering units, pipes |
| Installation | N/A | 588,000 | 588,000 | Installation, T&C, project management |
| Retrofitting | N/A | 93,100 | 93,100 | Wall, grease trap, electrical and water points |
| **Installation cost** | **6,857** | **1,758,757** | **1,758,757** | |
| Labor | 219,000 | 219,000 | 219,000 | Wage: HK$60/ hr; Labour input: 1hr/ day |
| System operation | N/A | 34,675 | 274,845 | Water and electricity: HK$1/ operation<br>Reference tariff<br>Electricity: HK$1.28/ kWh (non-residential)<br>Water: HK$9.05/ $m^3$ (domestic tier 4)<br>No. of operations<br>System collection: 9.5/ day<br>System ideal case: 75.3/ day |
| Maintenance | N/A | 268,300 | 268,300 | 21-month warranty period: HK$39,200<br>3rd year: HK$24,000 (+5% each year onward) |
| Waste collection charge | 19,223,820 | 14,670,810 | 7,588,350 | Bin collection fee: HK$1,386/ bin<br>Manual collection: 3.8 bins/ day<br>System collection: 2.9 bins/ day<br>System ideal case: 1.5 bins/ day |
| **Operation cost** | **19,442,820** | **15,192,785** | **8,350,495** | |
| **Overall cost** | **19,449,677** | **16,951,542** | **10,109,252** | |
| **Cost per kg of waste** | **26.8** | **21.4** | **13.9** | |

**Table 14.** Net Present Value and payback period of system collection

| | System Collection | | System Ideal Case | |
|---|---|---|---|---|
| Initial system cost (HK$) | 1,751,900 | | 1,751,900 | |
| Discount rate | 0% | 10% | 0% | 10% |
| NPV (HK$) | 746,235 | -216,904 | 7,588,530 | 3,987,390 |
| Payback period (year) | 7.0 | 11.4 | 1.9 | 3.1 |

