To investigate the most suitable technologies in Solid Waste Management and Water Management for Hong Kong Housing Estates

Environmental Technologies Foundation Limited.

Background

The Secretary for the Environment, Mr. Edward Yau, said in his speech on 29 Jan, 2008, "There remains a pressing need for the adoption of advanced technologies to reduce the volume of waste in view of the fact that the capacity of the three existing landfills is depleting fast and will be exhausted in the coming four to eight years." Hong Kong is densely populated and the majority of its residents are living in high-rise buildings. Disposal of waste from these entities is not an easy job. With the current stringent regulations on environmental concerns in countries around the world, scientists and engineers have been continuously looking for innovative and effective solid waste technologies that may reduce solid waste disposal. Concurrently, the problem of water scarcity and pollution becomes more pressing with the continuous growth in population in Hong Kong. Obviously, the demand on modern solid waste management and water management technologies most suitable for Hong Kong housing estates is increasing.

The Environmental Technologies Foundation Ltd., is a charitable organization. In line with our missions, we are dedicated to contribute towards Hong Kong's environmental well-being. We are obliged to devote our resource in searching modern technologies for Hong Kong.

Purpose

In this report, we review the present Hong Kong position in solid waste management and water management and introduce some modern technologies which provide benefits and feasibility of implementing to Hong Kong Housing Estates. This report is separated into two parts. Part I reviews and describes the technologies for Solid Waster Management while Part II covers the Waster Management technologies.

Methods

This report is complied by searching over the world wide internet. The research is compiled by literature review and information collection through the world wide internet, supplier, telephone, library and email communications with Hong Kong government officers. Also, site-visits were performed to understand the current waste management and water management system in existing public, Home Ownership Scheme and private housing estates.

Table of Content

Page

Part 1 --- Solid Waste Management

Part 2 --- Water Management

List of Figures **Page**

List of Tables

Part I --- Solid Waste Management

Abstract

In Hong Kong, the three operating landfill sites are going to reach their capacities in 4 to 8 years. In light of this pressing situation, technologies in solid waste management for Hong Kong housing estates are studied. Among different solid waste treatment and management technologies, the waste separation refuse chute technology (WSRCT) is found to be the most viable and suitable solid waste treatment technologies for increasing the amount of recyclables in Hong Kong housing estates. WSRCT is a modified refuse chute with a built-in micro-computer which leads the recyclables to a number of containers that can turn around when operated. The system enables glass, plastic, paper, metal, and other rubbish to be separated into different boxes. In the meantime, sorting recyclables before they are collected saves a lot of manpower and valuable space.

Objectives

The objectives of this part of the study are:

1. To review the current situation and regulations about Solid Waste Management in Hong Kong; and
2. To look for and introduce potential feasible solid waste treatment technologies that are applicable to Hong Kong housing estates,

Chapter 1 – Introduction

1.1 Background

According to the environmental report 2006, compiled by the Hong Kong Environmental Protection Department (EPD), there is relatively small percentage of Hong Kong housing estates which join the government campaign of "Source Separation of Domestic Waste", and further, pursuant to "A Policy Framework for the Management of Municipal Solid Waste", EPD would like to increase the rate of recycle to 45% of the total waste produced by the year 2007 from 40% in 2005. However, on its environmental report 2006, EDP implies that Hong Kong is lagging behind in its targeted waste management objective. The reason for this lag is due to the fact that the majority of Hong Kong residents are living in high-rise buildings. Waste from these accommodations is relatively more complicated to dispose of. Moreover, recovery programme in high-rises have presented a difficult challenge to waste handlers and residents. However, as more and more cities passed waste reduction mandates, the demand for recycling in housing estates is becoming more important. (Hong Kong Environmental Protection Department, 2005)

In Mr. Yau's speech of July 2, 2008, he also noted, "Notwithstanding the progress made in waste reduction and recovery, there remains huge volume of unavoidable waste that needs to be disposed properly. To dispose untreated waste to landfill extensions alone is not in line with the sustainable development principle. We have a pressing need for the adoption of advanced and more sustainable technologies to reduce the volume of waste and recover resources so as to deal with the municipal sold waste generated in Hong Kong more effectively." [The Hong Kong Government Information Centre, 2008] In order to find a modern technology for solid waste management suitable for Hong Kong housing estates, the current situation is reviewed.

1.2 Types of Solid Waste in Hong Kong

Similar to other developed countries, Hong Kong classifies solid waste into five categories. They are municipal sold waste, construction waste, chemical waste, special waste and other solid waste. The detailed interpretation of these waste are described below: (U.S. Environmental Protection Agency, 2007)

1) Municipal Solid Waste (MSW)

Municipal Solid Waste comprises solid waste from households, commercial and industrial sources. By definition, domestic waste refers to household waste, waste generated from daily activities in residential and institutional premises as well as refuse collected from public cleansing services. Public cleansing waste includes dirt and litter collected by the Food and Environmental Hygiene Department (FEHD), marine refuse collected by Marine Department and waste from country parks collected by the Agriculture, Fisheries and Conservatives Department. Commercial waste is waste arising form commercial activities taking place in shops, restaurants, hotels, offices, markets in private housing estates, etc. It is collected mainly by private waste collectors. However, some commercial waste is mixed with domestic waste and collected by the FEHD. Industrial waste is waste arising from industrial activities and does not include construction waste and chemical waste. It is often collected by private waste collectors. However, some industries may deliver their industrial waste directly to the landfills for disposal.

2) Construction Waste

Construction waste is defined as substance which is generated as a result of construction work and abandoned whether or not it has been processed or stockpiled before being abandoned. It is a mixture of surplus materials arising from site clearance, excavation, construction, refurbishment, renovation, demolition and road works. (U.S. Environment Protection Agency Department, 2008)

3) Chemical Waste

Chemical wastes are liquid, semi-solid and solid wastes which are hazardous in nature or constitute a risk of pollution to the environment. Indiscriminate disposal of chemical waste may pose very serious health, safety and environmental consequences.

4) Special Waste includes clinical waste, animal carcasses, livestock waste, radioactive waste, grease trap waste and waterworks / sewage sludge.

Since this project focus on the technology research that may be applicable for Hong Kong public and private housing estates, the domestic waste in Hong Kong is examined.

1.1.3 History of solid management policy in Hong Kong

Before 1989, Hong Kong utilizes the urban incinerators to incinerate most of the solid waste. After 1989, the Government abandoned the out-dated system of urban incinerators located at Kwai Chung, Kennedy Town and Lai Chi Kok and replaced them with 13 small landfills, which were eventually phased out through 1989-1996. Due to the potential health and safety reasons, a restoration program was implemented by the EPD. It is intended that these restored landfills are to be developed into recreational facilities like golf courses, multi-purpose grass pitches, rest gardens, ecological parks, etc. to provide green zones in the urban areas for people to enjoy a healthy living environment.

Starting from 1993, the municipal solid waste management system relies on three large, state-of-the-art strategic landfills in remote parts of the New Territories together with a network of refuse transfer stations (RTS) and collection services provided by both the Government and private sector. The common perception is that landfills are merely dumps at which solid waste is buried. In fact, they are scientifically designed and highly engineered facilities for managing waste disposal. Hong Kong's three strategic landfills are:

- The West New Territories (WENT) Landfill at Nim Wan;
- The South-East New Territories (SENT) Landfill in Tseung Kwan O; and
- The North-East New Territories (NENT) Landfill at Ta Kwu Ling.

Figure 1 - A photo of the three landfill sites in Hong Kong

1.4 Cost of solid waste disposal to the society

In every society, waste treatment attracts a significant amount of cost. In Hong Kong, the landfills take up in total 270 hectors of land, cost $6 billion to construct, and their running costs in 2004 amounted to $432 million. The annual costs of the Government's waste collection and transfer service amount to another $435 million and $355 million respectively. The full costs of managing Municipal Solid Waste (MSW) are hidden from the community.

While calculating the annual costs of handling and disposing of Hong Kong's waste is not an exact science, reliable data exist on which reasonable estimates can be based. The figures obtained, however, are still well below the true cost to the community for such services. They do not, for instance, factor in the opportunity costs of the restored landfills and their maintenance costs, and also omit:

- The costs of removing MSW from individual housing units to refuse collection points (RCP);
- The removal costs incurred by commercial and industrial concerns;
- The capital costs and land value of some 1,000 or so public and private RCP; and
- The land value of the seven Refuse Transfer Station (RTS) each occupying more than one hectare in the urban area, Sha Tin, Yuen Long and North Lantau, as well as several smaller RTS in the outlying islands.

The greatest significance is that the costs of dealing with MSW are mostly not borne by those who produce the waste. This is because:

1. Private owners, tenants and Home Ownership Scheme residents usually see the cost of waste collection in their building management fees (estimated at about $20 to $50 per household per month), but this represents only a portion of the overall cost in handling municipal solid waste.
2. Commercial and industrial entities pay for the removal of their MSW. While a small number of private waste collectors use the RTS, they contribute to only 2% of the recurrent costs of the RTS. Most of the subsequent handling and disposal costs are paid from the public purse. Those who send their waste direct to the landfills do not pay the landfill disposal costs at all.

Going by this trend, the fact is that if Hong Kong does not reduce the growth in the amount of waste that we produce, then, given the lead time to develop a modern landfill, within the next few years we will have to identify about 400 hectares of space for new landfills to serve Hong Kong up to 2030. This is equivalent to slightly less than one-third the area of Hong Kong International Airport, or is enough land to absorb and house half of Hong Kong's

population growth for the next decade.

To demonstrate the solid waste situation of Hong Kong in greater detail, a detailed statistical discussion is presented to examine the status of solid waste disposal in Hong Kong.

Chapter 2 – Waste management systems in Hong Kong

2.1 Hong Kong Solid Waste Statistics (Monitoring of Solid Waste in Hong Kong Waste Statistics for 2007)

The continued growth in wasteloads implies Hong Kong will be running out of landfill space far earlier than originally planned. It is estimated that the remaining landfill space will last only for 4 to 8 years if waste levels continue to increase at current levels. Unless solutions are identified immediately, Hong Kong will face a crisis in the next decade of having nowhere to put the thousands of tonnes of waste thrown away each day. New landfill sites must be identified. However, the community has become more resistant to having waste facilities near their neighborhoods. In terms of government expenditure, it costs around $125 per tonnes to build and operate landfills. Some 7.7 million tonnes were landfilled in 2002 so the total capital and operating cost spent since the commissioning of the landfills was up to $9 billion.

Based on the data for disposal of solid waste at landfills in 2007, Hong Kong has an average daily quantity of 6331 tonnes per day of domestic waste generated from household or public cleansing areas. This worked out to 45.45% of the total waste received at the landfills. Utilizing this set of statistical data, a pie chart is presented below:

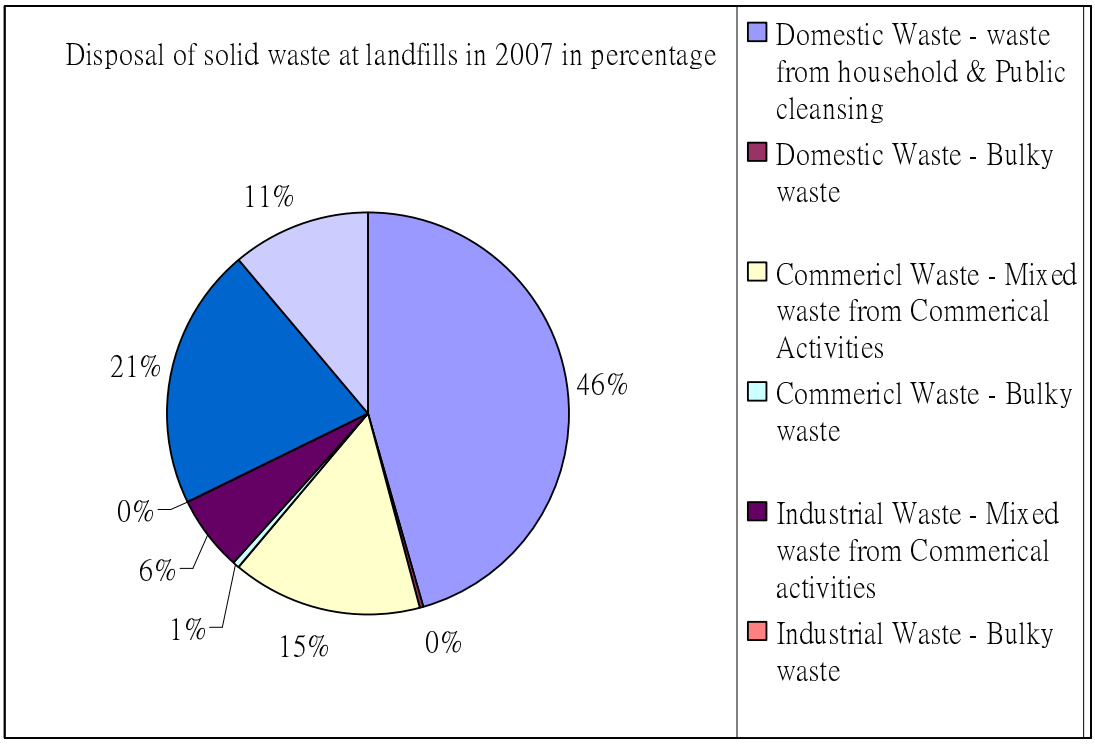


Figure 2 – Percentage distribution of solid waste disposal at the landfills in 2007

Source: Monitoring Solid waste in Hong Kong – Waste Statistics for 2007

The pie chart above, Percentage distribution of solid waste disposal at the landfills in 2007, demonstrates that it is highly desirable to look for innovative solution to reduce the amount of domestic waste generated from household. Despite the fact that it is decreasing as compared to previous years due to successful waste reduction campaigns, household domestic waste still remains to be the biggest contributor of waste delivered to the landfills. In addition, the chart reveals that:

1) Commercial waste delivered to the landfills has been steadily rising in the past few years.
2) Industrial waste delivered to the landfills jumps abruptly from 583 tons per day (tpd) to 866 tpd from 2006-2007
3) Construction waste delivered to the landfills has been declining ever since the construction waste disposal charging scheme is introduced. This indicated the construction waste disposal charging scheme is an effective waste reduction management policy

4) In 2007, if the change in construction waste is ignored from the statistical analysis, it demonstrated that the total amount of solid waste in tonne-per-day delivered to the landfills remained relatively the same as compared to the year of 2006. However, since these observations are not the focus of the report "waste separation refuse chute technology", no further study is pursed in this report.

According to a report, "Monitoring Solid Waste in Hong Kong", it observes that there was essentially no changes with respect to the municipal solid waste disposal rate (kg/person/day) through 2003-2007. However, Hong Kong Population is growing steadily. It can be concluded that the solid waste situation will get worse in the future if no significant changes are made.

It also notes that the composition of municipal solid waste in 2007 is as follows:-

1) Putrescibles, or otherwise known as food waste, is the largest contributor for the domestic municipal solid waste. This is followed by waste paper and waste plastics.

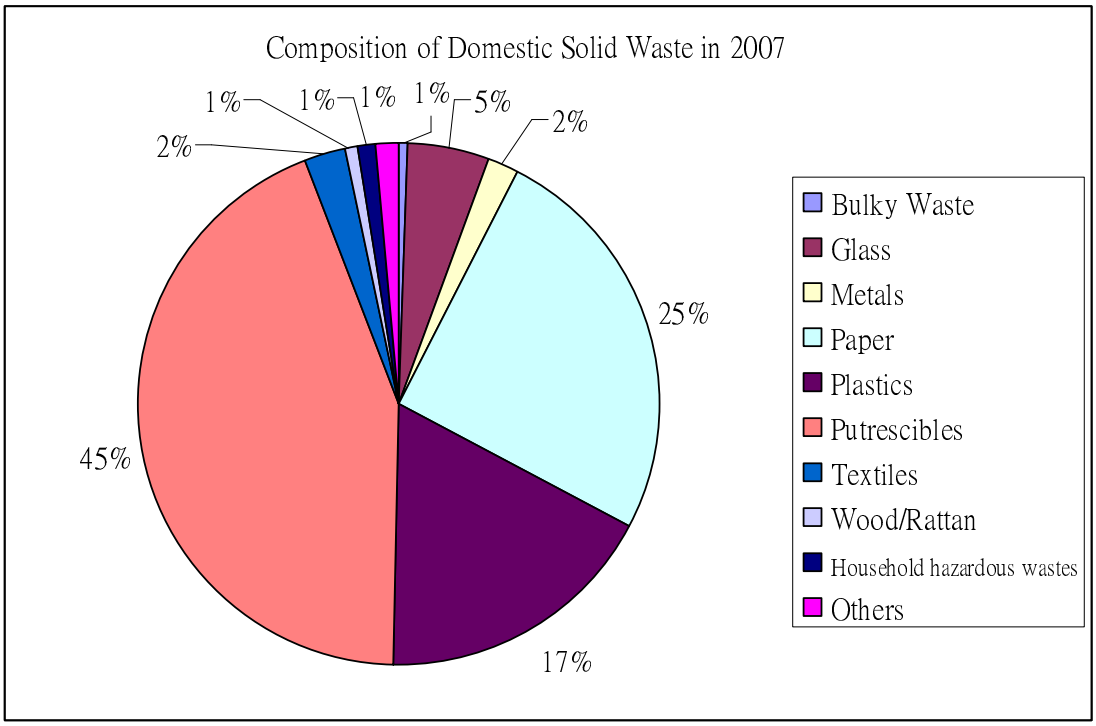


Figure 3 – Composition of Domestic Solid Waste in 2007

2) For commercial waste, the percentage of waste paper and waste plastic are higher

compared to the domestic waste

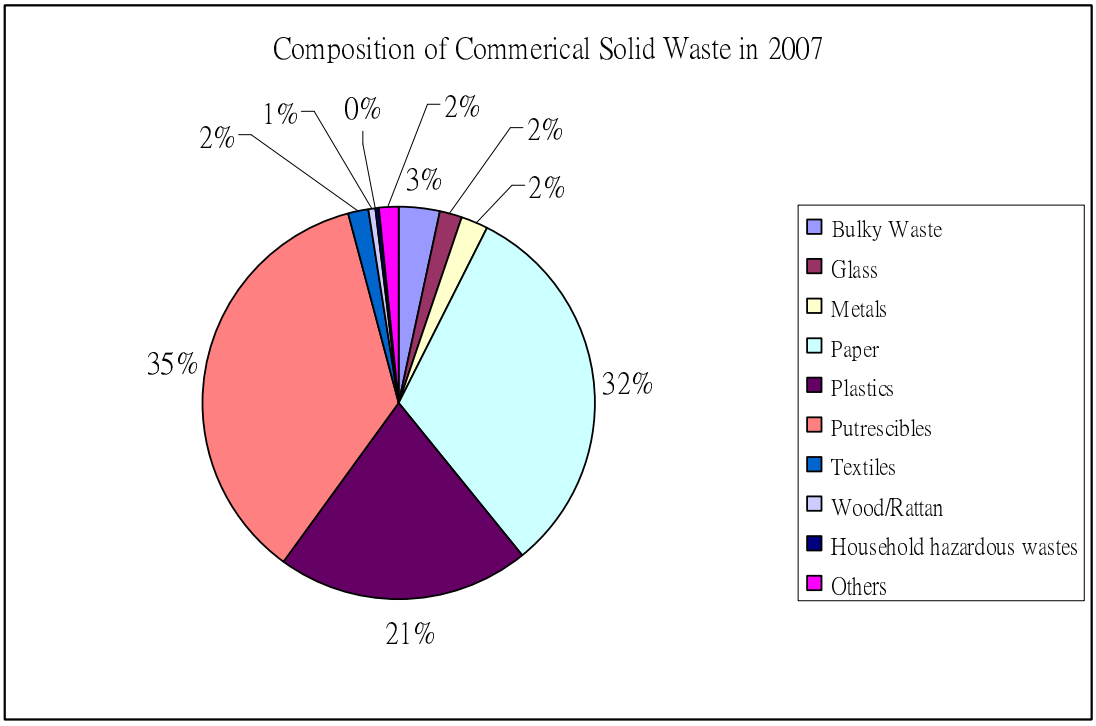


Figure 4 – Composition of Commercial Solid Waste in 2007

3) Waste wood or rattan occupies the largest portion of the industrial waste. It is followed by waste plastics

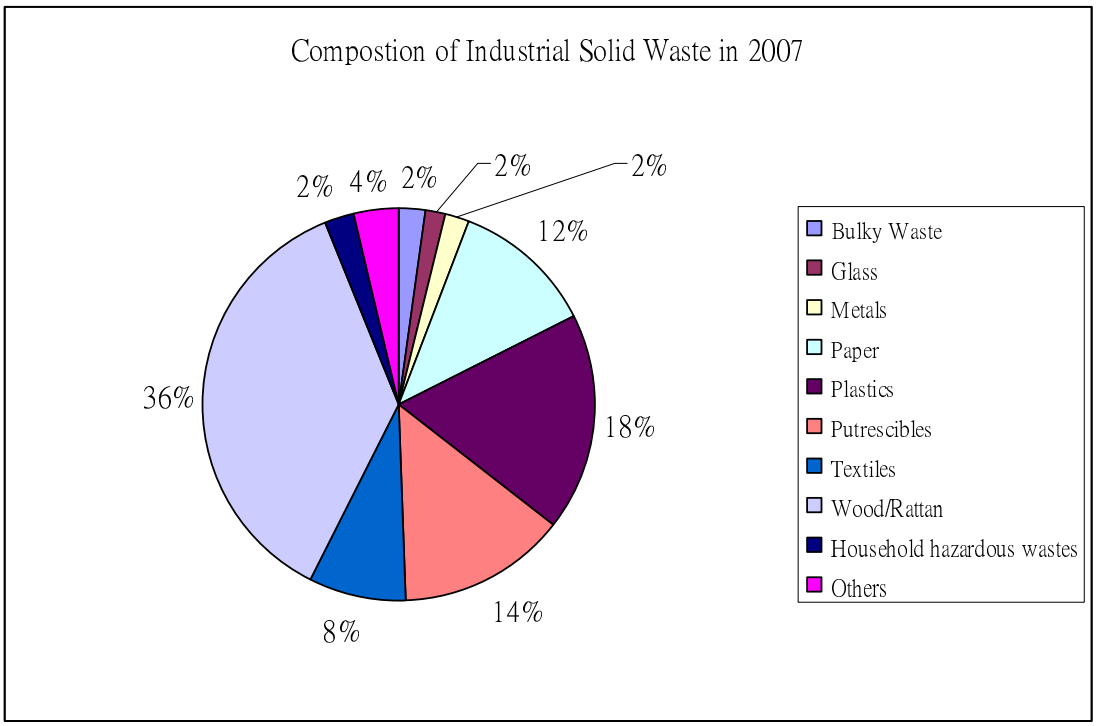


Figure 5 – Composition of Industrial Solid Waste in 2007

It also observes that:

1) Food waste is the biggest contributor of the total domestic waste. In the year of 2007, 38.4% of the total municipal solid waste is food waste. This statistical data suggested that in-vessel composting may be feasible to be applied in a Hong Kong housing estate.
2) Other than food waste, waste paper, newsprint is the second biggest contributor of the total domestic waste in Hong Kong.
3) Plastic pack represent 9.5%, 602 tpd out of 6372 tpd, of the domestic solid waste delivered to the land fills. This is one of the reason the Hong Kong government is actively pursing waste reduction policy such as the plastic bags charging scheme in order to reduce the use of plastic bags.
4) There is a higher percentage of plastic waste in commercial and industrial waste as compared to residential waste. This trend is more revealing for miscellaneous plastic waste like household utensils, packaging materials, toys, off-cuts, scraps….etc.