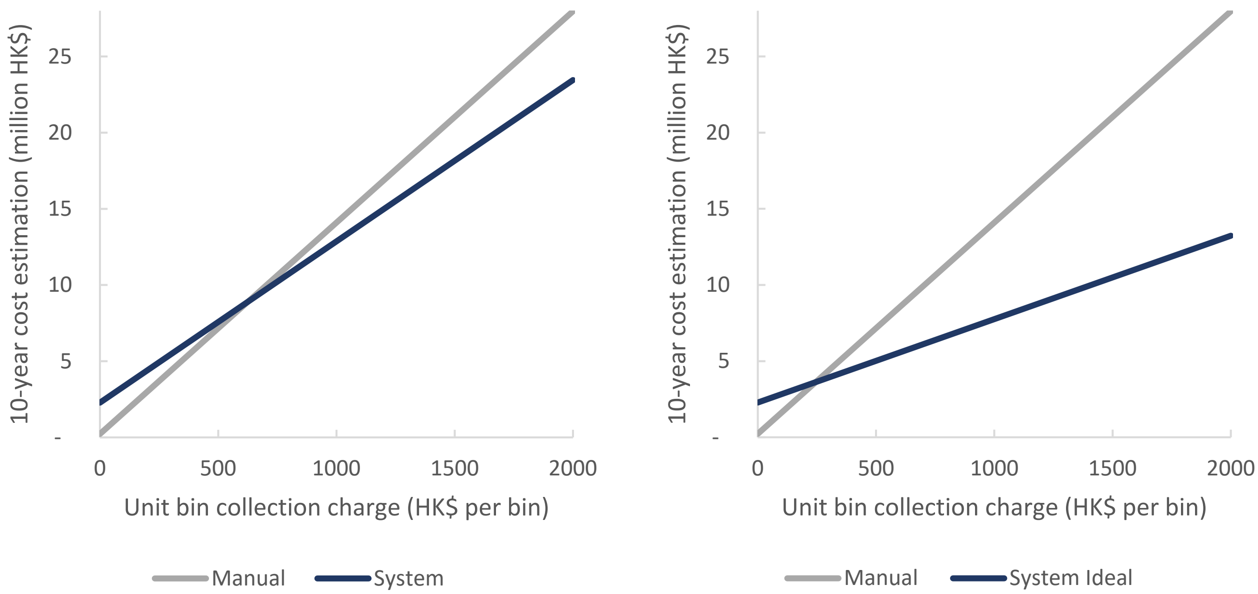



**Fig 6.** Comparison of 10-year food waste collection cost with varying unit collection charge by waste contractors (HKS per bin), according to studied system usage (left) and ideal scenario where all food waste is collected by system to achieve maximum volume reduction (right)

## 4. Recommendations

This section will evaluate the needs for modifying the waste collection system to fit for the unique features and the requirement of the catering service providers, namely middle and large-scale catering facilities, in Hong Kong. The feasibility for a territory-wide implementation of the system to improve the overall performance food waste collection in Hong Kong will also be investigated. Throughout the data collection period, our team has communicated closely with the catering company to gather feedbacks on the issues encountered on the daily operation of the food waste collection system. In short, there are five areas that require careful consideration when implementing such system at kitchens, namely inlet capacity and location, inlet operation time, pest and hygiene, odor, and waste bin collection.

### 4.1. Market Available Products

For the consideration of water content, generally, by the similar techniques in market, the volume could be reduced by up to 80% and the weight by up to 50%. Water content from food waste can either be removed by applying mechanical pressure (e.g. screw press and centrifuge) or heat.

Screw press has its limitations on the dewatering of food waste due to intrinsic chemical properties of food waste and water (Webb, 2018). Water molecules are polar and are able to form loose bonds with each other and other organic molecules in meat and vegetables by capillary sorption, adhesion and chemisorption (Heidenreich, Müller and Foscolo, 2016). Furthermore, long-chained organic molecules with varying polarities, such as polypeptides and polysaccharides, are able to associate with water molecules or entrap water molecules with folded and twisted chains.

Dewatering of food waste by screw press is challenging due to the present of bound water, which cannot be removed by applying mechanical pressure (Lee and Hsu, 1995). Thus, screw press is only able to remove the free water content of food waste. Our experimental screw press dewatering unit is able to reduce water content of food waste down to 60%. Similar to a screw press, a centrifuge can be used to create mechanical force for separating free water from food waste by pushing it against a fine mesh, and water content of food waste can be reduced down to 50-60%.

To achieve lower moisture content of food waste, heat energy must be applied to overcome the attractive forces of bound water. Thermal dewatering system is able to reduce moisture content of food waste down to 10%, but will generally require longer processing time and much higher energy demand compared with screw press system. For instance, each cycle of heating and drying process can take up to 8 hours to complete, which greatly limits the ability of the system to continuously process food waste when compared with the screw press or centrifuge process.

Since food waste generated from the C&I sector in Hong Kong is expected to be collected and transported to centralized resource recovery facilities (ORRCs) for further energy recovery and composting, food waste does not require extra heating, dewatering or composing process before collection at source. Thus, a food mincing system itself will be sufficient to achieve compaction of food waste for easy transportation without diminishing its organic content (i.e. for energy recovery at ORRCs).

## 4.2. System Modifications

Food waste and wastewater output, usage patterns, lifecycle costs and comments from catering staff are considered for system modifications. Suggestions on the modification of the system to future implementation in Hong Kong restaurants will be discussed in this section.