It classifies the solid waste into three major types: Putrescibles, Plastics and Paper. They made up of more than 80% of the municipal solid waste in Hong Kong whereas plastic and paper waste can be recycled for use. Also, it is observed that from 2006 to 2007, this percentage remained the same. Similar observations are noted from 2002 to 2006.

The report also denotes quantities and values of exported recyclable materials by type as follows:

1) There are 7 major types of exported recyclable materials in Hong Kong. They are: a) Ferrous metals b) Non-ferrous metals c) Plastics metals d) Textiles e) Wood, paper f) Glass & h) Electrical and electronic equipment

2) Among different types of recyclable material, glass has the lowest value per unit weight, (Dollar per tonne) at $300 per tonne. At the same time, during 2005-2007, only 70 tonnes of glass are exported for recycling. These data explains why there is a lack of local glass recyclers in Hong Kong.
3) Non-ferrous metals have the highest value per unit weight (Dollar per tonne) among the 7 types of exported recyclable materials in Hong Kong.

4) Waste plastics have the highest total value among the 7 types of exported recyclable materials in Hong Kong. This is followed by ferrous metals and non-ferrous metals then waste paper.

Waste is a common problem of affluent societies. Especially when people can afford greater convenience and more purchases tend to throw away more rubbish. Hong Kong is no exception to this. The statistics of the solid waste situation indicated that Hong Kong Solid waste disposal have an urgent need for improvement. The simple truth is that if Hong Kong does not reduce the growth in the amount of waste produced. Then, given the lead time to develop a modern landfill, within the next few years we will have to identify about 400 hectares of space for new landfills to serve Hong Kong up to 2030. Hence, there is a pressing need to reduce the volume of waste and recover recyclables so as to deal with the MSW generated in Hong Kong more effectively.

2.2 Waste reduction and recycling programs in Hong Kong

Hong Kong, like many developed places, has seen its wasteloads grow as its economy has grown. Municipal wasteloads have increased an average of about three per cent per year since 1986 - when the EPD was formed - mirroring Hong Kong's rapid economic expansion over the same period. At the same time, the population has grown by more than one million people and each person is throwing away more waste. The per capita level of domestic waste has risen from 0.95 kilogrammes per person per day in 1990, to 1.11 kilogrammes in 2002. The continued growth in wasteloads means Hong Kong is running out of landfill space far earlier than originally blamed. Though Hong Kong already has a MSW recycling rate of 40%, yet this can be further improved upon. The Government and the community have begun to pursue various initiatives at different levels:

The Hong Kong government has been examining waste recovery systems to identify the most cost-effective way for reducing the amount of municipal solid waste in Hong Kong. Up until today, some 28,000 three-coloured waste separation bins are now placed at some 9,300 points throughout the territory (including parks, sports venues, leisure and cultural facilities, Government buildings, hospitals, clinics, public/private housing estates, schools, RCP and by the roadside) and altogether 663,000 tonnes of MSW have been collected for recycling through this scheme since 1998. In summary, 2 major programs have been executed in Hong Kong.

The first major pilot programme is the Wet/Dry Waste separation Pilot Programme. It was carried out in four housing estates from April 2003 to July 2004. Participating households separated wastes into wet and dry wastes which were then gathered at Refuse Collection Points of the housing estates by cleansing workers. Contractors of the Food and Environmental Hygiene Department then delivered the wastes to Island East Refuse Transfer Station for sorting. The sorted dry wastes were sold to recyclers. Revenue generated was used to offset the sorting cost.

The second, and the one that has been continuously ongoing, is the source separation of domestic waste program. In the year of 2004-2005, a 12-month pilot programme on source

separation of domestic waste was launched in August 2004 in 13 housing estates in the Eastern District. The pilot programme aimed at making it more convenient for residents to separate domestic waste at source by encouraging and assisting property management companies to provide waste separation facilities on each floor of all buildings. The programme also aimed at expanding the types of recyclables to be collected to include all types of plastics, metals, paper, clothing and electrical products. In view of the positive results recorded under the pilot programme, a territory-wide campaign was rolled out in January 2005 to promote separation of domestic waste at source. Based on the results and analysis, the programme was found to be very successful and effective to improve recycling rate that led the Environmental Protection Department (EPD) to implement the programme territory-wide in 2005.

Other than the 2 major solid waste separation programme, businesses have been partnering with green groups and the Government to recover and recycle rechargeable batteries - a first for Hong Kong in encouraging producer responsibility. With businesses providing the recovery and recycling components, the public has access to more than 1,000 collection points in shops, housing estates, public buildings, schools and other public places at which to leave their rechargeable batteries that have reached the end of their useful lives.

2.2.1 Wet and Dry Waste Separation Pilot Programme

In the year of 2003, a pilot programme has been launched by the Environmental Protection Department on wet and dry waste separation of domestic waste, an alternative mode that attempts to provide more convenience to residents. The objectives are:

- To test this alternative mode of waste collection and sorting in further enhancing the waste recovery rates and reducing waste.
- To make it more convenient for residents to separate waste.
- To encourage residents to separate waste at home.

The 12-month pilot programme is launched in four housing estates in the Eastern District on Hong Kong Island, including Aldrich Garden, Heng Fa Chuen (Upper), LeSommet and Lei King Wan, with 7,877 households and a total population of about 24,000.

Under the programme, residents will be encouraged to separate their waste at source into 'dry' and 'wet' portions. They are provided with bags of two different colours - green for dry waste and black for wet waste (refuse).

Dry waste is waste that is dry and un-contaminated. Recyclables such as waste paper, metal cans, plastic bottles, floppy disks, batteries, glass bottles, old clothes, baskets, pens and shoes are all dry waste, from which we can sort out many useful materials for recycling. Wet waste (refuse) is dirty waste that is not accepted in the dry waste bag. It includes food waste, contaminated paper and tissue, containers with food scraps, diapers and used personal hygiene items, etc. Residents then place their waste at the back-stairs or refuse room of each floor - the black bag put in the refuse collection bin, and the green bag put beside the refuse collection bin or in a designated dry waste bin (In LeSommet, residents are requested to bring their dry waste bags down to a drop-off point on ground floor, in order to compare against floor-to-floor collection as practised in the other three housing estates).

Wet waste (refuse) was taken to the landfill. Dry waste was taken to a waste separation pilot facility at the Island East Transfer Station (IETS) for further sorting. The sorted dry wastes were sold to recyclers. Revenue generated was used to offset the sorting cost.

Figure 6 - Workers sorting the dry waste at the (IETS) for further sorting

Dry and wet waste separation is different from the existing 3-coloured-bin system. The latter requires us to source separate recyclables like paper, aluminum cans and plastic bottles, bring them down to the ground floor, and place them in the 3-coloured waste separation bins. It only covers three types of recyclables. The Dry and Wet Waste Separation covers many

different types of recyclables, and only requires us to put recyclables in one bag. This dry and wet waste separation pilot programme is only a trial and the 3-coloured-bin system is still being widely used in Hong Kong.

The Wet/dry Waste Separation Pilot Programme was carried out in four housing estates from April 2003 to July 2004. According to the Administration, the scheme was effective in improving domestic waste recovery rate, but the cost of this recovery method was too high. With the experience gained in the Wet/dry Waste Separation Pilot Programme, a 12-month pilot programme on Source Separation of Waste was launched in August 2004 in 13 housing estates in the Eastern District covering about 37 000 households and a population of about 120 000.

2.2.2 Source Separation of Domestic Waste

The Programme on Source Separation of Domestic Waste was launched territory-wide in 2005 to encourage more people to separate their waste for recycling. It began on a trial basis in 13 housing estates in Eastern District in 2004, reaching 37,000 households and 120,000 people, and it quickly proved to be successful. Some of the participating housing estates more than doubled the quantity of recyclables they recovered. They also earned additional income - for example, Heng Fa Chuen earned more than $100,000 from selling recyclable materials which can be used to subsidise management expenses. The success of the trial Programme led the Environmental Protection Department (EPD) to announce on 30 January 2005 that it would be implemented territory-wide, effective immediately.

The main objective of the programme is to facilitate residents to separate waste at source by encouraging and assisting property management companies to provide waste separation facilities on each building floor, and broaden the types of recyclables to be recovered. All residents need to do is to separate recyclables in the waste by category, such as waste paper, metals and plastics, and then take them to designated locations on each floor.

Under the Programme on Source Separation of Domestic Waste, a diverse range of recyclables is being recovered in housing estates, such as plastic shopping bags, compact discs and metal biscuit tins. Previously, only waste paper, aluminium cans and plastic bottles

were collected for recycling. Different from the previous programme, each participating housing estate is encouraged to adopt a waste separation and recovery system that best suits its particular physical and other characteristics and that is convenient for residents to use. Waste separation facilities can be set up at such locations as refuse rooms or staircase landings on each floor. In a refuse room, property managers may install a wall-mounted shelf for collecting waste paper and separate bins for metals and plastics, or they may provide a bin with compartments for different types of recyclables. In staircase landings, they may install metal collection bins. Collection times can also be adapted to suit needs, for instance by collecting different types of recyclables on different days of the week, say, metals on Mondays, Wednesdays and Fridays, and plastics on Tuesdays, Thursdays and Saturdays. Understanding the divisiveness of this programme, EPD has performed several promotion campaigns and a guidebook to assist estate tenants and property managers in taking part in the programme. Since one of the technology described in this report, WSRCT, is supposed to act as facilitating equipment for this programme, some of the keypoints of the Guidebook for Source Separation of Waste in Residential Buildings are summarized as below:

2.2.2.1 Guidebook for Source Separation of Waste in Residential Buildings

The Environmental Protection Department (EPD) is always promoting the separation of waste at the source. In 2005, the EPD presented a detailed guidance document of source separation of waste for property managers and Owners Corporation. The Guidebook is summarized in point form as shown below. (Hong Kong Environmental Protection Department, 2006)

- The design of your building will determine where and how to collect recyclable waste. There are 8 possible locations on each floor, illustrated in the inverted pyramid below from the most preferred to the least preferred. The order of preference is based on the following factors:
  - Relevant legislations from the Fire Services Department (FSD) and the Buildings Department (BD);
  - Security and hygiene related issues;
  - Level of convenience to residents; and

- Practicality from a property management perspective

➢ For any location the property manager or the owner's corporation to choose for collecting recyclable waste must meet ALL of the following criteria:

1. It already exists on your property;
2. It's accessible to residents and cleaners;
3. It has minimal safety risks and / or hazards (i.e. this location would not generally lead to injuries or accidents);
4. It's secure enough for residents to use under existing routine security arrangements; and
5. It complies with legislative and other relevant requirements.

➢ The figure is a systematic flowchart that could help people to decide on a location for collecting recyclable waste.

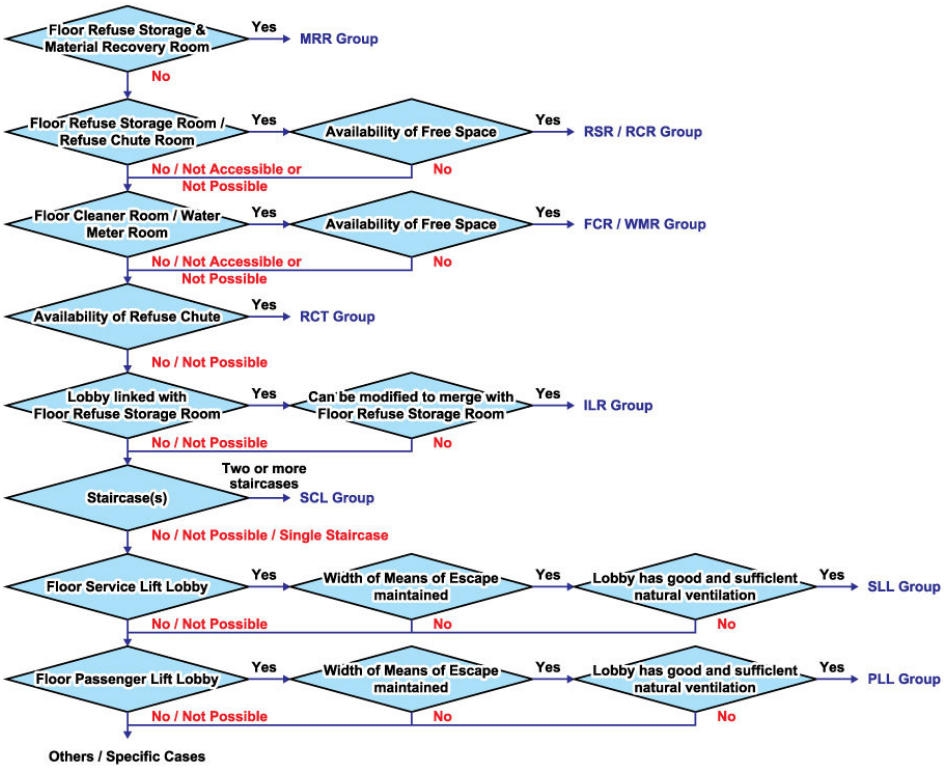


Figure 7 - Flowchart for Determination of Suitable Locations for Collecting Recyclable Waste in Residential Buildings

- Detailed descriptions of choosing a location and system for a housing estate

1) Floor Refuse Storage and Material Recovery Room (MRR)

   For MRR, there are 4 options for waste recovery:

   a) 3 bins, bring any time: Place 3 waste separation bins in the MRR on each floor. Residents bring their recyclables here and put them in the corresponding waste separation bins at any time. Cleaners empty the bins at designated times or whenever necessary. The recyclables can be sold directly to recyclers.

   b) 1 shelf plus 1-2 bins, bring any time: Mount a shelf on a wall of the MRR for stacking waste paper. One or two bins can be used to collect waste plastics and metals. (If only one bin is used, cleaners may have to sort the mixed plastics and metals at a central refuse collection point.) Residents deposit their recyclables at any time during the day.

   c) 1 bin, bring at specified times: Place only one waste separation bin in the MRR. Collect different types of recyclables on specific days, for example, waste paper on Mondays, plastics on Wednesdays, and metals on Fridays. Alternatively, specify time slots during the day when residents can deposit each type of recyclable, for example, 7am-11am for waste paper, 1pm-5pm for plastics and 5pm-9pm for metals. Cleaners therefore would not have to sort recyclables.

   d) Floor dividers: Divide the floor area of the MRR into 3 blocks, using coloured masking tape, for collecting waste paper, plastics and metals. Put a corresponding sign for each recyclable on the wall. Residents deposit their recyclables at any time during the day. Cleaners collect the recyclables at designated times or whenever necessary.

2) Floor Refuse Storage Room (RSR/Refuse chute room (RCR))

   For RSR/RCR, there are 4 options for waste recovery:

   a) 2 or more bins, bring any time

   b) 1 bin, bring any time

   c) 1 bin, bring specified times

d) Floor dividers

3) Floor Cleaner Room (FCR) / Water Meter Room (WMR)

For FCR/WMR, the options for waste recovery are similar to the #2 RSR/RCR

4) Refuse Chute (RCT)

a) Bring one type of recyclable at specific times: Residents dump different types of recyclables at specific times on specific days into the refuse chute. For example, 9pm-10pm could be designated for recyclables collection, with waste paper collected on Mondays and Wednesdays, metals on Tuesdays and Thursdays, and plastics on Fridays. During this time slot no other waste is allowed in the refuse chute (to prevent recyclables from being mixed with refuse). Cleaners do not have to sort the recyclables collected in the refuse storage chamber.

b) Bring any type of recyclables at specific times: Residents deposit any recyclables into the refuse chute at a specified time slot every day or on specified day(s) of the week. For example, 9pm-10pm on Mondays, Wednesdays and Fridays could be designated for recyclables collection. During this period, no other waste is allowed down the refuse chute (to prevent recyclables from being mixed with refuse). Cleaners have to sort the recyclables in the refuse storage chamber into waste paper, plastics and metals.

c) Bring pre-sorted recyclables at any time: Residents separate recyclables into individual, tied bags at home and deposit them down the refuse chute at any time of day. They can put different types of recyclables in different bags (e.g. one bag for waste paper, another for plastics, etc). Or they can place all recyclables into one bag. Cleaners sort the mixed recyclables into waste paper, plastics and metals in the refuse storage chamber.

5) Integration of lobby with floor refuse storage room (ILR)

- A lobby adjacent to a floor refuse storage room is the intercepted approach to a staircase or exit route, which acts as a fire and smoke check between the refuse storage room and the adjacent staircase or exit. It is enclosed throughout by walls and doors in accordance with the Code of Practice for Fire Resisting Construction 1996

(COPFRC1996) issued by the Buildings Department (BD). It is common to call the lobby area the "smoke lobby". It has specific requirements in terms of fire safety

- For ILR, the options for waste recovery are similar to the #2 RSR/RCR

6) Staircase landing (SCL)

   The waste separation bins shall be made of metal, non-combustibles or fire resistance materials. They should be properly fixed and secured. For waste separation, the estate should adopt 1 bin (with compartments), bring any time approach

7) Floor Service Lift Lobby (SLL)

   - A service lift is commonly used to transfer refuse from each floor to the ground floor of the building. The SLL can be used for placing waste separation bin(s), provided that they met all fire safety regulations.

   - For SLL, there are 3 available options for waste recovery a) 3 bins, bring any time b) 1 bin, bring any time c) 1 bin, bring at specific time

8) Floor Passenger Lift Lobby (PLL)

   - For PLL, the options for waste recovery are the same as SLL

9) Others

- In order to facilitate source separation properly, on a daily basis, property manager should:
  - Arrange for the collection of waste paper, plastics and metals from each floor on a regular basis. Keep the recyclables collection point in a clean and hygienic condition.
  - Store collected recyclables properly before they are picked up by the recycler(s).
  - When selling recyclables to a waste recycler, make sure the materials will be re-used or recycled, and not disposed of at landfills.

The practice of source separation of waste in residential buildings will increase recycling and thus reduce waste disposed to the landfill. However, before implementing source separation

as outlined in this guideline, property managers are strongly advised to review and verify if the building comply with various ordinances and regulations. Over the 3 years of progress, the programme has made a number of achievements. These achievements are published in the "Annual Report 2006 – Programme on Source Separation of Domestic Waste". They are summarized as follows:

- Among the housing estates with expanded ground-level waste separation facilities, some 120 of them reported that their waste recovery rates increased by an average 36%, by collecting a wider range of recyclables.

- Estates that installed waste separation facilities on each floor performed even better – some 70 of them reported an average 54% increase in their waste recovery rates.
- About 80 participating estates had never done any waste separation and recovery before joining the programme. Some estates installed waste separation facilities on each building floor and others set up waste separation bins on ground floor.

- The improved recovery of waste helped to reduce the quantity of waste requiring disposal to 3 – 4% overall among the participating housing estates.
- In 2006, the domestic waste recovery rate has increased to 20%

Despite the success of the programme, there are numerous difficulties in running the programme. A number of estates have faced difficulties in doing this and only 210 estates are using a floor-based system. The others have installed waste separation facilities at ground floor only. Some of the difficulties encountered included:

- lack of a refuse room to accommodate waste separation bins on each floor
- lack of space in refuse rooms to accommodate waste separation bins

- concern that placing waste separation bins on staircase landings will block means of fire escapes (regular rubbish bins are already placed there)

- concern that the cost of installing waste separation bins on all building floors is too high

In summary, the Hong Kong government had launched a number of programme in an attempt to improve the recycling rate and reducing waste generated from the residential developments. The wet and dry waste pilot programme attempted to separate waste from recyclable and non-recyclable from residential estates. However, after detailed cost consideration, it is found that the cost of capital and labour is too high to perform such a programme territory wide. Based on the experience gained from wet and dry waste pilot programme, the programme of source separation was launched to facilitate waste separation in residential buildings. The objective of the programme is to achieve waste separation at the source such that the maximum amount of recyclables can be divided from the waste stream. Adopting the experience gained in the past, this programme takes the different designs of the estates into consideration. After running the pilot programme for a year, it is found that it is an effective programme to reduce solid waste. In 2005, it was expanded territory wide and has been continuing ever since. Despite its success, it encountered a number of constraints and obstacles. One of the major obstacles is that most of the older Hong Kong housing estates are not designed for waste separation. The lack of space in these estates limits the effectiveness of waste separation on the source.