### Inlet and pipe modifications

According to system users, the location, capacity and processing time of inlet units are some of the major concerns during system operation. Specifically, the inlet units should be placed next to or close to generation sources of food waste, namely the food preparation and dish washing areas of kitchens, where wastes from food preparation and unfinished plates are generated and collected. In the case of the catering complex, an inlet should be placed near the siu mei (BBQ meat) section of the 3/F kitchen, as the section generated large amount of bones, egg shells and rice throughout the day. Unfortunately, an inlet could not be placed at the area due to space limitations of the existing kitchen design and layout. Thus, it is important to identify or predict food waste generation hotspots at existing or new catering premises, so as to optimize the placement of inlet units and offer convenience to kitchen staff for the disposal of food waste. Ideally, the location of inlets should be incorporated in the planning and design stage of new catering facilities for the proper laying of pipes and electricity and water supply points. The inlet capacity should also either have larger capacity or shorter processing time, such that a larger volume of food waste can be disposed at each cycle to reduce idling time of staff and the buildup of food waste at the kitchen. During the monitoring period, it was mentioned by the canteen manager that some food waste items, such as bones of whole chickens, cannot be fitted into the inlet unit. It is recommended that the staff can break the whole chicken into few smaller pieces before disposing them at inlets when such occasion arises, or catering facilities can opt for inlets with larger processing capacities if they anticipate generation of large food waste items during their day to day operations.

One way of increasing the capacity and shorten the processing time of inlet units is to replace 50mm transport pipes to wider 200mm pipes, such that it is not required for the system to break food waste into very small pieces before transportation. Therefore, the inlet units can dispose food waste with shorter processing and mincing time in each operation. This also has the benefit of reducing the chance of pipes getting clogged and keeping capacity of inlet units at 6L to keep the system compact and space requirement low. Additionally, inlet capacity can be increased by using inlets with larger feed volume. This is recommended if the catering facility is spacious and prepares all daily menu items in big batches, generating a large quantity of food waste in a short period of time. For instance, this scenario applies to the project kitchens where canteen staff prepare the majority of ingredients in one batch in the morning, creating a large volume of preparation waste in a few given hours.

Nevertheless, the designed capacity of all inlets (three 6L inlets, each with 180L/ hour processing capacity) for the study is more than enough for the catering complex that generates around 200kg of food waste per day. The given inlet capacity can process all food waste generated from the canteen and restaurants in under an hour. Multiple inlets were installed in the experimental study so as to provide convenience on food waste disposal for the catering staff.

**Replacement of dewatering unit with storage tanks**

In addition to increasing the capacity of inlet units, it is recommended that the dewatering feature of the system is removed, and the dewatering unit is replaced with an air-tight food waste collection tank (Fig 7). The modification will provide a number of benefits, including improvement of hygiene conditions, minimization of odor and pests, as well as reduction of system failure rate due to less mechanical moving parts (since majority of system failures recorded were due to malfunction of dewatering unit). System installation costs will also be reduced as a storage tank is cheaper to manufacture than a dewatering unit. Adoption of storage tank means that drainage connection is not required as no wastewater will be discharged from the system from the food waste collection process. The elimination of drainage requirement can enhance the installation flexibility of the system as system users will not have to concern about wastewater quality and discharge location.

Replacing the dewatering unit with storage tank will also reduce electricity and especially water consumption, since the unit represents about 9% daily electricity consumption and over 75% daily water consumption. High water consumption of the unit was mainly due to the frequent self-cleaning requirement for the screw press to eliminate potential clogging, which has been shown to be the problematic component of the system.

Furthermore, ORRCs are anticipated to be the default processing destination for food waste from the C&I sector in Hong Kong in the future, keeping the water and organic contents of food waste without prior dewatering will help to ensure energy and compost productions at the resource recovery centers. As the C&I sector will benefit the most from transportation savings, a food waste collection system with waste mincing function will be sufficient to achieve the desired outcome.

Regarding transportation, the collection tank is collected by a side-loader and therefore easy vehicle access to the tank or refuse room has to be considered. Each catering facility is suggested to be allocated with at least two storage tanks, such that the tanks can be deployed in rotation when one tank is collected for transportation to recycling facilities. Since food waste collection is performed on a daily basis, the storage tanks are suggested to be about double or even triple the volume of daily food waste output at catering facilities. For instance, the studied catering complex uses around 2.9 bins (180L capacity each) per day to collect its food waste, assuming all bins are filled to half full (90L, as instructed by the waste collection service provider), a system storage tanks should have capacities of minimum 500L. The redundancy is put in place to ensure smooth collection process, and acts as a buffer when collection service from waste contractors is suspended for a day or two due to severe weather or unanticipated events.

In the case where caterers would like to keep the dewatering feature, they should ensure wastewater discharged of the dewatering unit is connected to the grease trap and foul drain of the premise with other effluents, such as discharge from toilets and kitchens to the sewage treatment plant for processing. It should also be mentioned that regular cleaning and maintenance of the temporary storage tank and screw press are required to prevent clogging of the dewatering unit. Daily flushing of inlet units with hot or warm water will also reduce the likelihood of clogging of dewatering unit by dried food waste.

**Ventilation and pest control**

When the vacuum pump and storage tank units are placed within an enclosed area (e.g. refuse room), it is important to ensure the enclosure is well ventilated with exhaust fans, so as to reduce buildup of heat generated from vacuum pump and any odor from waste bins or storage tanks within the area. The food waste collection bin collecting food waste from dewatering unit should also be covered and enclosed as far as possible to prevent pests from crawling into the bin and contain the odor while it is collecting waste.

It is also important to apply pesticide gels regularly around gaps and on back-panels of the inlet units, as pests and insects may be attracted to inhabit and nest at the inner layers of the units. However, pesticides should not be applied at inlet openings to avoid contamination of incoming food waste. Regular cleaning and flushing of inlet openings with hot water is also useful in removing any food waste and scraps to avoid attracting pests. As such, it is also recommended that hot water supply is available at the vicinity of the inlet units, which is usually the case at the kitchen facility.

**Installation**

In order to optimize the system and accommodate all the above changes, it is recommended that the automatic system is installed in new catering facilities or buildings, such that the locations, power and water supply points, pipe layouts and drainage of the system can be planned and designed beforehand, and inlets can be placed close to food waste generation points and wider 200mm pipes can be easily fitted within the building. Retrofitting the system in existing facilities and buildings is still possible but there will be difficulties on finding appropriate space for system placement and pipe layout, and additional drilling work and provision of power, water and drainage points will be required according to the installation experience of this project. It should be mentioned that the maximum transport pipe length for the experimental small-scale system is 50m, which is suitable for food waste transportation three or four stories above ground. Longer transportation distance will require a more powerful vacuum pump and ventilation system for heat dissipation. Vacuum pump should be installed in refuse room or plant room for better noise control.

It is recommended that the centralised food waste collection system is installed in catering complexes that comprise of a number of food waste generation points either on the same or different floors, such as canteens and food courts in malls, institutions or factories, or hotel restaurants. These complexes tend to have a low turnover rate when compared to small restaurants, thus are more likely to fully utilise the system in the long-term and to achieve the most cost savings. System ownership is recommended to be given to property or hotel managements such that a change in tenant would not affect the continual operation of the system. A summary of recommendations is shown in Table 17.

**Table 15.** Summary of reported issues of food waste collection system and recommendations

| Issue | Description | Recommendation |
|---|---|---|
| Inlet capacity and location | • Size and capacity of the inlet units are too small<br>• Location of some inlet units is inconvenient | • Replace 50mm transport pipes to wider 200mm pipes<br>• Increase inlet capacity so it can process a larger volume of food waste per batch (if space permits)<br>• Inlet units placed close to food waste generation sources or incorporated in work benches for convenience, e.g. the food preparation and dish washing areas in kitchens<br>• Break large food waste items (e.g. whole chicken bones) into smaller pieces before disposal at inlet |
| Inlet operation time | • Each cycle of inlet operation is too long<br>• Catering staff do not have additional manpower and time for the disposal procedure | • Replace 50mm transport pipes to wider 200mm pipes to shorten the processing time required to break down food waste as they can be transported in bigger pieces without clogging the system |
| Pest and hygiene | • Flies and cockroaches are found around the inlet bench units at kitchens and around the collection bin in refuse room | • Apply insect repellent on the interior and back of panels of inlet units<br>• Cover or enclose waste collection bin to prevent pest infestation and odour leakage during collection process<br>• Switch dewatering unit with collection tank for better odour control |
| Odour problem | • Processed food waste gathered by the collection bin has created odour problems at refuse room | • Provide hot water supply to wash and flush food scraps out of inlet units<br>• Provide ventilation at refuse room to remove odour and heat<br>• Switch dewatering unit with collection tank for better odour control<br>• Regular washing and maintenance of temporary storage tank and screw press of dewatering unit |
| Waste bin collection | • The practice of replacing waste bins at refuse room after system implementation is inconvenient to catering staff | • Switch dewatering unit with collection tank to eliminate the need for catering staff to replace waste bins |