Chapter 3 Literature Review

3.1 Municipal Solid Waste Management Policies in Hong Kong

There are numerous articles in relation to the solid waste technologies and management policies for Hong Kong housing estates. To describe the present situation and challenges of the solid waste management in Hong Kong, the literatures presented here are divided into different sections. They are 1) Municipal waste management and 2) Environmental awareness.

1) Municipal waste management policies in Hong Kong

In Hong Kong, the Environmental Protection Department (EPD) is responsible for all environmental related tasks. To tackle the municipal solid waste (MSW) problem of Hong Kong in a holistic manner, the Government published "A Policy Framework for the Management of MSW 2005-2014" (Policy Framework) in December 2005. The Policy Framework for the Management of Municipal Solid Waste (2005-2014) published by the Administration in December 2005 which sets out a comprehensive strategy consisting of a series of proven policy tools and measures to achieve the following targets –

Target 1: Reduce the amount of MSW generated in Hong Kong by 1% per annum up to the year 2014.

Target 2: Reuse, recover and recycle to increase the overall recovery rate of MSW (45% by 2009 and 50% by 2014)

Target 3: Bulk reduction and disposal of unavoidable waste - to reduce the total MSW disposed of in landfills to less than 25% by 2014. (Hong Kong Environmental Protection Department, 2005)

One of the key measures being implemented, initiated in the 2004 and 2005 is the territory-wide programme of source separation of waste which was rolled out in January 2005. This programme aims to make it more convenient for residents to separate domestic waste at source by encouraging and assisting property managers and residents to set up waste

separation facilities on every floor of their buildings and to include the collection of more recyclable materials other than waste paper, aluminum cans and plastic bottles, such as other metal containers, mixed metal items, plastic bags and packaging, mixed plastic items, used clothing, electrical and electronic appliances, and computers. Through source separation and other measures contained in the "Policy Framework for the Management of Municipal Solid Waste in Hong Kong (2005-2014)", the domestic waste recovery rate has increased from 14% in 2004 to 23% in 2007. (Hong Kong Environmental Protection Department, 2005)

2) Environmental Awareness in Hong Kong

The aforementioned policy also aimed at promoting the public environmental awareness in Hong Kong. According to various environmental groups commissioned by the Chinese University of Hong Kong survey, it shows that over the past two years, public housing residents continued to raise their awareness of environmental protection. Their environmental protection knowledge raise to 73%, a 6 % increases compared to a year ago. At the same time, more residents to practice environmentally friendly life, nearly 70 percent of the respondents have the habit of separating household waste. The use of environmentally-friendly bags is 65%, a more than 10 percent increase two years ago. (Hong Kong Information Service Department, 2008)

Further, based on a public survey, *Opinion On Residential Waste Recycling Survey (市民對家居廢物回收的意見調查 調查編號#117),* the following are noted:

- The Research Association of Hong Kong has conducted a survey during 15-21 June, 2006. 1073 of Hong Kong Citizens aged over 18 were interviewed by telephone on their views of home wastage recycling. The results showed that 89% of respondents knew that the government has launched the 3 colored recycling bin home wastage recycling campaign, which is the recycling of paper, tin and plastic, and only 11% of respondents had no idea about such program. Within those who knew about the campaign, 48% of them claimed they participate in the campaign occasionally; 44% of them claimed they participate very often and only 8% of them claimed they never participate in the campaign. 49% of respondents said they have disposed materials other than the

assigned materials into these recycling bins, and 51% of them said they have not.

- Among the 1073 respondents, 84% will actively involve in recycling programs if the housing estate has waste separation facilities on each floor of their respective building. 86% of the respondents support the increase the type of recyclables to be collected
- Based on the survey results, the spokesman of the Research Association of Hong Kong concluded most of the citizens in Hong Kong are aware of the 3 coloured recycling bins programme in their housing estates. Also, about 85% of the respondents indicated they will increase involvement in recycling activities if the recycling facilities are setup in a way that is more conveniently for them to recycle. This indicated that, in general, Hong Kong citizens are active in environmental programs established by the EPD and is willing to participate if the supporting facilities are setup. (Hong Kong Research Association, 2006)

It demonstrated that Hong Kong citizens are more actively involved in environmental activities given that they are provided the right recycling facilities. However, at the same time, educational campaigns are still needed to promote using the recycling facilities. This survey indirectly indicated that innovative technologies or facilities may help in recycling for Hong Kong housing estates.

In Hong Kong, most of the high rise buildings are managed by professional property management companies. They are the most key participants in the process of residential environmental programme, campaigns and developments. There is an excellent article which reviews the environmental related activities and programme for Hong Kong housing estates. It discusses about green opportunities for Hong Kong housing estates, its success stories and its obstacles. General consensus in Hong Kong is that green activities in Hong Kong housing estates are a waste of money. On the contrary, this article provides some good example cases that after environmental campaigns were launched; the housing estate was able to reduce property management charges due to the reduction of consumption. The article is summarized in point form below: (Hong Kong Research Association, 2006)

- According to Mr. Lai, spokesman for the winner of environmental property management (public estate) award said that in the premises of public housing estate, due

to the fact that the working class is occupied with the working life, the majority of the green functions are achieved and performed by retirees and youngsters.

- He admitted that the initial cost of promoting environmental activities in public estates is high. Capital and employee investment in promoting the green campaigns are needed to convince the owners corporation to make the necessary changes. However, they managed to achieve cost saving results through these campaigns. For example, Wong Tai Sin, in 2005, achieved a reduction electrical usage by 5.08%. Water consumption reduced 6.04%. Also, the estate managed to achieve a 6.25% reduction in paper waste.

Compared to public housing estate, the continuity of the private property management firms are able to achieve more in the green campaigns, and with better results. For example, according to the Goodwell Property Management Inc, the winner for the environmental property management (private housing), the estate of 聽濤雅苑, in 8 years, Goodwell Property Management Inc managed to reduce 44% of electricity and 50% water consumption. These encouraging results lead to the reduction of property management fee of $1.5/ft^2 monthly, a total of 16.7%. The complete article is attached at the end of this report as appendix.

On the other hand, according to a research performed by the Ms. Chung Shan Shan from the Hong Kong Baptist University, *The Value-Action Gap in Waste Recycling: The Case of Undergraduates in Hong Kong by Shan-Shan Chung,* the following are noted:

- This study indicates that a clear gap between verbal commitment on recycling and corresponding action does exist in waste recycling in Hong Kong Baptist University
- The existence of a value-gap was indirectly suggested in a earlier study in which >98% of Hong Kong people agreed that they had the responsibility to protect the environment, yet only 30% to 60% of the same respondents reported that they had actually practiced environmental behavior.
- 20% made reference to situational constraints, such as inconvenient recycling bin locations and bin design, which hampered their recycling.
- Two steps are necessary to bring the discursive consciousness to positively influence the recycling behavior :

1) Create events to lower the barrier imposed by practical consciousness on discursive so that a "questioning the unquestioned" process is triggered

2) Provide them with information that would lead them to connect their actions with environmental impacts. E.g. putting up a sign at the waste bin to remind the bin users to recycle

This study indicated that although the general acceptance is that Hong Kong residents posses a high environmental awareness, they did practice recycling as much as some of the reports from the green groups as indicated.

According to the Subcommittee on Building (Refuse Storage and Material Recovery Chambers and Refuse Chutes) Amendment 2008 – Background brief and based on the aforementioned Municipal Solid Waste policy, the Hong Kong Environmental Protection Department had launched a number of programmes. These include the three-coloured separation bin scheme and the Wet/dry Waste Separation Pilot Programme (the Programme). At present, there are 28 000 three-coloured waste separation bins placed at some 9,300 points throughout the territory.

The revenue generated from this wet/dry program was used to offset the sorting cost. While the Programme in tandem with the three-coloured bin scheme in the four participating estates recovered 12% more recyclables than the three-coloured bin scheme alone in non-participating estates, it is considered not sustainable as the processing cost is high.

With the experience gained in the wet/dry Programme, another 12-month pilot programme on Source Separation of Waste was launched in August 2004 in 13 housing estates in the Eastern District covering about 37 000 households and a population of about 120 000. The pilot programme aims to make it more convenient for residents to separate domestic waste at source by encouraging and assisting property management companies to provide waste separation facilities on each floor of the building.

Some panel members of the investigation team at the Environmental Protection Department opine that segregation of domestic waste at source might not be practicable given the space

constraints of most households in Hong Kong. They therefore suggest that financial assistance should be provided to encourage more innovative recycling initiatives, such as incorporation of new features in building design to facilitate waste segregation. At the same time, EPD propose a number of amendments on regulation to facilitate recycling in Hong Kong estates.

The main purpose of the latest Amendment Regulations is to add a new regulation, 3A, to the Principal Regulations. The new regulation imposes a mandatory requirement that, where a plan relating to a domestic building or the domestic part of a composite building is submitted to the Building Authority for approval under section 14 of the Buildings Ordinance (Cap. 123), the plan must show provision for a refuse storage and material recovery room on every floor of the domestic building or of the domestic part of the composite building. The next section will review the ordinances that are related to solid waste management.

3.2 Municipal Waste related Ordinances and Regulations in Hong Kong

There are a number of environmental ordinances and regulations in Hong Kong that are related to the refuse chutes in Hong Kong housing estates. In this section, the statutory requirements of the domestic waste collection systems in Hong Kong were reviewed. The refuse collection systems in Hong Kong are required to comply with the Buildings (Refuse Storage and Material Recovery Chambers and Refuse Chutes) Regulation (Cap. 123 sub. Leg. H) under the Buildings Ordinance (Cap. 123) in the past. This regulation is called Buildings (Refuse Storage Chambers and Chutes) Regulations. This regulation was amended on 21 June 2000 to incorporate the provision of sufficient space for waste recovery activities and other requirements in new building developments.

Some of the main points from the Cap 123H regarding to the requirement of the refuse storage and material recovery chambers and refuse chutes are summarized below (Hong Kong Legislative Council, 2008) :-

1) Every refuse storage and material recovery chamber shall be approved by the Building

Authority and in such location as to provide ready access for removing any refuse container and recovered materials stored in the refuse storage and material recovery chamber

2) The passage which gives access to any refuse storage and material recovery chamber other than those with vehicular access shall be not less than 1.5m in width, without steps and paved, and shall have a longitudinal gradient not greater than 1 in 20.
3) Not less than one of the walls of every refuse storage and material recovery chamber shall be an external wall
4) No refuse storage and material recovery chamber shall have any dimension less than 1.5m and clear headroom less than 2 m
5) For every refuse storage and material recovery chamber, it shall be constructed of brickwork, concrete or other approved material. The internal faces of the walls shall be lined with glazed bricks, glazed tiles or other approved material. The ceiling shall be rendered in cement and finished with a smooth surface. The floor of every refuse storage and material recovery chamber shall be constructed of concrete not less than 100mm thick, lay to fall towards the gully, and finished with quarry tiles or other approved hard impervious material.
6) The door of every refuse storage and material recovery chamber shall be an external close-fitting steel type. It shall have a minimum dimension of 1.8m height, 1.25m width. The door shall be provided with a lock or other means of preventing unauthorized persons obtaining access to the refuse storage and material recovery chamber. However, every refuse storage and material recovery room shall be readily accessible by any occupier of the building at all times
7) Every refuse storage and material recovery chamber shall be provided with an outlet drain covered with grating and connected to a back inlet trapped gully. Every gully shall be situated in a position immediately outside the refuse storage and material recovery chamber. It is connected to a drain provided for the carriage of foul water.
8) For the purpose of cleaning, a water supply point shall be provided and connected to the supply of water provided for flushing the soil fitments in the building
9) Every refuse storage and material recovery chamber shall be provided with a mechanical

ventilation system with a minimum ventilation rate of 3 air changes per hour. Air purifying facilities will also be provided to the exhaust part of the ventilation system to the satisfaction of the Building Authority.

10) Every refuse storage and material recovery room shall have a minimum illumination level of 120 Lux measured at the finished floor level
11) Where a refuse chute is provided, it shall be vertical save and terminate at its lower level in a refuse storage and material recovery chamber
12) No refuse chute shall have a bend or offset in it except at its foot or above the level of the highest hopper. Where refuse chute has an offset at the foot, it shall have a slope of not less than 60 degrees to the horizontal and to be constructed of replaceable galvanized or stainless steel of not less than 3 mm thickness.
13) No refuse chute shall have an internal diameter of not less than 450mm. The internal surface of every refuse chute shall be smooth and impervious and shall be formed of or lined with glazed ware or other approved material. The walls of every refuse chute shall be constructed of solid brick or concrete of not less than 100mm thick.
14) Every refuse chute shall be provide at its lower end with a galvanized or stainless steel shutter so constructed as to enable the chute to be closed when necessary.
15) A ventilation pipe shall be provided at the top of the refuse chute. It shall have an internal area of not less than 0.05 m^2 and be carried up more than 1m from the top of the refuse chute. The end of ventilating pipe shall be provided with a grating or grille having apertures of an aggregate area not less than the sectional area of the pipe. The dimension of the aperture shall be not more than 10mm.
16) The refuse chute shall be provided with an access opening not less than 225mm in diameter above the level of the highest hopper for the inspection and cleansing of the chute.
17) Every hopper shall be situated in a place permanently ventilated to the open air. The hopper shall have an opening of not less than 250 x 150 mm and not more than 350 x 250 mm. It shall be constructed that it will remain only in a completely closed or completely open position and will not open of its own accord. The inner plate of every hopper shall project downward at an angle of not less than 45 degrees to the horizontal when the

hopper is closed

18) For domestic building and non-domestic buildings (except industrial), the minimum floor space of refuse storage chamber shall be not less than the total usable floor space divided by 347 and 925 respectively.

By Cap. 123 Sub Leg H, the general statutory requirements of the refuse storage and material recovery chambers and refuse chutes are recognized. This provides useful information for this study, which involves the design of refuse collection facilities in buildings.

Recently, according to the latest amendment of the Buildings Ordinances by the Hong Kong Legislative Council, one of the major problem encountered in implementing the source separation of domestic waste programme is that the majority of domestic buildings do not have a refuse storage and material recovery room on every floor and there is often a lack of space for placing waste separation facilities. Improper placing of waste separation facilities in the lift lobbies, corridors and staircases of these buildings may pose a fire hazard to occupants. Therefore, the Legislative Council has initiated an amendment to the ordinance. Based on the recent publication of Legislative Council Brief on the Amendment for the Buildings Ordinance (Cap.123H) Buildings (Refuse Storage and Material Recovery Chambers and Refuse Chutes) Regulation 2008, the following points are related to this study: (HKSAR Legislative Council, 2008)

A major problem encountered in implementing the source separation of domestic waste programme is that the majority of domestic buildings and the domestic part of composite buildings in Hong Kong do not have a refuse storage and material recovery room on every floor and there is often a lack of space for placing waste separation facilities. Improper placing of waste separation facilities in the lift lobbies, corridors and staircases of these buildings may pose a fire hazard to occupants.

Therefore, it is proposed that every new domestic building and the domestic part of every new composite building shall be provided with a refuse storage and material recovery room on every floor. It is proposed that a building of any of the following descriptions be

exempted from such mandatory requirement:

(i) a domestic building or composite building with one staircase only;

(ii) a domestic building designed for occupation by one single family only and with not more than 3 floors designed for habitation;

(iii) a composite building the domestic part of which comprises not more than 3 floors and is designed for habitation by one single family only;

and

(iv) a domestic building or composite building on a site of an area of not more than 500 square metres.

The main purpose of the Amendment Regulations is to add a new regulation 3A to the Principal Regulations. The new regulation 3A imposes a mandatory requirement that, where a plan relating to a domestic building or the domestic part of a composite building is submitted to the Building Authority for approval under section 14 of the Buildings Ordinance (Cap. 123H), the plan must show provision for a refuse storage and material recovery room on every floor of the domestic building or of the domestic part of the composite building.

3.3 Literature on Refuse Chutes in Hong Kong

Refuse chutes are a common facility in public housing estates developed after 1980. There are a number of articles related to the current issues and status of refuse chutes in Hong Kong high-rise buildings.

Poon, et al. (2002) provided a detailed analysis about the current refuse management in Hong Kong residential buildings, in which their surveys were carried out in both public and private housing estates with traditional type refuse collection systems. Their paper revealed that in public housing dissatisfaction was recorded on the hygienic condition of waste storage facilities on each floor and the central refuse collection points, while the collection was judged neutral to satisfactory in home ownership courts. Some key points in relation to this document are summarized below:-

- The objectives of this paper are: i) investigate what facilities are required to enhance sound management of municipal solid waste generated from residential buildings in Hong Kong ii) examine and evaluate current waste recycling collection systems and facilities iii) contrast and compare with the preferences of the residents
- In total, 92 housing estates were selected for on-site audits, 30 public housing estates, 28 home ownership scheme housing estate (HOSs) and 34 private housing estates. 100 tenants were randomly selected for questionnaire survey
- Based on the survey, most respondents in public housing estates prefer to dispose the waste through refuse chute by themselves. It is followed by disposing waste at refuse bins placed at lift lobbies. Door-to-door bag collection is the least preferred. Also, the reasons for NOT recycling are investigated. Thirty-six percents of the respondents opined that existing recycling facilities are not convenient enough in its location.
- Based on the survey, public housing estates seem to be better provided in waste management facilities. However, in all types of estates, means of ventilation in waste facilities and de-odorizing apparatus are lacking. 20-30% of refuse chutes are not functional in all the housing types studied. Although waste management facilities in private estates are not as well equipped as in public housing and HOS, the surrounding of the waste facilities is tidier.
- Residents in all types of housing wanted to have the waste clear from the corridor and if possible get it out of sight through the refuse chute or at the stair area. Door to door bag collection method is the least preferred
- It is also found that there is a connection between recycling rate and education level. More educated residents seemed to be more willing to engage recycling
- Automatic Refuse Collection System (ARCS) is investigated and examined in this study. In the ARCS, the environmental hygiene of the estates is improved. The cost of waste carts can be saved but not enough to offset the capital and maintenance cost of the ARCS. However, labor costs for removing the bulky waste manually cannot be saved. Moreover, the capital cost and operating cost for ARCS is far greater than that for conventional system. Also, a standby system is required in case of mechanical failure occurred in the ARCS.

There is **a**nother study by Edwin H.W. Chan and Grace K.L. Lee (2006), *"A review of refuse collection systems in high-rise housings in Hong Kong"*- The Hong Kong Polytechnic University (Edwin et al, 2006). It evaluates current refuse collection methods in Hong Kong with focus on refuse chute collection systems. Also, this paper evaluates and compare the conventional refuse chute collection system to the Automatic Refuse Collection System (ARCS). Details of this report are summarized as follows:

- The questionnaire survey indicated that Hong Kong citizens supported or preferred an automated refuse collection system that could treat the refuse in a more hygienic way.
- Though the occupants were willing to make some financial contributions, they were unwilling to pay the amount of money required to support the operation of the system.
- Refuse collection points are widely known as potential sources of disease and infection
- In Hong Kong, two types of refuse collection methods can be observed in residential projects. A conventional refuse collection systems (CRCS) is commonly used in various types of residential developments while the automated refuse collection system (ARCS) is mainly installed in public residential developments.
- The wastes produced by the residents are collected by refuse workers and temporarily stored in refuse collection points. The waste disposal contractors of the Food And Environmental Hygiene Department or other wastes collectors then transfer the refuse to refuse-transfer stations for final disposal at landfills.
- When the refuse is transferred from the estates, nuisance may be generated and health risks may be imposed on residents, refuse workers, or property management staff if the wastes disposal is not well managed
- There are two types of Conventional Refuse Collection Systems. One with refuse chute and the other without.
- For residential developments with refuse chutes, the occupants dispose of their refuse either directly to refuse chute or at designated areas on each floor. The cleansing contractors then collect their refuse to refuse-room on each floor and dispose of the wastes to the refuse chute through indoor refuse disposal inlets. The refuse collection

bin under the chute would store the refuse temporarily. The refuse workers transport manually the refuse collection bins inside the refuse chambers located at ground floor of different blocks to the central refuse collection point where the Food and Environmental Hygiene Department (FEHD) collects refuse daily at predetermined time.

- For residential developments without refuse chutes, the residents dispose their refuse at specified locations on each floor. The refuse workers collect the refuse and package them into larger plastic bags or place them into the collection bins. Then, the bags or the bins will be conveyed to the ground floor by the common passenger or goods lifts.
- The Automated refuse collection system (ARCS) is a computerized and centralized refuse collection system. The refuse is temporarily stored in refuse storage facilities and is disposed of through indoor refuse disposal inlets on different floors to the refuse chute or outdoor refuse disposal inlets. The sensors will be triggered once the storage facilities are full and the refuse released from the refuse discharge valves will then be transported to the central plant room through underground ductworks by the suction of air. The refuse enters into the cyclone type refuse separator, which separates the air and refuse for further treatment. The exhaust air is discharged to ambient air after treatment by de-odourizing facilities such as carbon filter or chemical scrubber while the refuse is compacted and stored in a refuse container ready for disposal.
- For examples, the automated (ARCS) systems are installed in Hong Kong and Shanghai Bank Headquarters, Cathy Pacific and Lufthansa flight kitchens and Hong Kong Science Centre, etc.

- For Conventional Refuse Collection System

Merits of CRCS	Limitations of CRCS
- Lowest installation cost, operation and maintenance costs as it does not involve	- Nuisances such as spills and odor would be generated during the transfer

mechanical devices or underground refuse conveying ductwork	of refuse
- Ease of construction. Ease of operation, no particular training is required for the cleaning workers	- Bags containing refuse disposed of into the refuse chute may break before reaching the refuse collection bin underneath or the refuse may be thrown everywhere in the refuse chamber when the total amount of refuse exceed the deprived capacity

Table 1 – Merits and limitations of the conventional refuse collection systems

- For Automatic Refuse Collection System

Merits of ARCS	Limitations of ARCS
- Unpleasant smell and spill of refuse are significantly reduced	- Connect all refuse chutes from different blocks to the central plant room, extensive underground conveying ductwork pose difficulties for variety of utility services
- Total numbers of refuse workers required for conveying refuse can be greatly reduced	- More underground spaces required for transportation piping
- The number of transfer stations for compacting the refuse before moving to the landfill can be reduced	- Underground refuse transport on pipe works increased installation and maintenance cost
- Noisy movement of refuse collection vehicles can be eliminated	- High running cost and energy consumption cost for suction

Table 2 – Merits and limitations for the Automatic Refuse Chute system

- The popularity of the ARCS in Hong Kong residential developments is still low in

comparison with conventional system.

- From the cost-benefit point of view, it was also not cost effective for the private sector to install the automated (ARCS) system in private residential developments, especially for small development with homes less than 3000 flat units.
- Apart from the instillation cost, the high operation and maintenance cost is also a reason making the automated (ARCS) system less attractive.
- This study showed that the labor cost for handling refuse could NOT be reduced. This is because property management staff pointed out that self disposal was not preferable in HK especially in public housing estates because some residents would dispose substances that may damage the refuse chutes or cause fire accidents
- In this study, it is recommended more resources should be put on the management of existing refuse collection facilities before introduction of new refuse collection proposals

3.3.1 Articles on Refuse Chutes in Hong Kong estates

Not all buildings in Hong Kong has a refuse chute installed. However, buildings that were constructed after 1980s normally have refuse chutes installed. For example, for the case of public housing estate, only four out of 148 public rental housing estates of the Housing Authority are not equipped with refuse chutes, namely, Sai Wan Estate in Hong Kong Island, Ngan Wan Estate and Lung Tin Estate in Lantau Island, and Cheung Kwai Estate in Cheung Chau. This issue has been brought up at the Legislative Council and the questions and reply are reported as follows: (HKSAR Legislative Council, 2002)

Following is a question by the Hon Albert Chan and a written reply by the Secretary for Housing, Planning and Lands, Mr Michael Suen, in the Legislative Council:

Question: It is noted that, although the refuse collection rooms in some public rental housing ("PRH") estates are equipped with chutes connecting all floors of the block, some cleaners do not make use of the chutes to transport the collected refuse. Moreover, as the refuse collection rooms in some PRH estates are often locked, residents dump their rubbish into the

collection bins at the lift lobbies or place it outside their units outside the specified refuse collection hours.

In this connection, the following points are answers:

(a) For Hong Kong Public and HOS, only four out of 148 public rental housing estates of the Housing Authority are not equipped with refuse chutes, namely, Sai Wan Estate in Hong Kong Island, Ngan Wan Estate and Lung Tin Estate in Lantau Island, and Cheung Kwai Estate in Cheung Chau.

(b) Out of the 144 public housing estates equipped with refuse chutes mentioned above, the refuse chutes of some or all blocks in nine estates are not in use because of tenants' objection and geographical constraints. Specific reasons include nuisance to nearby residents as a result of noise generated by the chutes when in use, frequent blockage of refuse chutes causing inconvenience to tenants, and lack of direct vehicular access to remove rubbish from the collection points of refuse chutes. Details are set out at the Annex. (HKSAR Legislative Council, 2002)

<table>
<tr><th>Estates</th><th>Blocks involved</th><th>Reasons for Disuse</th></tr>
<tr><td>Upper Wong Tai Sin Estate</td><td>Seven blocks</td><td rowspan="6">In view of residents’ complaints about noise nuisance caused by the refuse chutes when in use, after consultation with the Estate Management Advisory Committees, use of those refuse chutes have stopped. Upon confirmation with site-visit, the refuse chutes Kwong Yuen Estate are back in service in 2005.</td></tr>
<tr><td>Sha Kok Estate, Sha Tin</td><td>Two blocks</td></tr>
<tr><td>Leung King Estate, Tuen Mun</td><td rowspan="4">All blocks</td></tr>
<tr><td>Kwong Yuen Estate, Sha Tin</td></tr>
<tr><td>Fu Shin Estate, Tai Po</td></tr>
<tr><td>Tsui Lam Estate, Tseung Kwan O</td></tr>
</table>

Estates	Blocks involved	Reasons for Disuse
Wah Fu Estate (I), Aberdeen	All blocks	In view of residents' complaints about noise nuisance from refuse chutes and inconvenience resulting from frequent blockage of the chutes, use of those refuse chutes has stopped.
Shek Kip Mei Estate	One block	The building block is located on the top of a slope. Refuse collection vehicles cannot reach the refuse chutes directly for removing refuse from the huge collection bins used with the chutes. Wicker bins are used for collecting and transporting rubbish instead.
Kam Peng Estate, Peng Chau	All blocks	As the estate is in Peng Chau, there is no vehicular access to the chutes to remove refuse from the huge collection bins. Wicker bins and plastic bags are used for collecting and transporting rubbish instead.

Table 3 – Reason for Disuse of Refuse Chutes in Hong Kong (2002)

(c) To ensure safety and avoid blockage, refuse chutes should be used by cleansing workers who are familiar with the operational procedures. Hence, it is not appropriate to allow residents to use the refuse chutes to dispose of rubbish. As refuse chutes are installed inside the refuse rooms on each floor, to forestall occurrence of accidents and crimes inside the refuse rooms, the Housing Department should lock the doors of refuse rooms at all times.

An article (health.atnext.com, 2002) described some of the problems and obstacles encountered by estate property management using the refuse chutes in the past. Its contents are summarized as follows:

Due to the design of the Hong Kong's refuse chute, it is difficult to clean and sanitize if there is any leakage or leachate. Oversized refuse or garbage would cause clogging. Due to these concerns, some property management firms would choose to use the elevator to transport the floor refuse. However, the uses of the lifts are well known to cause hygiene problems. It will cause odour issues and increase labour cost.

- On the other hand, property managers stated that their estates has the standard refuse chute, the impact noise when the refuse is disposed down to the chute causes noise disturbances to lower-level residents. They stressed that the transportation of refuse using the elevator lift will be restricted to "refuse transfer only" during garbage collection period. Before they reopen the elevator to the estate tenants, they will make sure the used elevators are in perfect hygiene condition.

According to a spokesman of the Housing Authority, although current legislations do not enforce all estates must possess a refuse chute, there are legal requirements for the hygiene of refuse rooms and refuse chutes. (Next Media Interactive Ltd., 2006)

Chapter 4– Refuse Chute Systems in Hong Kong

A refuse chute, or sometimes called a rubbish chute, or garbage chute, is an inclined channel in which refuse can be passed down from the opening of each floor to a central refuse room on the ground floor of a building. Today, there are 2 major types of refuse system available in the market. They are:

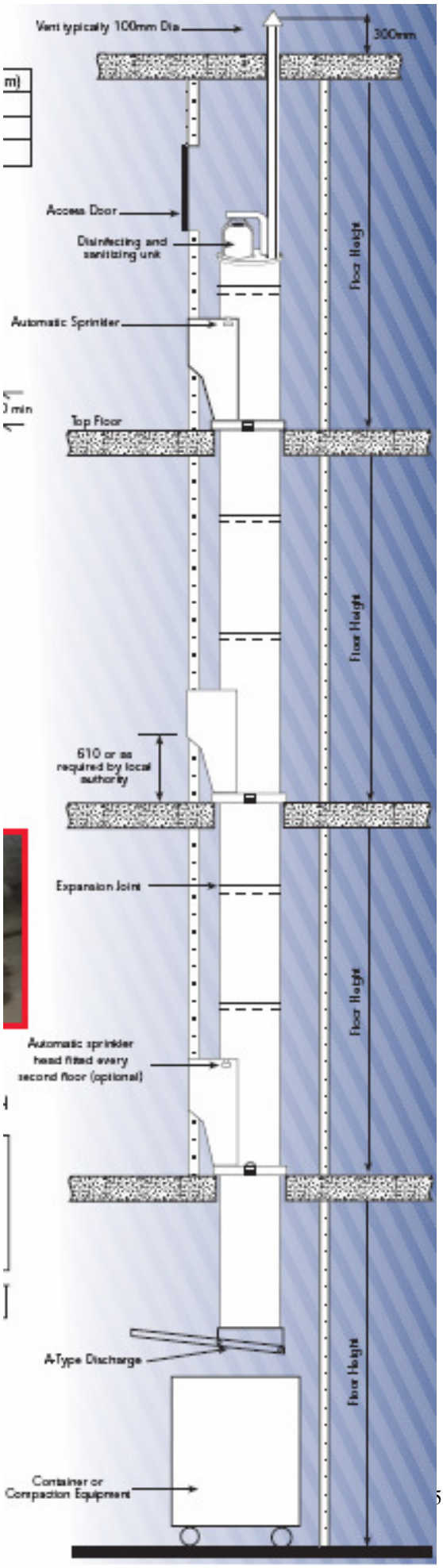
1) Traditional or Conventional refuse chute system
2) Automatic or vacuum refuse chute system (ARCS)

In addition to the two major types of refuse chute system, a new type of refuse chute, called the Waste Separation Recycling Chute Technology (WSRCT) as described in this report, is coming to the market. The waste separation recycling chute is very similar to traditional refuse chute with the addition of waste separation bins to improve waste separation. In Hong Kong, only the traditional refuse chute system and the ARCS are in operation commercially. The details for this innovative waste separation refuse chute technology is discussed in more detail in the next chapter (Chp. 5)

4.1 Traditional Manual Refuse Chute System

A traditional refuse chute is an inclined channel in which refuse can be passed down from the opening of each floor to a central refuse room on the ground floor of a building. A typical refuse chute is as shown by the diagram at right:

For later models, the bottom end of the refuse chute is usually connected with a hopper which collects the trash in a compactor to reduce trash size. The top of the refuse chute is connected to the roof of the building with ventilation system to discharge unpleasant odour. In Hong Kong, all refuse chute systems installed in Hong Kong housing estates have to comply with the Buildings Ordinance, Chapter 123 (CAP 123H BUILDING (REFUSE STORAGE AND MATERIAL RECOVERY CHAMBERS AND REFUSE CHUTES) REGULATIONS). The ordinance not only outlines the requirements of the design parameters for chute systems, it also set the standards for refuse storage room in each floor of the building. More details with respect to the design of refuse chutes in Hong Kong public estates are presented in Appendix H.



4.2 The Automatic Refuse Collection System (ARCS)

The main benefit of the ARCS is to eliminate the unpleasant nature of refuse collection work. Domestic waste collection will become a cradle-to-grave procedure from household to landfills without direct contact of the refuse. No more messy and smelly refuse collection / storage areas will be next to the homes. This will provide a cleaner and sanitary environment. There are two types of ARCS: mobile automatic refuse collection system and the stationary automatic refuse collection system. For the purpose of this study, only the stationary automatic refuse collection system is described in detail.

The stationary automatic refuse collection system collects the refuse from each floor of a building and transports it by means of air in a conveyance pipe system to the central refuse collection plant. The system consists of refuse disposals inlets integrated with the building refuse chute on each floor, floor conveying pipes, discharge and air-inlet valves and a central refuse collection station. All current ARCS applications in the public housing estates in Hong Kong are stationary automatic refuse collection systems.

Some refuse is prohibited to be discharged into the ARCS, including inflammable/explosive refuse, heavy objects (e.g. stone, metal, etc.), sticky material, inflatable objects; offensive odour objects, acids, alkalis, fertilizers, chemicals and large quantities of water. These items, including large bulky waste, have to be transported manually by the cleaning personnel via the elevator.

Self-closing and volume-controlling indoor type refuse disposal inlets are installed in the refuse room on each floor of the domestic blocks. A flush mounted, front operable panel with red, amber and green LED lights and low volume dual pitch buzzer is integrated with the disposal inlet to indicate availability of the inlet for refuse disposal. The self-closing disposal inlet will not cause any noise nuisance to the nearby flat units.

An electromagnetic lock is adopted to lock up the inlet in case of system fault, refuse accumulated at the ground floor storage facility reaching the threshold level. The electromagnetic lock shall be capable of being overridden through a self-return key switch on the panel.

In ARCS, there is a central plant which consists of a refuse separator, air blowers, water

scrubber, refuse compactors and containers, control system, ……etc. Air blowers are located in the central refuse collection plant to induce the necessary air flow to carry the refuse to the central plant and cater for changes in pressure requirements due to differences in the length of refuse conveyance paths.

The refuse from different domestic blocks mixed with air sucked to the central plant, which falls into the refuse separator. The refuse separator is to separate the refuse and air stream. The separated transport air passes from the upper part of the separator to the dust filter and deodourizing filter (water scrubber) before being exhausted to the outside air. Normally, ARCS are coupled with a special type of refuse collection vehicle fitted with lifting hooks subsequently removes the filled container and transfers the container to the landfill. The empty container will be returned to the estate.

A schematic diagram of the ARCS adopted in Hong Kong is demonstrated below:

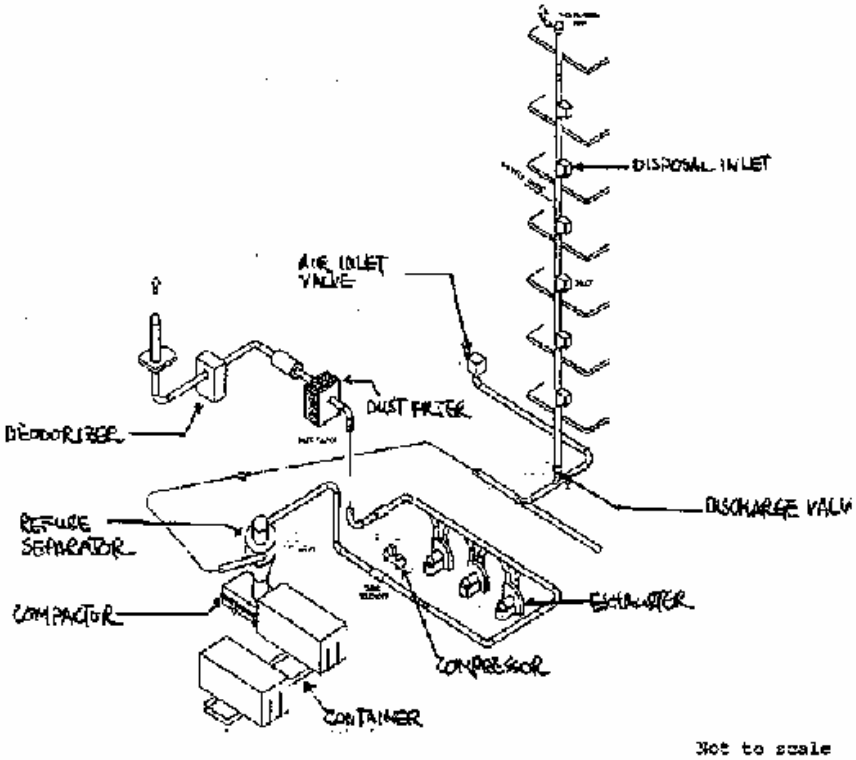


Figure 9 - A schematic diagram of the ARCS

4.3 Current collection methods in Hong Kong

In Hong Kong, the private domestic housing estates and public housing estates are either installed with or without refuse chute. The buildings are usually having two main types of traditional waste collection methods: door-to-door collection and temporary waste storage facilities on each floor. For door-to-door collection, tenants will leave their refuse bags in front of their door and the cleaning workers will collect them from time to time. For temporary waste storage (e.g. refuse bins) method, tenants will discard the refuse into refuse bins provided at lift lobbies, staircase, refuse rooms or other assigned areas. For those buildings/estates with refuse chute, the cleaning staff will collect the refuse bags at a certain pre-determined time and then put them down the refuse chute inside the refuse room on each floor. There will be a refuse bin below the chute to store the refuse in the refuse chamber located on the ground floor of each building. The loaded refuse bins at the ground floor refuse chamber are pushed by the cleaning workers to the central refuse collection point of the estate where the Food and Environmental Hygiene Department will collect the stored refuse daily at a certain time.

Figure 10 - Typical refuse chute in use for Hong Kong estate

Bulky refuse such as furniture is transported through lifts or staircases down to the junk collection point on the ground floor for temporary storage. Normally, there is one junk collection point for an estate. When transporting the refuse bins from the refuse chamber to the refuse collection, there is always a risk of having waste leakage or spilling, therefore non-detachable lids are necessary. The disadvantage of the traditional waste collection system is the impact on the environmental condition of each floor. Refuse bags or bins are located at common areas, which initiate health hazards to tenants and cleaning workers. Cleaning workers have to transport the refuse bins to the central collection point. This will make the estate area dirty and smelly, as spillage and odour are unavoidable.

4.4 Solid waste collection process in Hong Kong

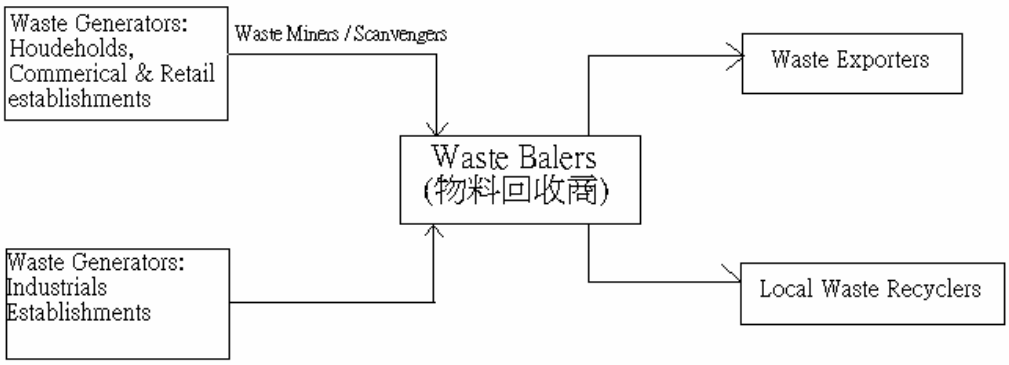
In simple terms, solid waste management can be separated into three major categories. They are:

i) Waste collection

ii) Waste segregation and waste recovery

iii) Waste treatment

Solid waste segregation and recovery is considered to be one of the key elements in solid waste management. Contrary to a community-based waste recycling program in most of the developed countries, waste recovery is a business in Hong Kong. The waste recovery industry can broadly be divided into three levels although there are minor variations in specific material collection network. The interrelations of the various parties in the waste traders are depicted in diagram below.



As depicted in the diagram above, waste generated coming from households, commercial and retail establishments transfer the recyclables through two mediums. In Hong Kong, the job of sorting marketable waste materials from household waste, public cleansing and commercial waste is left to waste removers, building cleaner, hauler and street scavengers. This group of people can be generalized as waste miners. Waste miners collect and sort the waste materials into different grades and categories. The materials they retrieve include aluminum cans, copper (in electrical cables), newspaper, cardboard, metals, clear glass bottles, rags, old white and brown goods, etc. Scavenging of marketable waste usually occur very close to the point of waste generation such as within residential, commercial and industrial buildings, or further down, at municipal refuse collection points and even on the

street, such as picking up recyclables from public rubbish bins. The scavenging activities sometimes cause nuisance and inconveniences to the public. These waste miners sort the recoverable waste into types and grades and sell them to the waste traders in the next level – the waste balers. The rest of the waste, which contains small amount of recyclables and recoverable items, was sent to the refuse collection point by cleaning contractors overseen by property management firms. Waste retrieval and recovery at this level is generally informal. This means that the activities and the work force are unregistered and generally unregulated.

Waste balers buy waste materials from the waste miners, further sort the waste and then compact them into transportable bales. In Hong Kong, waste paper is the chief recycling material, although they also engage in the buying and selling of a variety of wastes including aluminum cans or assorted metals. Large waste balers may source from industrial waste themselves or collect waste in quantity from other neighborhoods (usually from housing estates, schools and institutions. Those relying on industrial waste supply usually have contractual agreement with large recyclables generators, such as plastic or printing factories.

The last level of the waste recycling in Hong Kong is the waste exporters and the waste re-processors. The baled waste will be sold either to the local waste re-processors or to exporters. Waste exporters usually have extensive connections with the processing industries in other countries. Recyclers on waste paper, clean plastic scrap, ferrous, non-ferrous metals and wood can be found in Hong Kong. The waste recyclers turn the waste material into new or same nature products and sell them to users of the recycled products. In Hong Kong, some waste recyclers not only reprocess the waste materials but also directly export the materials overseas.