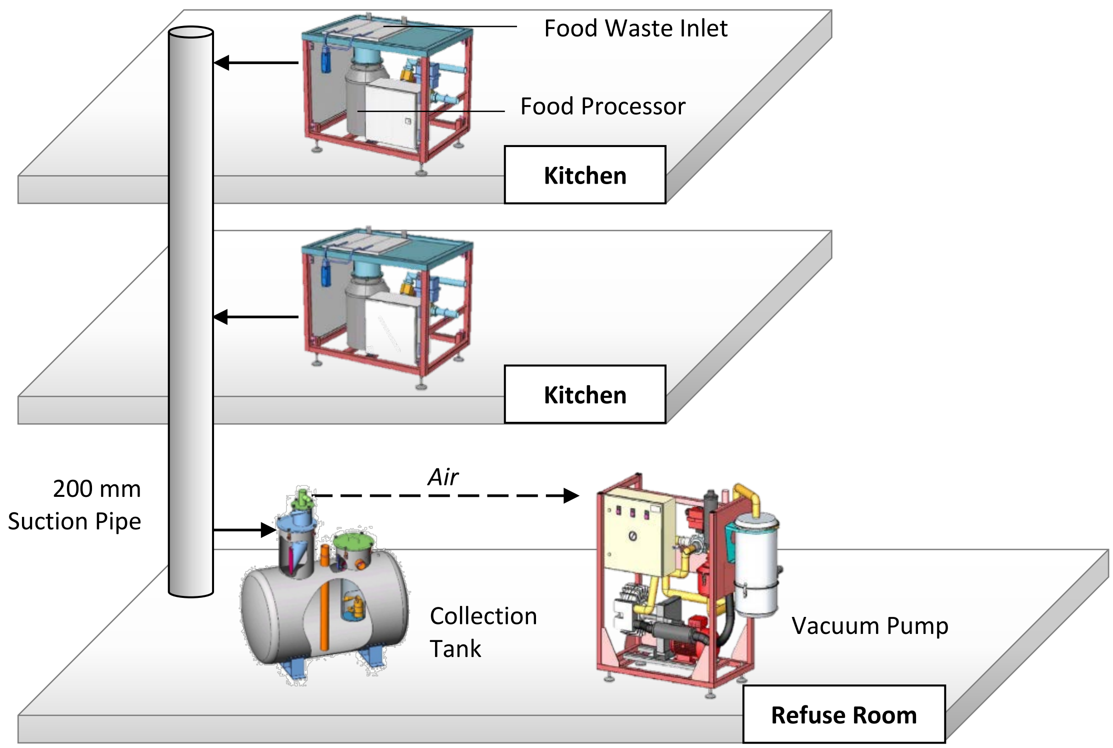



**Fig 7.** Schematic diagram of food waste collection system with collection tank

## 5. Conclusion

This project investigated the benefits resulted from the implementation of food waste collection system and difficulties catering staff faced when using the system. The project revealed a number of areas for improvement in terms of system design, installation and operation to fit for unique features and requirement of the catering service providers. The system was shown to be cost-effective in the long term when compared with manual collection of food waste, despite the relatively low daily usage of the system by catering staff. Significant cost-saving was observed form the compaction of food waste through food mincing process, and hence reduction in transportation costs from waste contractors. Maximum cost-saving can be achieved if all food waste generated is collected and compacted by the system. The viability of the system is mainly determined by the transportation cost from waste contractor as the ongoing cost contributes to minimum 75% of overall costs in manual or system collection scenarios.