Despite the well-established waste recovery system, waste miners, waste balers and waste exporters faced many obstacles and difficulties in their sector. This is primarily due to Hong Kong "positive non-intervention" approach. However, generally speaking, the profit margin for the waste recovery industry is low. It is common for waste miners and waste balers to encounter fluctuations in their revenue result to an opportunistic way of operation which means that capital investment will be minimal and that long-term business connections are not important to them. In other words, high operation cost and the uncertain business prospect are the two challenges that waste industry have to confront today.

4.5 Solid waste collection process in high-rise buildings in Hong Kong

This section presents how the refuse is collected in high-rise buildings and transported to the public fill area. For the majority of Hong Kong estates, a refuse chute is utilized to facilitate the transportation of garbage. Currently, according to the Hong Kong Housing Authority, two refuse handling systems are utilized in the public housing estates. They are Central Compactor System (CCS) and Distributed Compacting System (DCS).

In CCS, the process flow of the garbage in Hong Kong estate can be summarized in the following diagram:

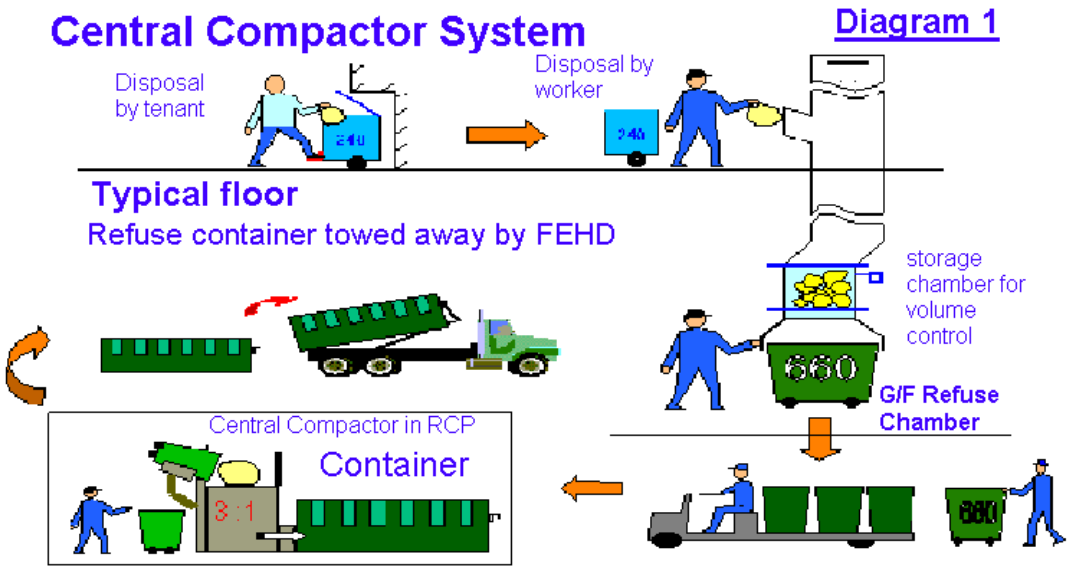


Figure 11: Hong Kong Central Compactor System Flow Diagram

The garbage is typically packed in small bags disposed by estate tenants into a standardized 240L bin. Then, within a set time period of each day, the cleansing worker will move the 240L bin to the refuse chute room. The cleansing worker will drop the bags to the refuse chute via the hopper. The refuse is stored in the ground floor storage chamber. When the chamber is full, a signal will be delivered to notify the cleansing worker at the ground level. He or she will empty the storage chamber and transfer the refuse to a 660L standardized trolley. The storage chamber with motorized gates at the bottom of the refuse chute controls

the volume of refuse loaded into the refuse storage bins before transfer to refuse collection points. At the refuse collection points, a central refuse compactor reduces the refuse to one-third of the original volume for storage in a sealed container before sending off to refuse transfer stations or landfills.

The second type of the refuse collection system is the Distributed Compacting System (DCS) which is similar to the CCS and designed for smaller housing estates with less than 2400 flats,. In DCS, a small-scale compactor installed at the bottom of the refuse chute automatically compact the refuse to half of the original volume and squeezes out the foul liquid content before loading into refuse storage bins for transit to refuse collection points. (See Figure 12)

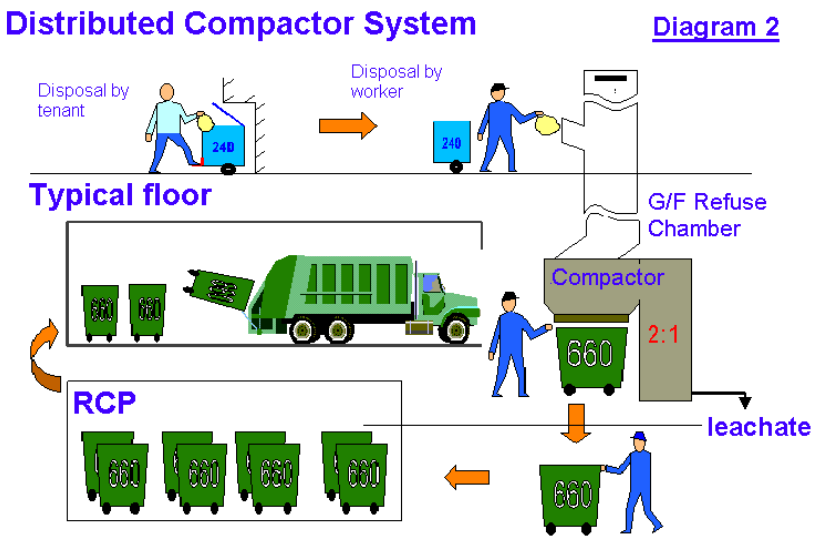


Figure 12 –Hong Kong Distributed Compactor System Flow Diagram

Also, at the refuse collection points, as compaction has reduced the volume of refuse to about 50% to 66% of its original size, the refuse handling area is left with more open space. In addition, both systems are designed with control devices at the bottom of the refuse chute to prevent over-packing of the refuse storage bins and spillage in the collection and transportation process to achieve a higher level of cleanliness and hygiene

Chapter 5 – The Waste Separation Refuse Chute Technology

5.1 The Waste Separation Refuse Chute Technology (WSRCT)

Pursuant to requirements on the waste reduction mandates of the North American and European cities, refuse chute manufacturers have developed an innovative refuse collection system that allows residents to separate the recyclables at the push of a button conveniently located in their respective floor of the estate. Essentially, a WSRCT is a normal refuse chute equipped with a built-in micro-computer. It sorts and distributes refuse semi-automatically to different containers. The system, which fits in similar space as the chute and container now in use, can segregate glass, plastic, paper, metal, and other rubbish into separate boxes, which is controlled through a micro-computer. Next to the chute door, there is a panel with buttons for various types of recycling material (as well as for non-recyclables). At the press of a button, the micro-computer locks all other floors' chute doors and sets the recycling container turning until the right box comes under the chute. For some advanced models, a compactor is included.

The WSRCT is now employed in some High Rise Refuse Collection systems. It has the following advantages over the traditional chute systems:

1) It eliminates the cost associated with floor-to-floor recycling collection programme.
2) It increases recycling rate which reduces trash volume going to the landfills.
3) It relieves the workload of cleaners and cleaning contractors from carrying recyclables down the elevator to a drop-off room or leaving them in bins in the trash chute.
4) It minimizes the size of chute rooms on each floor.

The WSRCT also has other merits as well as limitations which are summarized in the following table:

Merits	Limitations
It fully coincides and in compliance with current government waste management policies and principles (E.g. Source Separation of Domestic Waste in Residential Building)	The benefit of the improved waste separation may improve the cleaning worker's "miscellaneous money" revenue instead of the overall benefits of the owner's corporation
It provides convenient separation of waste. Also, it reduces the workload of the cleaning worker in public estates	When the recycling trays are in use, all other floor doors are LOCKED. This is one of the major technical limitations of this technology. However, this problem will NOT exist if the entire system is operated by one cleaning worker, which is a common practice in Hong Kong estates.
It increases buildings revenue by increasing the amount of recyclables	Not only capital cost is required to retrofit existing refuse chute. Some electrical and maintenance fees may be required for the system to be functional.
It improves the hygiene of the floor refuse chute room by reducing the accumulation of valuable recyclables on the floor refuse chute room	
Indirectly, it enhances the safety (fire safety) of each floor by reducing the accumulation of flammable recyclables on the refuse chute room or staircases	

Table 4: Merits and Limitations of the Waste Separation Refuse Chute Technologies

5.2 Evaluation on its merits and limitations

5.2.1 Merits of WSRCT

1) **It fully coincides and is in compliance with current government waste management policies and principles (E.g. The Programme on Source Separation of Domestic Waste)**

The main benefit of this technology is the improvement of waste separation at the source of waste generation. It is expected this technology will improve solid waste separation by providing convenience to residents and/or cleaning workers. To elaborate on this view, the solid waste management policy is reviewed in the following paragraphs.

In Hong Kong, almost all of the estates, whether it is private, public or HOS, relies heavily on the cleaning workers to perform waste separation and recycling. A tabulated table below summarizes the common waste collection methods and typical locations at which waste separation occurs. There are four major types of waste collection methods commonly adopted by Hong Kong property management companies. Normally, waste separation is handled at the following locations:

Waste Collection method	Waste Separation location
Door-to-Door Collection	At the source; Residents separate the waste in separate containers
Residents leave garbage at the staircase or corridor	In the refuse room on each floor.
Residents leave garbage inside the refuse room	At ground floor of refuse chute room
Disposed, to the refuse chute, or collection centre by residents	Central recycling facility of the entire estate

Table 5 - Waste collection methods and waste separation locations table

Currently, Hong Kong housing estates are facing a number of difficulties in waste separation

and recycling. The difficulties are:

A) Hong Kong Environmental Protection Department follows the "positive non-intervention" approach in the environmental field and pollution control. Therefore, most of their programs, e.g. source separation of domestic waste programme in residential buildings is entirely voluntary. At the moment, only a portion of the Hong Kong housing estates are willing to participate. This is due to the fact that capital investment is associated in solid waste management (reduction, separation and/or recycling) to the housing estates with no direct benefits to the housing estates themselves other than marketing image. Further, due to the physical constraints many of the older estates do not take recycling and source separation into considerations.

B) Based on surveys and research studies, it is known that Hong Kong people's environmental awareness is lower in comparison to other developed countries.

C) The pressing needs of solid waste management only raised in recent years, the Hong Kong housing estates are not designed with sufficient space to provide waste separation and recovery facilities on each floor of the building.

D) From the property management standpoint, the hygiene conditions of the building are higher than the environmental concerns of the housing estate. In Hong Kong, due to the relatively low environmental awareness of the waste miners and space limitations, the increase in waste separation in a floor-based system as outlined by EPD may affect the hygiene of common buildings.

E) Usually, higher rate of recyclables or recovery does not necessarily converted to revenue. It is because the waste miners or cleaning workers claim these extra benefits for themselves as the miscellaneous money (下欄錢) as quoted from property managers. The efficiency of recycling cannot be maximized as waste miners mostly look for the most valuable recyclables. Those non-profitable recyclables are not picked out. Comparing with other countries/areas, this practice in Hong Kong has created an exceptionally high ratio for metal recycling, per volume basis, in the total revenue from recycling wastes.

According to the "Guidebook on Source Separation of Waste in Residential Buildings", refuse can be separated based on the various methods outlined in the guideline. The concept of this guideline is to rely on residents to bring their recyclables at specified times. However,

this time-based waste separation is very inconvenient for residents in the housing estates. In Hong Kong, it is difficult for the ever-so-busy residents of the estates to adopt this type of policies. The WSRCT may be able to alleviate this issue by reducing the amount of recyclables to be stored in the Material Recovery Room. The methods of Floor Refuse Storage Room (RSR/Refuse Chute Room (RCR)), Floor Refuse Chute (RCT), and Integration of Lobby with floor Refuse storage Room (ILR) may be applied. In short, the guidebook applies to buildings that utilize the refuse chutes.

For example, with the waste separation method of Refuse Chute (RCT), EPD suggested to:

a) Bring one type of recyclable at specific times: Residents dump different types of recyclables at specific times on specific days into the refuse chute. For example, 9pm-10pm could be designated for recyclables collection, with waste paper collected on Mondays and Wednesdays, metals on Tuesdays and Thursdays, and plastics on Fridays. During this time slot no other waste is allowed in the refuse chute (to prevent recyclables from being mixed with refuse). Cleaners do not have to sort the recyclables collected in the refuse storage chamber.
b) Bring any type of recyclables at specific times: Residents deposit any recyclables into the refuse chute at a specified time slot every day or on specified day(s) of the week. For example, 9pm-10pm on Mondays, Wednesdays and Fridays could be designated for recyclables collection. During this period, no other waste is allowed down the refuse chute (to prevent recyclables from being mixed with refuse). Cleaners have to sort the recyclables in the refuse storage chamber into waste paper, plastics and metals.
c) Bring pre-sorted recyclables at any time: Residents separate recyclables into individual, tied bags at home and deposit them down the refuse chute at any time of day. They can put different types of recyclables in different bags (e.g. one bag for waste paper, another for plastics, etc). Or they can place all recyclables into one bag. Cleaners sort the mixed recyclables into waste paper, plastics and metals in the refuse storage chamber.

For options a, b, although theoretically possible, these two practices are very inconvenient

and troublesome for the residents to adopt. For option c, although this option may be feasible, according to the cleaning worker at the site-visit, it is not uncommon that bags ruptured when the bags reached the bottom of the refuse chute. The tedious work of giving out different coloured bags to the residents is not favourable for the property management companies.

2) It provides convenient separation of waste with the push of a button and reduces the workload of the cleaning worker in public and/or private housing estates.

This is intrinsic with respect to the WSRCT. However, in most cases, it is well known that the property management officers always arrange cleaners to collect the refuse instead of allowing the tenants to dump it into the chute in housing estates with traditional refuse collection. One of the major benefits of this technology is to reduce the workload of the cleaning workers in the estate.

In traditional practice, cleaning workers only put non-recyclables down to the refuse chutes. They separate the recyclables and temporarily store them in the floor refuse room. Whenever they have time, they will move the recyclables to the ground floor with elevator or the stairs. If the WSRCT is utilized and adopted, with the push of a button, the cleaning workers no longer need to store the recyclables (like paper) at the floor refuse room anymore. They may be able to dump the recyclable directly down to the refuse chute when they collect the waste from different units on the same floor.

3) It increases buildings' revenue from increasing the amount of recyclables

The increase in revenue of the building by increasing the amount of recyclables collected is based on the fact that it is more convenient to the cleaning worker or the tenants to separate waste. Although this extra revenue will not be significant, it may be able to offset some of the capital investment of this technology. Overtime, this extra revenue from selling the additional recyclables will be beneficial to the housing estate.

4) It improves the hygiene of the floor refuse chute room by reducing the accumulation of valuable recyclables on the floor refuse chute room

Similar to the previous point, the WSRCT is expected to improve the hygiene of the floor refuse chute room by reducing the accumulation of valuable recyclables on the floor refuse chute room. Recyclables like aluminum cans, plastic containers and/or papers may be contaminated with food and water remains. According to a property manager in one of the site visits, this is one of the reasons why the housing estate did not join EPD's source separation of domestic waste program.

5) It improves the safety (fire safety) of every floor by reducing the accumulation of flammable recyclables on the refuse chute room or staircases

Similar to the previous point, the WSRCT may be able to improve the fire safety of every floor by reducing the accumulation of flammable recyclables on the refuse chute room or staircases. This is especially true for the case of waste papers and cardboards.

5.2.2 Limitations of WSRCT

Despite the merits of its feasibility for Hong Kong housing estates, like all other technologies, it carries shortcomings.

1) The benefit of the improved waste separation may improve the cleaning worker's "miscellaneous money" revenue instead of the overall benefits of the owner's corporation As described previously, in Hong Kong, higher rate of recyclables or recovery does not necessary mean more revenue to the particular housing estate. It is because the waste miners or cleaning workers claim these extra benefits for themselves as the miscellaneous money (下欄錢). Therefore, the extra recyclables separated from the waste stream may not be reflected on the revenue of the housing estate from selling the recyclables. Based on EPD's spokesman, although some recyclable materials might be taken by cleaning workers or 'waste miners', they would be delivered to recyclers for recycling and it could help contribute to waste reduction in Hong Kong.

2) When the recycling trays are in use, all other floor's door is LOCKED. This is one of the major technical limitations of this technology. However, this problem will NOT exist if the entire system is operated by one cleaning worker, which is a common practice for Hong Kong housing estates.

   This is the major technical limitation of the WSRCT. This technical difficulty is best illustrated by an example. Let's assume one Hong Kong housing estate adopts a technology like the High Rise Recycling System. Further we assume, tenant A, wants to dispose some newspaper waste on floor 15. He approaches the hopper and pushes the button on the hopper door. At the same time, tenant B, wants to dispose a bag of kitchen waste to the same refuse chute. However, since the refuse chute is directly set to the "recycling paper section", tenant B has to **wait** until tenant A has finished dumping the newspaper waste and the chute is re-opened. (Assume Hi-Rise Recycling system / Hardall Tri-Sorter). For Hong Kong housing estates, due to the large number of levels >22, this may cause inconvenience to tenants.

   Since the property management officers in Hong Kong always arrange cleansers to collect the refuse instead of allowing the tenants to dump it into the chutes in estates with traditional collection, the technical limitation of this technology is eliminated. This is

because in Hong Kong, only 1 cleaning worker operates a single building at a time, there is no chance for two persons using the same chute at the same time.

3) Not only capital cost is required to retrofit existing refuse chute. Some electrical and maintenance fees may be required for the system.

   Since traditional refuse chute typically does not have any sort of electrical connections, the WSRCT does incur an expense to cover the E&M operational and maintenance. This expense is mainly used to maintain the electrical and mechanical devices for the hopper doors and the valve doors at the ground floor. However, the operational cost is expected to be so small and acceptable.

5.3 Components of a Waste Separation Refuse Chute

The components of the Waste Separation Refuse Chute are very similar to a regular, traditional refuse chute used in Hong Kong. In simple terms, it can be described in three major parts: Hopper doors, the chute (Tunnel portion) and the bottom part (Discharge portion). It is made up of a number of major components: Floor Refuse Doors, Discharge, The chute and the compactor. All of the refuse chutes used in Hong Kong have some degree of fire proof. However, the degree of smoke-proof and fireproof varies by different manufacturers.

5.3.1 The Floor Refuse Door

The Floor Refuse Door is the access point which tenants or cleaning worker put their refuse or garbage to the refuse chute. In different countries, it is also called Hopper Door, Refuse Door, or Service door (linen chutes). It is designed as the inlet for the delivery of the waste. On the market, there are two types of floor refuse doors available in the market 1) Side-hinged floor refuse doors 2) Bottom-hinged floor refuse doors.

Under most cases, however, Hong Kong estates uses bottom-hinged floor refuse doors. These doors are made in galvanized steel. Most of the doors are equipped with hydraulic return for self-closing. In fact, under the Hong Kong Buildings Ordinance Cap123H, all hoppers shall be situated in a place permanently ventilated to the open air. It shall be so constructed that it will remain only in a completely open or completely close position and will not open of its own. For safety concerns, some manufactures included electrically interlocked doors allowing option of central locking system to prevent chute use during bin removal or chute sanitizing. Also, some suppliers offer locks off other doors when one door is opened. In the cases of waste separation refuse chute technology, all of the manufacturers described utilize this feature. The floor refuse chute door comes in different sizes. In Hong Kong, it is found that the floor refuse chute door in Public and HOS estates are smaller as compared to typical sizes in foreign countries like the U.S. and U.K. For the waste separation refuse chute technology described in this document, next to the refuse doors, the control panel of the types of waste is displayed.

The floor refuse chute door portion always included the chute intake section. Depending on different manufactures, features such as the automatic sanitizer or automatic fire sprinkler can be mounted in this section. Listed below are photos of some typical floor refuse chute doors

A refuse chute door inside the hopper room at a HOF estate.
(Picture taken from Sunningvale Garden)

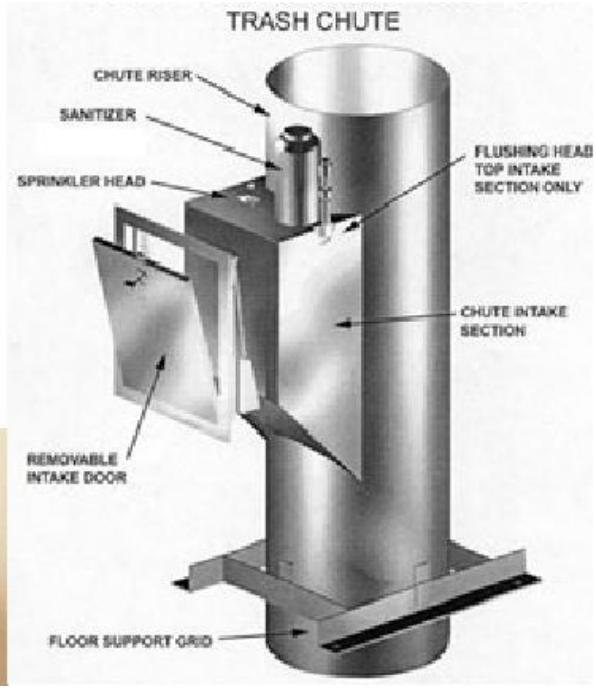
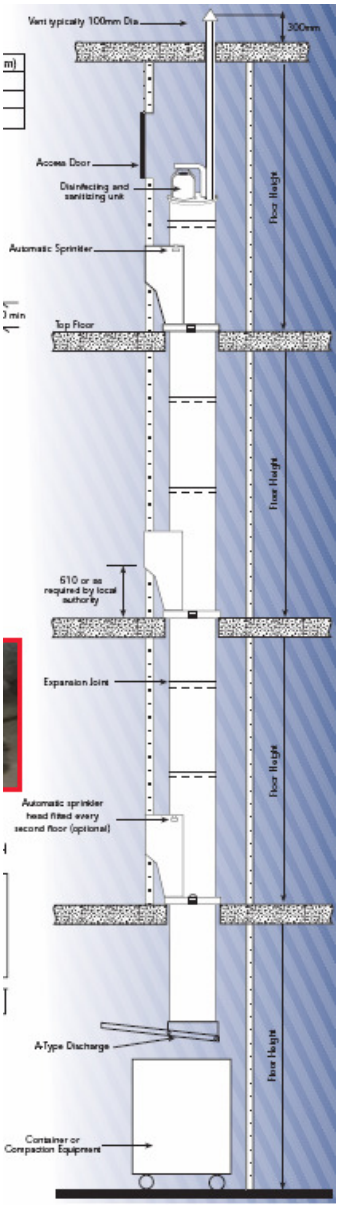


Figure 13 - 1) Top Left– A traditional hopper door/ in use at Sunningdale Garden 2) Bottom Left– A demonstration refuse chute / hopper photo 3) Right – Explosion view of the trash chute / hopper door section.