In addition to testing the performance and functionality of the collection system, the project team hopes that the system can complement the "Food Waste & Yard Waste Plan for Hong Kong 2014-2022" as one of the technologies in the long term that is able to maximize food waste collection and recycling while reducing transportation costs of the process. The study is anticipated to bring environmental, social and economic benefits, including raising food waste collection and diversion rates from landfills for energy recovery, willingness of C&I sector to sort and recycle food waste and handling capacity and cost-effectiveness of food waste recycling process.

## Acknowledgement

The work described in this report was supported by a grant from The Recycling Fund, Hong Kong Productivity Council of The Hong Kong Special Administrative Region (HKSAR), China (Project Reference: ISP-1617-06-001).

## Disclaimer

Any opinions, findings, conclusions or recommendations expressed in this material/ event do not reflect the views of the Government of the Hong Kong Special Administrative Region, the Advisory Committee on Recycling Fund or the Recycling Fund Secretariat.

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# Appendix

i. Monthly quantity of food waste collected before and after system operation

| Before System Operation | | | After System Operation | | |
|---|---|---|---|---|---|
| **Month** | **Quantity per month (kg)** | **Quantity per day (kg)** | **Month** | **Quantity per month (kg)** | **Quantity per day (kg)** |
| Jun-18 | 5,400.0 | 180.0 | Jul-19 | 6,768.0 | 218.3 |
| Jul-18 | 6,058.5 | 195.4 | Aug-19 | 7,295.0 | 235.3 |
| Aug-18 | 6,598.5 | 212.9 | Sep-19 | 6316.0 | 210.5 |
| Sep-18 | 5,615.0 | 187.2 | Oct-19 | 6688.0 | 215.7 |
| Oct-18 | 6,549.5 | 211.3 | Nov-19* | 2,472.0 | *206.0* |
| Nov-18 | 6,141.0 | 204.7 | **Average** | **6,766.8** | **217.2** |
| Dec-18 | 6,060.5 | 195.5 | | | |
| Jan-19 | 5,839.0 | 188.4 | | | |
| Feb-19 | 5,733.0 | 204.8 | | | |
| Mar-19 | 6,212.5 | 200.4 | | | |
| Apr-19 | 6,188.5 | 206.3 | | | |
| **Average** | **6,036.0** | **198.8** | | | |

*1 to 12 November 2019 only.

ii. Monthly number of bins used for food waste disposal before and after system operation

| **Before System Operation** | | **After System Operation** | |
|---|---|---|---|
| **Month** | **No. of bins per day** | **Month** | **No. of bins per day** |
| Jan-19 | 3.8 | Jul-19 | 3.4 |
| Feb-19 | 3.9 | Aug-19 | 3.0 |
| Mar-19 | 3.8 | Sep-19 | 2.8 |
| Apr-19 | 3.8 | Oct-19 | 2.8 |
| **Average** | **3.8** | Nov-19* | *2.8* |
| | | **Average** | **2.9** |

*1 to 12 November 2019 only.

iii. Kitchen survey

| **Date** | **No. of Inlet Usage** | **Volume (L)** | **Weight (g)** | **Volume change from mincing process** |
|---|---|---|---|---|
| 30-Jul-19 | 13 | 52.8 | 16,906 | -53% |
| 2-Aug-19 | 20 | 92.9 | 29,201 | -62% |
| 7-Aug-19 | 11 | 45.7 | 13,948 | -69% |
| 15-Aug-19 | 10 | 46.3 | 15,496 | -62% |
| 22-Aug-19 | 11 | 49.6 | 14,313 | -49% |
| 12-Sep-19 | 18 | 89.7 | 25,352 | -63% |
| Average | **13.8** | **62.8** | **19,202.7** | **-60%** |
| Per inlet usage | **N/A** | **4.5** | **1,388.1** | **N/A** |