5.3.2 The Refuse Chute (or the tunnel section)

The tunnel section is the body of the refuse chute. Essentially, the tunnel section is a long circular pipe that connects from the top of the building to the bottom discharge. The critical element of the section is the diameter of the chute pipe. The main pipe can be passed downed from the opening of each floor to a central refuse room on the ground floor of a building. The chute pipe can be made from different materials like fiber reinforced cement and galvanized steel. A typical refuse chute is designed as shown in the diagram:



In Hong Kong, under the Buildings Ordinances, a ventilation pipe shall be provided at the tope of the refuse chute. Further, it shall have an internal area of not less than 0.05 m^2. Usually, an electric fan is installed near the exit to ensure circulation and draw unpleasant odor within the chute. Also, all refuse chutes in Hong Kong shall be provided with an access opening of not less than 225 mm in diameter above the level of the highest hopper for the inspection and cleansing of the chutes. In more recent models, usually an automatic sprinkler system is available to provide cleaning of the refuse chute.

5.3.3 The discharge Section

The discharge section is located at the bottom end of the refuse chute. Alternatively, it is called the foot of the refuse chute. When the garbage is in contact with the discharge door, it often generates significant amount of noise, which is a noise pollution hazard. Some refuse chute designers added plastic pads to act as noise dampers. For some refuse chute designs, drains, which connected to the sewage lines, is included to deal with leachates leaked from the garbage bags when they are dropped. For more advanced models, compactors are also included to provide on-the-spot waste compression to reduce the size of the refuse sent to the public waste collection areas. Under Hong Kong Buildings Ordinances, if the refuse chute has an offset at the foot, it shall have a slope of not less than 60 degrees to the horizontal and to be constructed of replaceable galvanized or stainless steel of not less than 3mm thickness. Further, the refuse chute shall be provided at its lower end with a galvanized or stainless steel shutter so constructed as to enable the chute to be closed when necessary. Listed below are some of the pictures for the discharge section of the refuse chute:

Figure 15 - Typical refuse chute discharge section designs for the discharge section

Figure 16 - A picture of the discharge section of the refuse chute at Sunningdale Garden, Block#3

For the waste separation refuse chute technology described in this document, this section is the main difference compared to the traditional refuse chute. This is the section at which instead of 1 standard 320L refuse chute bin, 2 or 3 bins are placed at the refuse storage and material recovery chamber.

This is the most important component of the technology being studied. In traditional refuse chute system, this component does not exist. In essence, this component is a set of containers that can turn around when operated. As demonstrated from the diagrams below, computerized control valve doors direct the materials disposed above to different containers. The system, which fits in the same space as the chute and container now in use, enables glass, plastic, paper, metal, and other rubbish to go into separate boxes. It is controlled through a circuit board fixed next to the chute door. The board has a button for each class of recycling material (as well as for non-recyclables). At the press of a button, a microcomputer locks all other floors' chute doors and sets the valve doors turning until the right box comes under the chute. The computer also counts the loads and gives a signal by phone when the box is full (Hi-Rise Recycling Systems). A picture of the discharge section of the Hardall Tri-sorter is demonstrated below:

Figure 17 - A demonstration photo of the Hardall Tri-separator provided by Hardall International Ltd.

5) The Waste Sorter

This is the most important component of the technology being investigated. In traditional refuse chute system, this component does not exist. In essence, this component is a set of containers that can turn around when operated. As demonstrated from the diagrams below, computerized control valve doors direct the materials disposed above to different containers. The system, which fits in the same space as the chute and container now in use, enables glass, plastic, paper, metal, and other rubbish to go into separate boxes. It is controlled through a circuit board fixed next to the chute door. The board has a button for each class of recycling material (as well as for non-recyclables). At the press of a button, a microcomputer locks all other floors' chute doors and sets the valve doors turning until the right box comes under the chute. The computer also counts the loads and gives a signal by phone when the box is full. There is more than one system available in the market. One of them is the NuReTec 3000 developed by Nu-Recycling Technology, Inc.

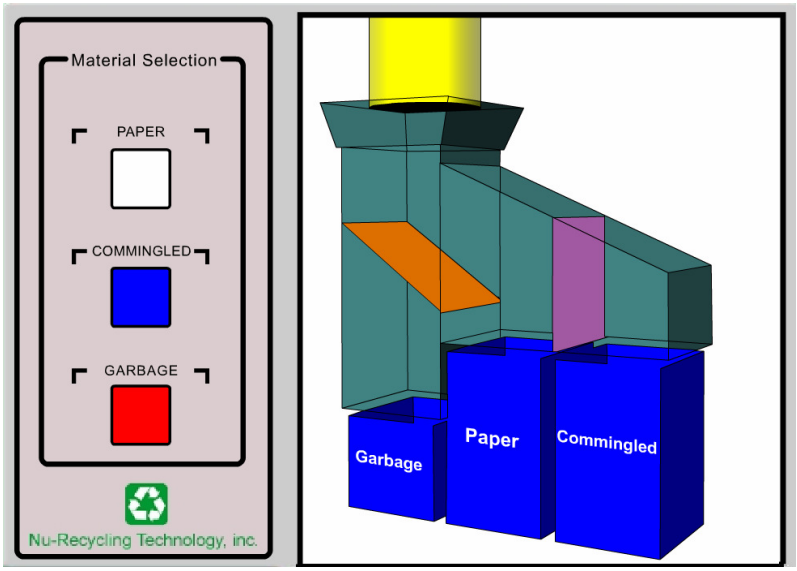


Figure 18 – Schematic Diagram of the NuTec3000 for Nu-Recycling Technology Inc.

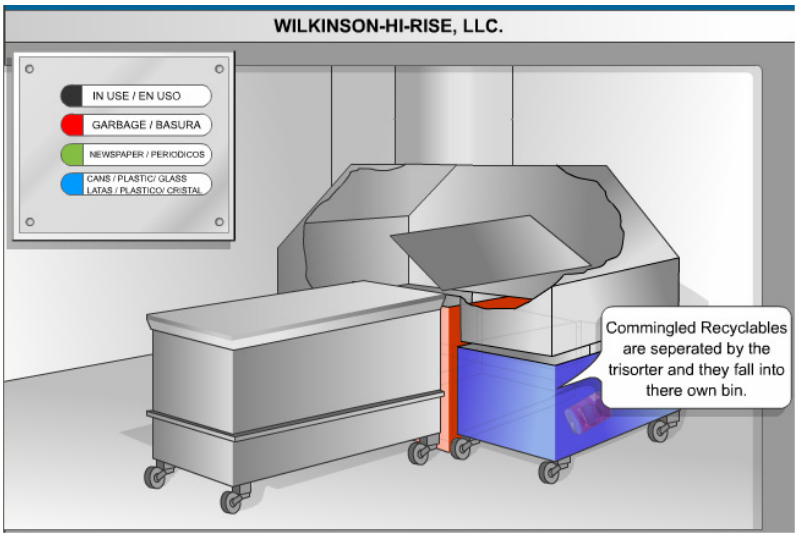


Figure 19 – Schematic Diagram of the ICD2000 Recycling Chutes from Wilkinson Hi-Rise Chute Manufacturers

To get a better understanding on how the system works, flash demos on how they work can be found from the following websites:

http://www.wilkinsonhirise.com/demo.html

http://www.nuretec.com/demo%5B1%5D.swf

5.4 Manufacturers of the Waste Separation Refuse Chute Technology

In essence, all of the manufacturers for the Waste Separation Refuse Chute Technology adopt the same technology with some sorts of modification at the bottom part of the refuse chute. Instead of having only 1 waste container located at the bottom of the chute, there are more containers. At the same time, mechanical "valve doors" and a turning table regulated by a microcomputer are installed.

In total, four manufacturers of such technology are found. They are:

1) ICD 2000 Recycling Chute by Wikinson-Hi-Rise Chute Manufacturers
2) Hardall Waste Disposal System – Hardall Tri-sorter
3) Nu-Tec Recycling System – NuReTec®3000
4) Western Chutes – Western Tri-Sorter

Out of these four companies, the Hi-Rise Recycling System and the Hardall Tri-separator are selected to be the best candidates. The following paragraphs review the technology of their models with more details.

5.4.1 ICD 2000 Recycling Chute by Wilkinson-Hi-Rise Chute Manufacturers

Hi-Rise Recycling developed a semi-automatic refuse collection system that allows residents to separate the recyclables at the push of a button conveniently located in their respective floor of the estate. Basically, Hi-Rise Recycling system is a chute leads to a pie-shaped container with up to six boxes that can turn around when operated. The system, which fits in the similar space as the chute and container now in use, enables glass, plastic, paper, metal, and other rubbish to go into separate boxes. The Hi-Rise system is controlled from a circuit board fixed next to the chute door. The board has a button for each class of recycling material (as well as for non-recyclables). At the press of a button, a microcomputer locks all other floors' chute doors and sets the recycling container turning until the right box comes under the chute. The computer also counts the loads and gives a signal by phone when the box is full. And a particular piece of equipment breaks up the non-recyclables.

In addition, this is the one of the few WSRCT manufacturers which provides custom design in accordance to the design of the building. This is one of the most well-known refuse chute multinational manufacturer in the United States.

5.4.2 Hardall Recycling Chutes (Hardall Tri-Sorter OR Hardall Bi-Sorter) by Hardall International Ltd.

The design of the Hardall Recycling Chute is very similar to the Hi-Rise Recycling System. The merit of The Hardall Tri-Sorter is the only waste separation refuse chute technology which has a Hong Kong Representative, Allied Engineers Limited. Also, the initial ball-park cost of the Hardall Recycling Chutes is the lowest amount among the four manufacturers. The Hardall Recycling Chutes are the ones of their latest technology of Hardall International Ltd. In their brochure, they claim "To meet the present day demands for the management and utilization of generated refuse Hardall International Ltd can now offer a dedicated recycling waste management system which is simple, cost effective and user friendly."

Either internal or external, the Tri-Separator will facilitate the dispersal of three types of waste. One exit would be for general waste or greater volume waste, with the other two for either: plastic, bottles, glass or paper. To operate the Tri – Separator, the user will pre – determine the intended exit point by simply selecting the correct designated push button. The discharge will stay in a permanently fixed open position to receive general waste dropping directly into a Galvanized waste container / compactor. However, if recycling waste is discharged, the user will again select a pre – determined push button and an electrically operated reinforced deflector will move within the discharge chute section and deflect the recycled waste to an alternative waste container / compactor. The process is simple and ensures the user / management select the wastes final destination before the hopper door can be opened.

The Tri – Seperator can be utilized to accommodate the end users requirements, but the main goal remains the same. Recycling of all types of generated waste materials (Refer to the schematic diagram of the Hardall Tri-Sorter as shown below)

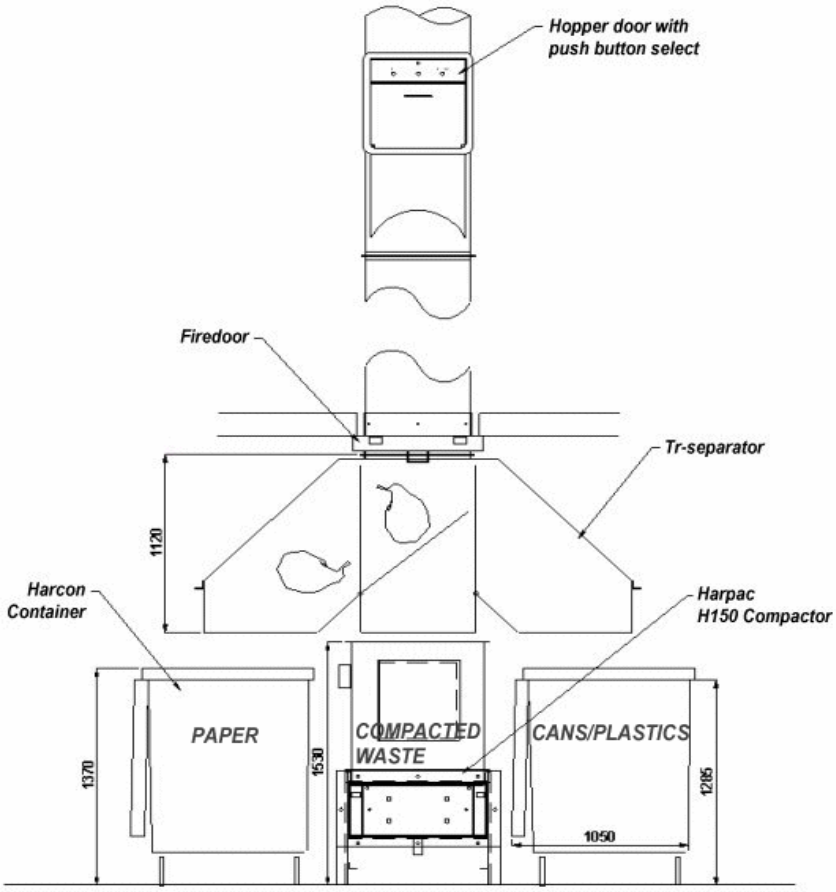


Figure 21 – Schematic Diagram of the Hardall Tri-Sorter Refuse Chute

The Harpac H150 Compactor is an optional feature. Usually, for Hong Kong estates, the compactor is not required under normal circumstances as it will be compacted by the refuse trucks.

Hardall International Ltd. stated that since the product is in their infancy (very early stage of selling in U.K.), the actual performance is not available at this present time. In terms the amount of increase in recyclables, based on a spokesmen of Hardall International Ltd. "In simply terms a Bi-Separator would effectively reduce general waste by 50% - one outlet would be directed towards general waste container - the second outlet would be directed towards recycled waste. Naturally the recycled waste would either be limited to one particular product, thus vastly reducing the percentage or a number of agreed products (to be separated at a recycling centre) A Tri Separator would also offer approximately a 50% reduction in terms of generated general waste - however the Tri Separator offers an extra recycling outlet."

5.4.3 NuReTe 3000 by Refuse System Corporation

The NuReTe 3000 Recycling System is another waste separation refuse chute system. While the design is very similar to the other manufacturers, the major difference in this design can be demonstrated as shown in the picture below:

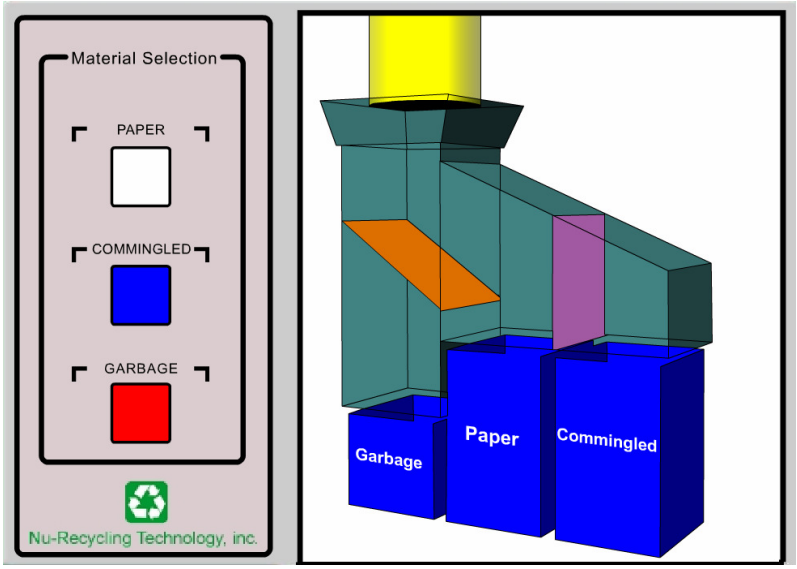


Figure 18 -

Instead of the regular waste container located at the centre, this design placed the general waste at the side of the chute. In terms of the types of waste: Garbage, paper and commingled recycled waste is believed to be the best for Hong Kong housing estates. Based on the brief communication with the manufacturer, the spokesman indicated that its cost is in the ballpark of USD 100,000.

5.4.4 Western Multi-Sorter Refuse Chute

This is fairly similar to the first 2 systems as described above. Please refer to the Appendix for some of the design features. There is another design of separating the refuse chutes into 3 sections. However, since this will take up more space than expected, this design is ruled out as the main concern for Hong Kong housing estate. This type of design is expected to be more suitable for larger flats on each floor in U.S and other European countries.

5.5 Cost Considerations for the Waste Separation Refuse Chute Technology

Cost is always the most important concern for any environmental project. In this case, it is expected that the major cost involved in this project is the capital investment on the purchase and installation of the Waste Separation Refuse Chute Technology (i.e. the Hardall Tri-Separator).

Since the intent of this document is to generate interest for different parties, detailed breakdown of the purchase of the equipment, installation and labor cost cannot be made. Due to the business nature of the manufacturer below, detailed cost analysis can be made after an interested party is available.

Based on email communication with the Wilkinson Hi-Rise Inc, their spokesman said "We have done 10 projects with this firm over 10 year period. Cost of equipment is about US$1000 per floor for control panels per floor for existing chute. The ground floor equipment is about US$35,000.00. New building would be about US$2000 per floor which would include the chute. The ground floor equipment is the same price."

Assuming a 30 floor flat, this will work out to a total of US$95,000.00 of investment.

Hardall Bi-Separators and Hardall Tri-Separators

What are the cost of installing the Hardall bi-separators & Hardall Tri-separators? This is not commercial and a ball-park figure is required. Also, does Hardall provide any engineering service on retrofitting from a traditional refuse chute to the Hardall bi-separators & Hardall Tri-separators? If yes, what is the ball-park cost?

a) Cost to fit the units to new build would be i) Bi Seperator at £5,000.00 GBP - ii) Tri Seperator at £7,500.00 GBP

b) Cost to retrofit the units to existing build would be i) Bi Seperator at £7,500.00 GBP - ii) Tri Seperator at £10,000.00 GBP

Western Multi-Sorter Refuse Chute

Just a ball park figure for a 30 story building, is about US$100,000, this includes the tri-sorter unit and 30 electrical interlock doors.

5.6 Expected challenges for the waste separated chute refuse technology

Based on this study, it is opined that the waste separation refuse chute is the solid waste treatment technology feasible to be implemented for Hong Kong housing estates. However, despite its advantages and potential benefits, a number of challenges are recognized. They are listed as follows:

1) This technology will facilitate waste separation in high-rise buildings in Hong Kong. However, the manufacturers have not been able to provide some experimental statistical figures to demonstrate the exact amount of recyclables increased after the WSRCT is installed. Therefore, it is advisable to perform a pilot testing program to evaluate the effectiveness of the technology. Details of this project are described in depth in chapter 6.

2) In terms of the engineering design difficulties, two major issues are identified: i) the size of the hopper door: According to the Hong Kong Buildings Ordinances Cap 123H, the hopper shall have an opening of not less than 250 x 150 mm and not more than 350 x 250 mm. None of these manufacturers has the aforementioned size in stock, which will be the major technical difficulty in implementing the WSRCT in Hong Kong. However, the Hong Kong agent for Hardall system, claim that this will not be a problem as their new WSRCT model uses the same size as the traditional ones and there should be no problem with retrofitting. ii) The size of the new discharge for the WSRCT: Since the discharge of the WSRCT has 2 or 3 containers lined up side-by-side, there may be a spacing problem whereas the standard requirement for Hong Kong's refuse storage and material recovery room is of the minimum size of 1.5m x 1.5m.

3) For some estates, the size of existing refuses chute room, or the material recovery on the ground floor and, may not support the new, innovative refuse separation bins. Customized design of the refuse chute has to be adopted.

4) The concern of such a business proposal is the negotiation of property management and owner's corporation to support such a trial project. The most difficult part of such a proposal

is to negotiate interested parties to be involved. Since there is no immediately foreseeable profit by the property management company or the owners corporation, it will be a major challenge to find an estate that is willing to participate. To facilitate this cooperation, it is advisable to emphasize on the improvement of environmental image and publicity of the participating estate if they are willing to participate in the project. Further, the retrofitted refuse chute will belong to the estate after the trial.