iv. Dry weight experiment

| Before System Processing | | | After System Processing | | |
|---|---|---|---|---|---|
| **Date** | **Moisture Content** | **Density (g/L)** | **Date** | **Moisture Content** | **Density (g/L)** |
| 30-Jul-19 | 69.1% | 320.2 | 15-Jul-19 | 66.7% | 480 |
| 2-Aug-19 | 81.8% | 314.3 | 16-Jul-19 | 62.1% | 660 |
| 7-Aug-19 | 70.1% | 305.2 | 17-Jul-19 | 61.1% | 720 |
| 15-Aug-19 | 81.5% | 334.7 | 22-Jul-19 | 59.1% | 440 |
| 22-Aug-19 | 83.3% | 288.6 | 23-Jul-19 | 66.7% | 420 |
| 12-Sep-19 | 72.0% | 282.6 | 24-Jul-19 | 69% | 320 |
| Average | **76.3%** | **307.6** | 25-Jul-19 | 63.0% | 460 |
| | | | 26-Jul-19 | 61.9% | 420 |
| | | | 29-Jul-19 | 65.3% | 490 |
| | | | 30-Jul-19 | 65.1% | 430 |
| | | | 14-Aug-19 | 53.8% | 520 |
| | | | 15-Aug-19 | 65.8% | 380 |
| | | | 22-Aug-19 | 69.4% | 490 |
| | | | 27-Aug-19 | 58.3% | 480 |
| | | | 3-Sep-19 | 70.0% | 600 |
| | | | 12-Sep-19 | 62.5% | 400 |
| | | | 20-Sep-19 | 73.2% | 410 |
| | | | 24-Sep-19 | 66.0% | 530 |
| | | | 3-Oct-19 | 60.0% | 600 |
| | | | 22-Oct-19 | 61.5% | 390 |
| | | | 7-Nov-19 | 71.7% | 460 |
| | | | **Average** | **64.4%** | **481.0** |

v. Monthly electricity consumption (kWh)

| Month | Inlet 1 (3/F) | Inlet 2 (3/F) | Inlet 3 (4/F) | Vacuum pump (G/F) | Dewatering unit (G/F) | Monthly Total | Daily Average |
|---|---|---|---|---|---|---|---|
| Jul-19 | 10.28 | 8.51 | 8.14 | 202.64 | 15.38 | **244.95** | **8.75** |
| Aug-19 | 10.38 | 8.59 | 8.14 | 190.26 | 19.76 | **237.13** | **8.47** |
| Sep-19 | 9.81 | 8.52 | 8.14 | 162.43 | 30.37 | **219.27** | **7.83** |
| Oct-19 | 11.47 | 11.71 | 10.32 | 133.63 | 19.88 | **187.01** | **5.34** |
| Nov-19* | 2.34 | 2.28 | 2.01 | 32.29 | 2.15 | **41.07** | **5.87** |

*1 to 8 November 2019 only.

vi. Monthly water consumption (m3)

| Month | Inlet 1 (3/F) | Inlet 2 (3/F) | Inlet 3 (4/F) | Dewatering unit (G/F) | Monthly Total | Daily Average |
|---|---|---|---|---|---|---|
| Jul-19 | 0.7 | 0.1 | 0 | 2.0 | **2.8** | **0.10** |
| Aug-19 | 0.5 | 0.1 | 0 | 2.4 | **3.0** | **0.11** |
| Sep-19 | 0.5 | 0.2 | 0 | 2.6 | **3.3** | **0.12** |
| Oct-19 | 0.2 | 0.3 | 0.1 | 1.8 | **2.4** | **0.07** |
| Nov-19* | 0.1 | 0 | 0 | 0.4 | 0.5 | **0.07** |

*1 to 8 November 2019 only.