5) The main concern of this project is the capital investment involved as there is no direct profit in such a project. The question would always be who is willing to bear the cost of the trial project. If such a project is supported financially by the EPD or other organization, the funding may help to support the program. Also, it is expected the manufacturer or distributor, e.g., Associated Engineers Limited, should bare some of its installation cost as this trial programme is an effective advertisement for their company and technology. However, the Environmental Conservative Fund alone, based on its history, may not be able to support all of the cost of such a project.

Chapter 6 – Conclusions and Recommendations

6.1 Conclusions and Recommendations

In any developed society, waste increases as population grows, Hong Kong has no exception. The Environmental Protection Department has been promoting waste reduction and recovery for many years as it is the most important aspect of environmental protection. However, in one of its latest report, it pointed out that the three strategic landfills would start to approach their capacity one by one in the early to mid 2010s. Therefore, there is an urge for the adoption of sustainable technologies to reduce the volume of waste and recover resources so as to deal with the municipal solid waste generated in Hong Kong more effectively.

Based on this research, among different solid waste treatment and management technologies, the waste separation refuse chute technology (WSRCT) is considered one of the most viable and suitable solid waste treatment technology for increasing the amount of recyclables in Hong Kong Estates. The system, which can be retrofitted in the same space as the chute and container now in use, can segregate glass, plastic, paper, metal, and other rubbish conveniently, at the press of a button, to go into separate boxes. Sorting recyclables before they are collected saves labour, space and offers efficiency and hygienic environment. Obviously, it is suitable for high-rise buildings. It is believed that this type of technology could increase recycling activities in Hong Kong housing estates. However, since there is no statistical data available to prove its effectiveness, a "waste separation refuse chute technology" demonstration project is recommended. Among different manufacturers of the refuse chutes, the ICD Recycling chute from Wilkinson-Hi-Rise and the Hardall Tri-Sorter from Hardall International Ltd are recommended to be tested for Hong Kong Public and HOS housing estates.

6.2 Future Studies

Since this is the first report on WSRCT by the Environmental Technologies Foundation Ltd, we have not obtained the full co-operation of the manufacturers. Presently, one of the major challenges of the waste separation refuse chute technology is that there are no statistical data to demonstrate the effectiveness in increasing the amount of recyclables in an estate. Obviously, to get real and practical data, a demonstration project will be desirable. To run such a demonstration, further actions are necessary for funding and co-operation from prospective and interested parties, which include EPD, Property Management companies, such as Chevalier Property Management, Associated Engineers Limited, manufacturers and owners corporations.

Part 2 --- Water Management Technologies

Abstract

Water scarcity is getting more and more serious in the World. The affected countries include USA and China. This report tries to study the situation of the fresh water position in Hong Kong and explains the existing methods on fresh water treatment and waste water management. Countries such as Japan and Taiwan have been setting up grey water treatment centres in buildings for generating reclaimed water for flushing or irrigation. In Hong Kong, advanced technologies have been introduced in two sewage treatment plants in Hong Kong for generating reclaimed water to promote water reuse. The total area of Hong Kong is 1104.27km^2, as provided by the Survey and Mapping Office of the Lands Department in February 2008; about 6.7% of Hong Kong land is used for residential use (Broad Land Usage Distribution, 2007). Public housing occupies about 21% of total Hong Kong residential buildings. Public housing estates are the target of this report and two site-visits have been taken for data collection. Reverse Osmosis (RO), membrane bioreactor (MBR) and vibratory shear enhanced processing (VSEP) are introduced. The conclusion is that MBR and VSEP are recommended to treat grey water in public housing estate. The cost effectiveness should be tested after the pilot scale test.

The objectives of this part of the study are:

1) To review the water supply system in Hong Kong housing estates
2) To study the ordinances and regulations for water management policies in Hong Kong
3) To investigate current technologies for water management in Hong Kong
4) To study modern water management technologies that may be feasible to be used for Hong Kong housing estates

Chapter Seven: Water in Hong Kong

7.1 Sources of Hong Kong Fresh Water

The perfect water piping system provides convenience to Hong Kong people and supports the rapid development of Hong Kong as a commercial and financial centre. In the old days, Hong Kong rely totally on rainfall as its source of freshwater. However, the annual rainfall in Hong Kong is not sufficient for Hong Kong's growing need; therefore, the Hong Kong Government signed an agreement with the Guangdong Authorities for importing Dongjiang water to Hong Kong.

According to the website of the Water Supplies Department, the Dongjiang water after attraction from the river runs in a separate aqueduct separate from riverside pollution and factories waste. After the Dongjiang water has been treated in the Bio-nitrification Plant at the Shenzhen Reservior, it is delivered to the Muk Wu Pumping Station (木湖抽水站) on Hong Kong side as shown in Figure 21. The water keeps monitoring at the East Bank Section of Dongjiang's main stream (東江幹流東岸斷面) and Muk Wu Pumping Station in Hong Kong.

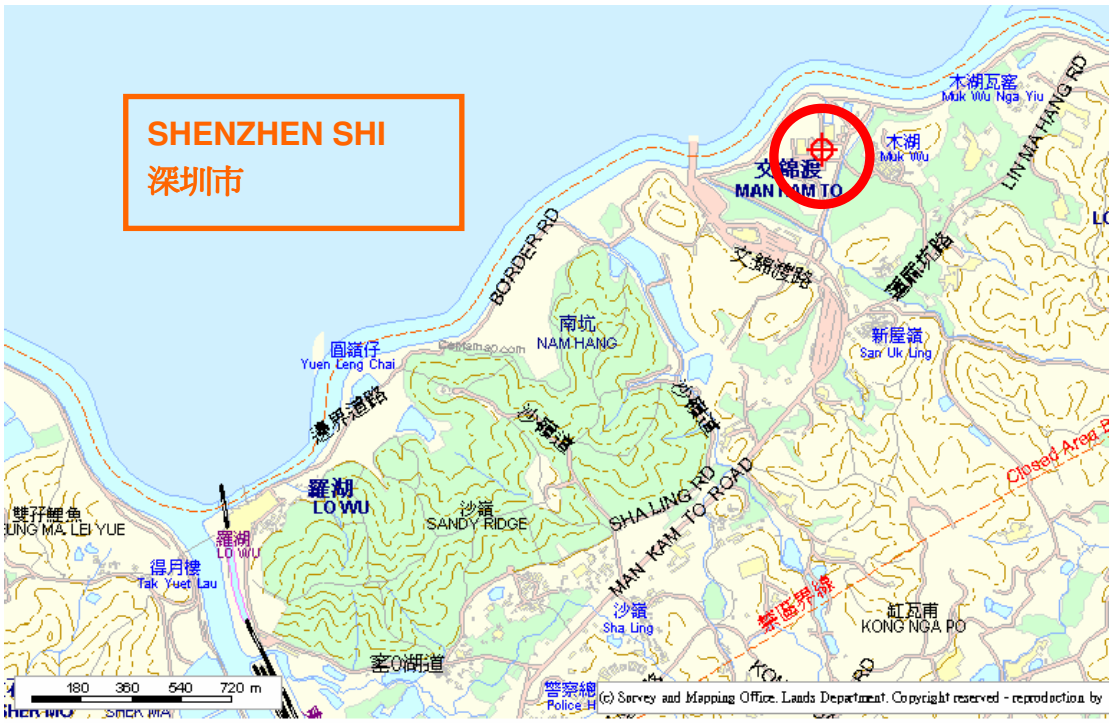


Figure 21 - Location of Muk Wu Pumping Station. (the Circle)

The rainfall is collected by the rainwater catchments and the reservoirs itself. There are

seventeen impounding reservoirs for fresh water storage in Hong Kong. The total capacity of all the reservoirs is 586.050 Mm^3. The individual capacity of those reservoirs are listed in Appendix A.

7.2 Global Freshwater Shortage

In the world, there are 31 countries, including China, almost equal to 8% of the world population, are facing chronic fresh water shortages. According to estimation from the European Commission, the affected countries will increase to 48 countries by 2025. The total number of affected people will be 2.8 billion, which is about 35% of the world's projected population. The fresh water stress between 1995 and 2025 can refer to the coloured world map in figure 22. The data of water stress are categorized into four ranges, which are represented in four different colours; they are orange, light orange, light blue and blue. The colours stand for water withdrawal at that year as over 40%, 40% to 20%, 20% to 10% and less than 10%, respectively. The orange will significantly increase in 2025 comparing with 1995. The area of the freshwater stress over 40% spreads horizontally. China is estimated to increase from 20%-10% range to 40%-20% range from 1995 to 2025. In the near future, Dongjiang water remains essential in providing sufficient fresh water for Hong Kong. However, if China stopped the supply, Hong Kong would face severe fresh water shortage. To prevent this emergency status, Hong Kong should try not to rely on Dongjiang water supply.

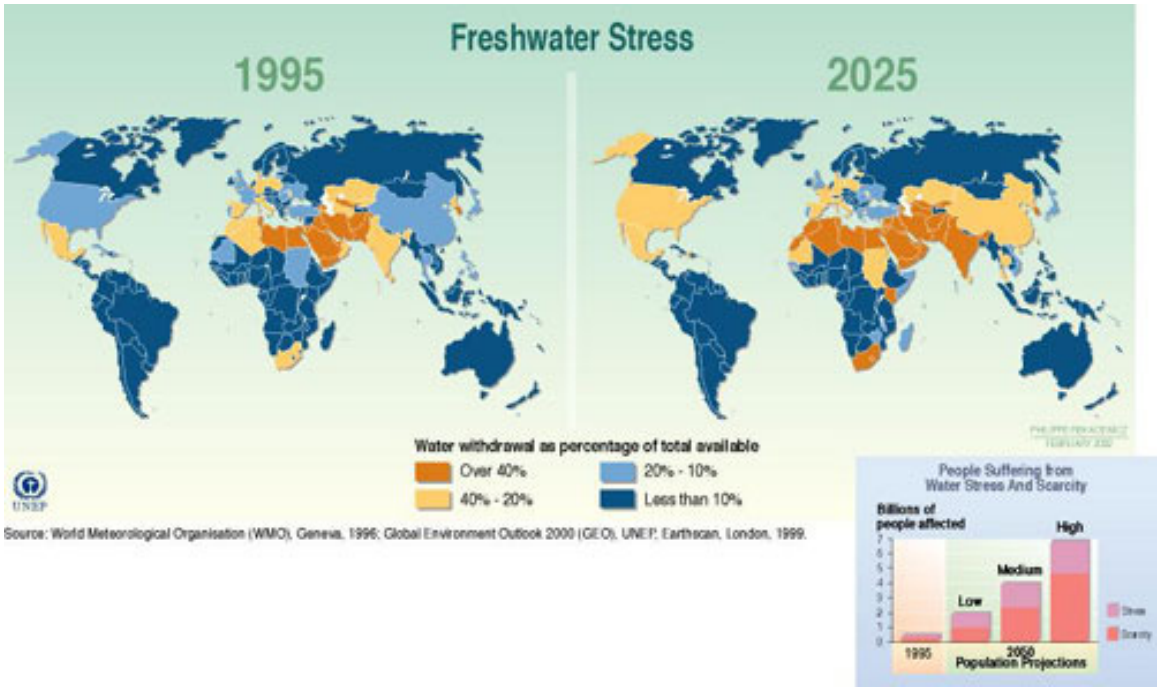


Figure 23. Freshwater Stress 1995 and 2025. (European Commission, 2002.)

The solution to achieve fresh water independent is to save the fresh water consumption, use reclaimed water and introduce suitable water and wastewater treatment technologies for Hong Kong.

7.3 Situation of Hong Kong Fresh Water

The source of Hong Kong fresh water is mainly dependent on rainfall; however, it is not stable and insufficient for consumption in Hong Kong. The growth of Hong Kong population increases the pressure on freshwater supply. The unstable and insufficient rainfall is not enough for consumption; therefore Hong Kong Government signs a contract to import Dongjiang water from Kangdong for providing Hong Kong with substantial amount of fresh water regularly.

The amount of water supply from Kangdong is discussed every three years. The latest contract is valid for 2005-2008. There is 1100 million cubic metres Dongjiang water delivered to Hong Kong for three years. All details are discussed between the Director of Guangdong province Water Resources Department and the Director of Water Supplies Department in a formal meeting. However, Hong Kong would turn into fresh water autarky due to the water stress on our main fresh water source – China.

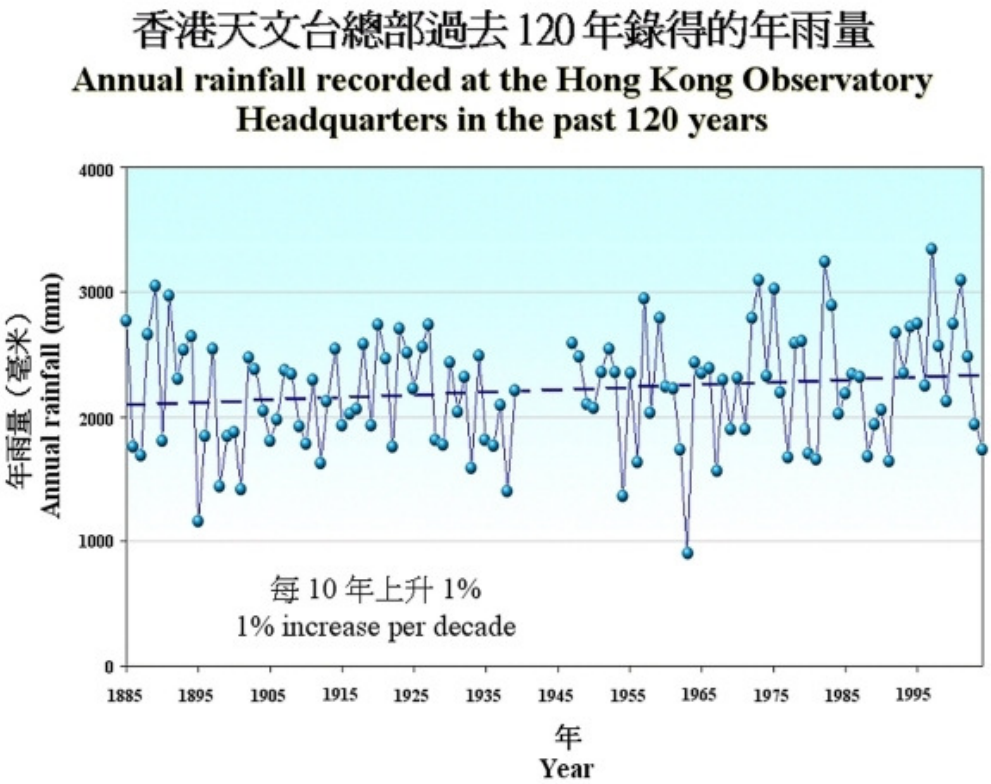


Figure 24. Annual rainfall recorded at the Hong Kong Observatory headquarters in the past 120 years. (Projected Change in Hong Kong's Rainfall in the 21st Century)

According to the Hong Kong Observatory, the annual rainfall records in the past 120 years are shown in Figure 23. It shows the rainfall fluctuated from the lowest rainfall 1700 mm in 1991 to the highest rainfall in 1997. Therefore the rainfall is not stable in providing sufficient fresh water for Hong Kong and cannot be relied as the main source of fresh water. Besides, owing to the economic growth and increase in the population the demand for fresh water is bound to increase. Increased water consumer gives stress on water supply; therefore Dongjiang water is indispensably required by Hong Kong.

Purposely to escape the heavy reliance on fresh water supply from Kangdong, Hong Kong's Water Supplies Department has tried to change the water supply system by promoting seawater for flushing to save freshwater. This change helped Hong Kong to save 741,000m^3 freshwater (Seawater for Flushing). Also, a reclaimed water plant was built in Ngong Ping and they will complete the expansion in Shek Wu Hui STWs for daily water supply to the nearby facilities.

7.4 Fresh Water Treatment

In Hong Kong, the fresh water is to pass through the water treatment plant before going to the public. The purposes are to ensure the water quality is safe for drinking and achieve the water quality standards of the World Health Organization (WHO). The treatment processes include screening to remove course solid; sedimentation to remove suspended solid; and to add chemicals (e.g. alum, lime, chlorine, fluoride). Alum and lime are used to coagulate the suspended particles into larger size, which can be easily removed by sedimentation; chlorine is used for sterilization while fluoride is for strengthen user's teeth. After all the treatment processes within the water treatment works, the clean water is distributed to the pumping stations and service reservoirs for further distribution to consumers.

The water supply is for all types of consumers including residential, commercial and non-industrial. In this report, residential users are the only one we concerned. In Hong Kong, residential building can be basically classified into three classes: public housingestates , home ownership scheme housing estate (HOS) and private housing estates. All the clean water firstly enters the control valve of the building and pumped up to the roof water tank after passing through the sump tank under ground or on the ground floor.

7.5 Waste Water Treatment

In Hong Kong, the residential waste water is collected through the underground waste water piping system and is led into the nearby sewage system. The Drainage Services Department (DSD) is responsible for the job. Its website provides relevant information to let the public know what they are doing in sewage treatment. In Hong Kong, there are sixty-seven sewage

treatment plants with different levels of treatment process: 24 plants for preliminary treatment; 37 plants for secondary treatment; 2 plants for primary treatment; 3 plants for chemical enhanced primary treatment and 1 tertiary treatment plants.

Sewage treatment plants are classified into five categories. This paragraph introduces their duties. Firstly, the preliminary treatment contains screening and grit removal. It removes all solids larger than 6mm in diameter from the sewage. Secondly, primary treatments perform screening, grit removal and a primary sedimentation process. Thirdly, chemically enhanced primary treatment is similar to the primary treatment; however it adds chemicals to enhance the removal of suspended solids and the biochemical oxygen demand (BOD). This process costs higher than the primary treatment but produces treated water of better quality. The fourth treatment method is called secondary treatment. This process utilizes the biological treatment process to purify the sewage after primary treatment. The organic matter in the settled sewage is decomposed by micro-organisms, which is the biological treatment process. The last treatment method is called tertiary treatment. This treatment process should be done after secondary treatment. Ngong Ping Sewage Treatment Works, as an example, uses advanced biological method, filtering and disinfections process to treat the sewage. The treated water from tertiary treatment is named as reclaimed water, which is safe for flushing and can be used for irrigation and cleaning. In addition, Shek Wu Hui Sewage Treatment Plant is being constructed for expanding the area of the plant and adding the advanced technology to become a tertiary treatment plant. The construction completion anticipates in early 2009.

7.6 Quality of Treated Waste Water

The water effluent from the sewage treatment plants is under supervision and the results of eight major sewage treatment plants are posted on DSD website. Those eight sewage treatment plants are Shatin, Tai Po, Shek Wu Hui, Yuen Long, Sai Kung, Stonecutters Island, Siu Ho Wan and Stanley Sewage Treatment Works (STW). The measured elements include flow rate, 5-day biological oxygen demand, total suspended solid, nitrogen content and *E.coli*.

A water quality report of April 2008 is used for the following analysis. According to the value of designed "dry weather flow", Sai Kung STWs is the lowest (8×10^3 m^3/day), while Stonecutters Island STW is the highest, (1725×10^3 m^3/day). This variation is due to the fact that Stonecutters Island STWs treats all the waste water from Kwun Tong, To Kwa Wan, Kwai Chung, Tsing Yi, Tseung Kwan O and North West Kowloon; which are densely populated urban areas. Sai Kun is a low density area, which produces much less waste water comparatively; so that the designed dry weather flow is lower.

	Shatin	Tai Po	Shek Wu Hui	Yuen Long	Sai Kung	Stone-cutters Island	Siu Ho Wan	Stanley
DWF	236	88	80	70	8	1725	180	11.6
Ave. (April 08)	227	**92**	77	14	8	1315	42	9.2

Table 6. Dry weather flow (DWF) and average daily flow in eight major sewage treatment plants on April 2008.

The situation of waste water production in April 2008 can be seen from Table 6. All of the average daily flow in those eight plants is under the designed dry weather flow, except the Tai Po STW. That means most of the day in April 2008 had been measured higher than the designed DWF. This phenomenon can be caused by the new development of that district and the weather, for example, the increase of population and the number of rainy days.

The effluent monthly report mentioned those four main parameters from eight STW. According to the April 2008 report, all the parameters are under the license standard, which means all the effluent is under the safety line. The graded information of effluent quality from those eight STW can be found in Appendix B.

Chapter Eight: Hong Kong Regulations on Water Management

Environmental Protection Department (EPD) website (resources & publications – resource materials) has listed out many booklets, leaflets/posters and reports, which are useful for recognizing the environmental activities. EPD is responsible to introduce requirements and activities of environmental conservation in Hong Kong. The activities included grease traps for restaurants and food processors, connection to sewers under Water Pollution Control Ordinance, guidelines for the design of small sewage treatment plant, the Habour Area Treatment Scheme (HATS) programme, and Quality Water Recognition Scheme for Buildings. These topics are described and discussed in the following paragraphs.

8.1 Grease Traps for Restaurants and Food Processors

The guideline on grease traps is published for restaurants and food processors, which produce oily waste water during the good production process. The details of a grease trap design are not discussed, but the waste minimization procedures are good reference:

a. Scrape dirty serving dishes and cooking utensils into a garbage bin before washing

b. Dispose of floor sweepings and food scraps to a garbage bin before washing floors and food preparation surfaces.

c. Use metal strainers or baskets in all drains. If this slows things down, keep two strainers on hand; quickly place one over the drain while the other is emptied.

d. Take care not to discharge excessive quantities of detergent and/or hot water as these are also considered to be pollutants.

These procedures are not only applicable for restaurants and food processors, but also at home. For example, the food scraps should not be drained into the sewage piping system but separating them into a garbage bin.