vii. Inlet usage

| Log Date | | Inlet 1 (3/F) | Inlet 2 (3/F) | Inlet 3 (4/F) | Daily Total |
|---|---|---|---|---|---|
| 12-Aug-19 | Mon | 15 | 3 | 0 | 18 |
| 13-Aug-19 | Tue | 12 | 0 | 0 | 12 |
| 04-Sep-19 | Wed | 3 | 1 | 0 | 4 |
| 05-Sep-19 | Thu | 7 | 0 | 0 | 7 |
| 06-Sep-19 | Fri | 9 | 8 | 3 | 20 |
| 07-Sep-19 | Sat | 0 | 0 | 0 | 0 |
| 08-Sep-19 | Sun | 0 | 4 | 0 | 4 |
| 09-Sep-19 | Mon | 10 | 7 | 0 | 17 |
| 10-Sep-19 | Tue | 13 | 7 | 0 | 20 |
| 11-Sep-19 | Wed | 11 | 0 | 0 | 11 |
| 12-Sep-19 | Thu | 10 | 7 | 0 | 17 |
| 13-Sep-19 | Fri | 4 | 0 | 0 | 4 |
| 14-Sep-19 | Sat | 0 | 0 | 0 | 0 |
| 15-Sep-19 | Sun | 0 | 6 | 0 | 6 |
| 16-Sep-19 | Mon | 13 | 5 | 0 | 18 |
| 17-Sep-19 | Tue | 11 | 8 | 0 | 19 |
| 18-Sep-19 | Wed | 4 | 0 | 0 | 4 |
| 19-Sep-19 | Thu | 8 | 0 | 0 | 8 |
| 20-Sep-19 | Fri | 6 | 2 | 0 | 8 |
| 24-Sep-19 | Tue | 16 | 6 | 0 | 22 |
| 25-Sep-19 | Wed | 20 | 6 | 0 | 26 |
| 27-Sep-19 | Fri | 2 | 0 | 0 | 2 |
| 28-Sep-19 | Sat | 1 | 1 | 1 | 3 |
| 04-Oct-19 | Fri | 4 | 5 | 3 | 12 |
| 05-Oct-19 | Sat | 2 | 0 | 4 | 6 |

| | | | | | |
|---|---|---|---|---|---|
| 11-Oct-19 | Fri | 8 | 7 | 0 | 15 |
| 12-Oct-19 | Sat | 1 | 1 | 1 | 3 |
| 18-Oct-19 | Fri | 4 | 1 | 1 | 6 |
| 19-Oct-19 | Sat | 0 | 0 | 0 | 0 |
| 20-Oct-19 | Sun | 0 | 3 | 0 | 3 |
| 21-Oct-19 | Mon | 3 | 4 | 0 | 7 |
| 23-Oct-19 | Wed | 7 | 4 | 1 | 12 |
| 24-Oct-19 | Thu | 0 | 3 | 7 | 10 |
| 25-Oct-19 | Fri | 8 | 5 | 0 | 13 |
| 26-Oct-19 | Sat | 5 | 0 | 0 | 5 |
| 27-Oct-19 | Sun | 3 | 0 | 0 | 3 |
| 28-Oct-19 | Mon | 9 | 0 | 0 | 9 |
| 29-Oct-19 | Tue | 2 | 2 | 0 | 4 |
| 30-Oct-19 | Wed | 9 | 6 | 2 | 17 |
| 31-Oct-19 | Thu | 5 | 6 | 0 | 11 |
| 01-Nov-19 | Fri | 3 | 5 | 0 | 8 |
| 02-Nov-19 | Sat | 1 | 1 | 1 | 3 |
| 03-Nov-19 | Sun | 0 | 2 | 0 | 2 |
| 04-Nov-19 | Mon | 8 | 1 | 0 | 9 |
| 05-Nov-19 | Tue | 9 | 1 | 0 | 10 |
| 06-Nov-19 | Wed | 10 | 5 | 1 | 16 |
| 07-Nov-19 | Thu | 8 | 4 | 0 | 12 |
| Daily Average | | **6.0** | **2.9** | **0.5** | **9.4** |

- END -