8.2 Connections to Sewers under the Water Pollution Control Ordinance (WPCO)

This guidebook explains the reason for setting up the sewerage system what benefits the system provides to the public. The sewerage system provides safer and healthier living

conditions to the public; a halt to pollution caused by malfunctioning treatment facilities on site; no further need to operate, maintain and monitor treatment facilities on site; and easier compliance with pollution control legislation.

The maximum penalty for not connecting the wastewater to the public sewer is a fine of $100,000 and a daily fine of $5,000 if the offence is proved to be continuous.

The steps for making the connection begin by sending a notice to the owner of the premises from the government, and the owner of the premises need to employ an authorized person or private contractor to do the job. The authorized person and contractor should be registered under the Buildings Ordinance. For premises subject to the control of the Buildings Ordinance and in Developed Areas in the New Territories require one more step, which is getting the relevant District Lands Officer's approval.

After the completion, the government will inspect the terminal manhole and other drainage work, and then connect the terminal manhole to the public sewer. The owner is to remove or seal up all pipes leading to the treatment facility.

8.3 Guidelines for the Design of Small Sewage Treatment Plants

The guidelines for the design of small sewage treatment plants is applicable for the population less than about 50 only, which is not match with our project target. However, it listed out the criteria, which are useful, for the sewage treatment plant design. The general design considerations are listed below:

- Block and location plans of site;
- Maximum number of persons (resident and non-resident) to be served;
- Presence of shops, restaurants or other service trades;
- Possibility of the need for future extensions to the plant;
- Proposed location of discharge

According to such information, EPD will formulate the required effluent quality standards. All the mechanical equipment, which is functioning in the sewage treatment plant, should be provided with on-line standby units.

Other than the application, the second issue should be considered is safety. For examples, the entrance to the sewage treatment plant should have a proper door without the use of steps or ladders and accessible by a vehicle. A second pedestrian entrance/exit should be provided as far as possible for emergency purposes at the opposite end of the plant room. The minimum

water retention time for the sewage treatment plant should be at least 20 minutes at the peak flow.

The basic components for a sewage treatment plant contain an equalization tank, coarse screen, fine screen, primary sedimentation tank, fine screen and final sedimentation tank. The detailed design criteria can be referred to the Appendix C.

8.4 The HATS Programme

The Habour Area Treatment Scheme (HATS) has started Phase One construction since 1994. The progress of HATS is reported regularly to the public through its website. Phase Two is on progress. Around 720,000 cubic metres seawater is used for toilet flushing from the Harbour each day. If the quality of seawater from the Harbour can be improved, seawater flushing provides more confidence to the user and reduces the consumption of freshwater on flushing toilet. The methods used in this programme can be the reference for designing the suitable sewage treatment system for estate use.

Biological Aerated Filter (BAF) is a good technology for treating waste water. The beneficial of BAF is compact in size and flexible to operate, and would remove more pollutants than chemically enhanced primary treatment. Trial sum of this facility is taking place on Stonecutters Island to confirm its feasibility and cost-effectiveness for Hong Kong.

Since the cost spends on construction, operation and maintenance of the sewage treatment system is over a few billions, and the sewage charge is expected to increase gently per year. The expense on sewage treatment is an economic pressure to Hong Kong residents.

8.5 Quality Water Recognition Scheme for Buildings

Certification scheme on promoting water quality was not only for water quality assurance, but also for water system management. Since 22 July 2002, a Fresh Water Plumbing Quality Maintenance Recognition Scheme was established and administrated by the Water Supplies Department. The name was changed to Quality Water Recognition Scheme for Buildings on 1st January 2008 launching with a series of new features (Water Supplies Dept., 2008).

The objectives of this programme are to increase the confidence on using tap water; to encourage the performance of building management agent on tap water quality; to make compliance of the prescribed criteria under the Scheme with those building management agents; and to assist people to do self-assessments on plumbing conditions. The interested parties can apply for recognition under this scheme by achieving the criteria mentioned below.

Normally, this scheme is applied by the building management agent or the owner's corporation, which will ensure that the plumbing system is inspected at least once a quarter year by licensed plumbers or qualified building services surveyors or engineers and certified to be in good physical condition. Second, all defects will be rectified by licensed plumbers or qualified persons. Third, cleansing the water tanks will be held at least once every three months. Lastly, water samples are taken in accordance with the recommended procedure and tested for items specified, at least once a year for new application and at least once every two years for renewal application. The water sample should be taken within 3 months from the date of submission of the application or renewal and the test results should comply with the acceptable limits of water quality indicators. The tested result will signify whether the application successful or not.

There are 3 grades of Certificates to awarded buildings once the name of the scheme had been changed. New participation or continuous participation with less than 3 years got BLUE Certificate; SILVER Certificate was for continuous participation with 3 years or more but less than 5 years; while GOLD Certificate was for continuous participation with 5 years or more. Since this scheme had been started less than a year, all of the on-listed 2,098 buildings were holding the BLUE Certificate (Water Supplies Department, 16 May 2008).

The scheme required the applicant to check the plumbing system regularly and rectify all the found defects preventing the water wastage by leakage. According to the last name list of applicant on 1 December 2007, there were 1,999 buildings. The applied parties included domestic buildings and commercial buildings, which reflected that the certification scheme attracted any building management agent to build up their performance on management services. The good plumbing system management is the most effective method to minimize water leaking problem.

Chapter Nine: Recognition in Hong Kong Water

A successful research should be approached with strategy as what Joseph Hughes suggested. There are four steps in solving the developing world's water and sanitation problems. First, researchers must determine how big the problem is; second to analyze water distribution dynamics; third to understand the complexity of systems required and last to create new approaches (Dynamic Pressure Control Enhances Urban Water Management, June 2007). The problem had been determined and instructed, then we have to understand the complexity of systems required before making conclusions and recommendations on water saving.

"Recognition in Hong Kong Water" introduced the existing plumbing system in public housing estates; hence we had visited two estates for collecting the most updated details with on-site observation. The comparison of two estates is provided in the paragraphs below.

In Hong Kong, there are over 1,360 housing estates of which 193 are public estates. The first step for collecting the information of housing estate population could be found from the Hong Kong Housing Authority (HA) website or electronic map on web, for example, Centamap. The biggest housing public estate contains 12,310 flats of Sau Mau Ping Estate in Kwun Tong while the smallest contains 245 flats of Kam Peng Estate in Islands (found from HA website). Details, which is collected by January 2008, on Hong Kong public housing estate can be found in Appendix D. The number of units in an estate lower than 2000 is called small housing estate; between 2000 to 6500 is medium; and over 6500 is big estate. Purpose to recognize more about the plumbing system in domestic buildings, observation in person was the best way. Therefore, two estates had been chosen for site visit and both estates were managed by Chevalier Property Management Limited.

The visited estates were Sunningdale Garden (順欣花園) and Kwong Yuen Estate (廣源邨), which both located in New Territories. Sunningdale Garden was sold under Private Sector Participation Scheme by the Hong Kong Housing Authority, while Kwong Yuen Estate was Public Housing Estate. The following paragraphs included the introduction of estates, and the comparison between two estates in population, facilities, water system management, and living habit.

9.1 Sunningdale Garden

Sunningdale Garden is a private housing estate in Shek Wu Hui and we took the visit on 25 January 2008 morning. The estate contains 4 blocks with a total of 830 units, which is categorized as small estate. According to the information provided from the Assistant Estate

Manager of Sunningdale Garden, Mr. Yu, he said that the latest water bill costs about HK$48,000, including the water consumption of 4 blocks and 24 shops on the ground floor. Since the flushing water in this estate is fresh water, the water bill should involve the water supply charges and sewage charges. We had also visited the refuse room on 20th floor, building's top, and the main refuse station on ground floor near the car park.

Freshwater is the only water supply for any purpose in this estate, which has no water recycling facilities. Mr. Yu said that they only follow the requirement from the Hong Kong legislation, the Deed of Mutual Covenant and the guidance of Environmental Protection Department (EPD) on water piping system.

Security guard and the estate manager have to do the inspection at least once per four hours and once per day during the inspection respectively, plumbing system has also been checked visually. They clean the water tanks once per season which follows the guideline from the Water Supplies Department. Actually, this estate has potential to apply the "Quality Water Recognition Scheme for Buildings" successfully, however, they are not on the list and Mr. Yu did not explain it.

At the end of the visit, Mr. Yu is helpful to provide the floor plan of the drainage system and the statistics about water usage and waste treatment of the whole estate for our reference.

9.2 Kwong Yuen Estate

After visiting the private housing estate in Shek Wu Hui, we would like to recognize more about the public housing estate, which are the place most Hong Kong people living in Kwong Yuen Estate had been chosen as the second destination, which is located in Sha Tin. This estate is also managed by Chevalier Property Management Limited. Although Kwong Yuen Estate was a public housing, the Tenants Purchase Scheme (TPS) started since January 2001 (Housing Department Press Releases), some units had been bought by the residents and slightly separated from the Housing Authority's management. Therefore the residents established their Owner's Corporation for managing daily events. As follow, Chevalier Property Management Limited had been authorized by the Owner's Corporation to manage this estate continuously. The interviewees of this estate are Mr. Mok and Mr. Timmy Tsang.

Focus on the water treatment, this estate had no water recycling facilities and followed the requirements of Hong Kong Legislation, the Deed of Mutual Covenant and the guidance of EPD on water piping system. The security guard takes inspection once per four hours when the estate manager takes once per day. During the inspection, they will check the leakage of water piping visually. Once they receive the report on water leakage, they will contact the employed technician to do the repair as soon as possible.

Unfortunately, this estate did not join the "Quality Water Recognition Scheme for Buildings" although they had been cleaning the water tanks once per season. Mr. Tsang explained that they did not know how to apply the scheme.

At last, Mr. Mok leaded us to visit all the refuse station within the estate and the refuse room on 16/F of Oak House (廣橡樓). While we were doing the site visit, Mr. Tsang was preparing some statistics of water usage for us, we are very please with their assistance.

The flushing water in Kwong Yuen Estate is sea water, which is no need to pay for.

9.3 Comparison between Sunningdale Garden and Kwong Yuen Estate

9.3.1 Population

According to the questionnaire from both two estates, the population of Sunningdale Garden is about 3,320 (830 units times 4 people) while the Kwong Yuen Estate is about 18,000. The result shows the typical difference between private housing and public housing. Generally, the population of private housing is lower than the public housing.

9.3.2 Water System Management

Both two visited estates only follow the Hong Kong Legislation, the Deed of Mutual Covenant and the guidance of EPD on water piping system. Refer to Hong Kong news, government department encouraged citizens to save the water usage, improved the water quality of Victoria Harbor by upgrading the facilities in wastewater treatment plant and promoted the "Quality Water Recognition Scheme for Buildings". Although both two visited estates were not on the list of the Scheme, the fresh water can also be guaranteed. It is because both estates has cleaned the water tanks once a season, which meet the minimum requirement for keeping the water tanks clean.

9.3.3 Facilities

The water system units or facilities between two estates are normally the same, no special facilities, after taking the site visit and questionnaire.

9.3.4 Living Habit

After the interview, we understand more about the facilities and structural design of the buildings of both estates, and also the living habit of the residents. However, we did not by any problems or differences on living habit on water management system by observation during the visit.

* assume 4 persons living in a unit

Chapter Ten: Water Saving Methods

10.1 Freshwater Saving Promotion

Nowadays, water scarcity is not only threatening a part of human being in the World but all. The Third World countries are facing the most serious water scarcity while other countries are fighting against the water shortage. Countries, including China (developing country) and United States (developed country), are using many methods to mitigate this problem, for example, water saving throttle and reclaimed water. Water saving can be done in "compulsory" or "optional" ways. Compulsory way means to make rules for people to obey, which is a must; while optional way means people can choose to obey or not. For instances, legislations are one of the compulsory way; energy saving air-conditioner is a product for consumer to choose as another option.

The first step to reduce fresh water consumption is to educate people with good saving water habit. If everyone understands the reason to save water, they would appreciate to do so. Governmental website has been promoting how to have good habit on water saving. The website is called "GovHK: Tips for Saving Water".

The website encourage people should not use or store more water than immediately required at home; and never rinse your hands, clothes or vegetables under a running tap – do so in a bowl or sink. Using shower instead of a bath is suggested to save 80% of the water. If a bath is needed, try using the water left over to wash the floor or to water plants. Washing machine or dishwasher should be in full load for every application, and cut down the rinse cycle if possible. Immediately fixation should be done once dripping taps is discovered. It is because they can waste up to 70 litres of water a day.

The Hong Kong government website, called GovHK, has listed out the tips for saving water at work, which is not discussed in this report. It is because home is the most obvious place to start saving water than workplace. More information can be found in Appendix E. Other than education, technologies and intelligent product are essential to save water.

10.2 Water Saving Device

Rearrangement of plumbing system requires planning, coordinating and managing by the architectural professions, therefore using water saving device is faster and more convenient to start saving water.

Special designed water tap can save water, for example, infra-red water tap, mushroom-button water tap and two-button flushing system. Infra-red sensor water tap

effectively avoids people who forget to turn the tap off. Mushroom-button water tap starts providing water once the button is pushed. When the push button returns to normal, the water stops supply. Two-button flushing system is new for providing two choices to the user. The difference between two buttons is the volume of water used per flushing. User can choose the water volume for each flushing depending on their needs. More and more commercial buildings, plaza and domestic buildings are using those water saving devices for promoting environmental protection and saving water bill.

In Hong Kong, Chinese Cuisine Training Institute (中華廚藝學院) did an excellent job on saving water. Cooking required a huge amount of water for cleaning, therefore this institute installed water throttles to reduce the water consumption and also the sewage. Institute did double blind test method to check the efficiency of the water throttles on water saving. This test had been spent over a year and completed in April 2004. The collected data represented that 20% to 25% of water had been saved in average. All the collected data were presented as a bar chart as figure 4 on their website.

Figure 24. - Data of water consumption before and after water throttles installation from September 2003 – April 2004. (Chinese Cuisine Training Institute)

Other than using water throttles for water saving, changing the flushing system also achieves the same purpose. According to the website of TOTO, which is the world's largest plumbing products manufacturer, environmental protection concept is added into their products. In the beginning, flushing system was designed by using a certain amount volume of water, which is about 6 liters, for flushing. Six liters of fresh water instantaneously becomes sewage whatever you throw a piece of tissue or a pack of tissue. Some people announced that this living habit should be changed with suitable facilities for saving fresh water. The most

updated toilet was designed with two buttons. Both buttons are used for flushing, but flushed by different volume of water. Most of toilet is designed to use 6 liters per flush. Two-button toilet gives consumer another option to use 3.375 liter per flush to flushing out their rubbish.

Eco-friendly products are investments for the sustainable development of the World. However, people should use it in the correct way to bring the product into full play. Otherwise, water scarcity will happen to the whole World earlier than the expectation.

10.3 Reclaimed Water

Using reclaimed water for cleaning is a good idea to save the drinkable water, but it is not applicable in Hong Kong till this recent moment. The water quality of the reclaimed water is monitored by the Drainage Services Department, and the possible usages of reclaimed water are for cleaning roads and vehicles; irrigating parks and sport fields; flushing toilets; fire fighting; industrial production; and urban development and landscaping. Although they are not the biggest portion of water consumption in Hong Kong, we should treasure and use whatever a drop of water at its highest value.

As the water scarcity is becoming worse, many countries have suggested recycling the waste water for non-portable use as introduced follow. Waste water can be classified into two classes: black-water and grey-water. The main differences between two classes are defined by the content of organic matter and pollutants. Black-water represents the sewage which contains high content of organic matter, such as excreta and pollutants. Grey-water is chosen to be the origin of reclaimed water because it has low contents of organic matter and pollutants (March, J.G. et al., 2004). The collection points include bathtubs, showers, hand-washing basins, laundry machines, kitchen sinks and so on.

Grey-water collection, treatment method and transportation are under consideration for producing reclaimed water. United Kingdom (UK), Spain and Taiwan encourage new buildings to separate plumbing system for grey-water collection. A-quality-of-life policy group in U.S., announced a statement about "Changing building standards and layouts could make a dramatic difference to the way water is used and recycled."(BBC NEWS, 31st May 2006). The group also suggested using porous pavements and car parks to ensure almost all rainwater is gathered underground. Unfortunately, it is not applicable for Hong Kong since underground water is not a source of fresh water in Hong Kong.

The first journal about reclaimed water application in a hotel is published in Spain, which is situated in the southwest Europe. Actually, Spain is facing the water shortage. One of its islands Mallorca, require fresh water being shipped from the Ebro River on the mainland to

postpone the influence from water scarcity. Also, desalination was adopted as a solution (March, J.G. et al., 2004). The plumbing system was rearranged from conversional approach (Figure A) to alternative approach (Figure B).

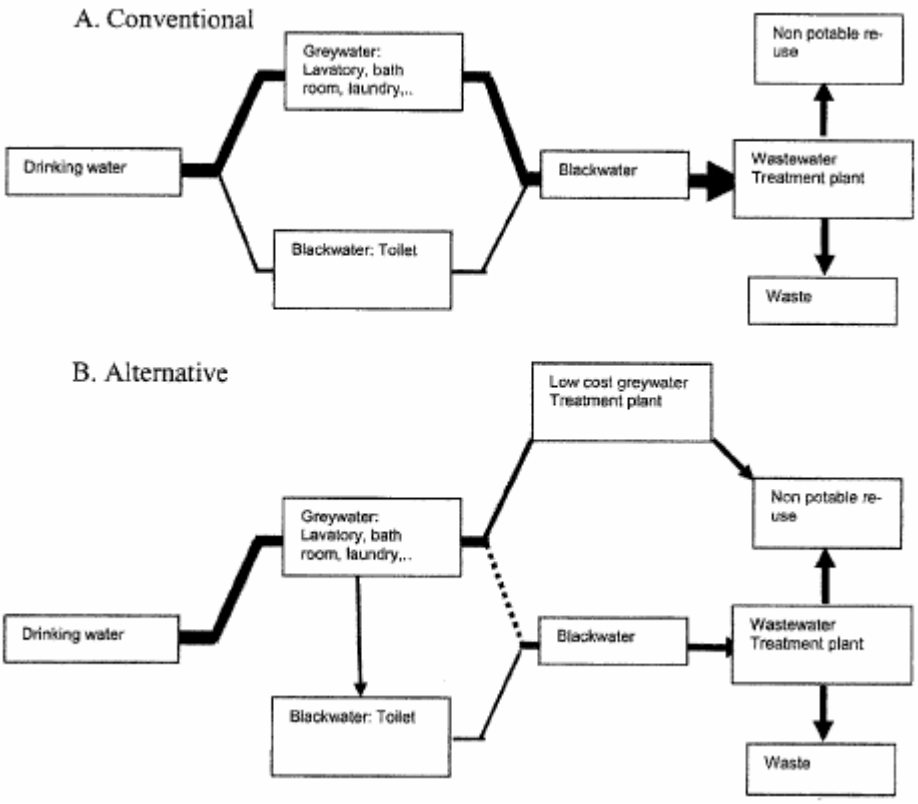


Figure 25. Conventional and alternative schemes for urban water use and treatment (March, J.G. et al., 2004)

For the conventional approach, drinking water is used for both flushing and other cleansing purpose, then assembled as black-water and transported to the waste-water treatment plant for clarification and disinfection before discharging to the nature. The new designed hotel applies the alternative approach to reduce the demand of drinking water for flushing and also the workload of wastewater treatment plant. Comparatively, the technology for grey-water treatment is less complicate than black-water treatment comparatively since wastewater treatment plant is required to remove a large amount of organic matters and to deal with heavy sludge disposal. Although the alternative approach significantly reduces the treatment cost, it increases about 5% of the plumbing budget. Grey-water treatment contained filtration (nylon sock type filter with 0.3mm mesh and $1m^2$), sedimentation and disinfection (sodium hypochlorite). The researchers indicated that the payback period of these hotels is 14 years, but the result is highly dependent on the seasonal activity of the tourist industry, the amount of occupancies and the changes of water bill and taxes.

The Chung Hua University in Taiwan has published a research report, in Chinese, about the

sustainable development of water in the World and Taiwan. According to the journal, a separated plumbing system is employed by buildings in an estate in Japan, which forms a Waste water Recycling Center with central water collection facility and transportation plumbing system. All the collected waste water is treated and to the quality requirement before returning to the water supply plumbing. The total area of Shinjuku urban center contains about 50 x 10^4 m^2. Thirty three sand filters are used where 68m^2 for each. Their waste water treatment capacity is 450,000 m^3/d. All the reclaimed water is pumped up to the separate roof tanks, and distributed into the non-drinkable pipes for flushing within estate Shinjuku. It appears that the plumbing design in Shinjuku may be suitable for Hong Kong public housing.

The reclaimed water is useful and cost effective. Its uses, include flushing, cultivation and cleaning, are applied in many other countries. In Hong Kong, the information on this kind of facilities and utilization is reported in Ming Pao of 10 March 2008. The article is about the plan for saving fresh water consumption in Northern New Territories. At present, most of the flushing system is using fresh water, which is consumed at high costs. For reference, 1m^3 Dongjiang water costs around 4 dollars (in 2007) while 1m^3 desalination water costs about 7 dollars, they are not cost-effective compared with recycled water (再生水) which costs 1 dollar per one cubic meter. In Hong Kong, there is only one wastewater treatment plant using the technologies to generate recycled water. It is Shek Wu Hui Sewage Treatment Works. Since 2005, Environmental Protection Department has expended 15 million dollars for building facilities up to do reverse osmosis, chlorine addition and other tertiary treatments. The recycled water from Shek Wu Hui is only supplied to Northern New Territories for drinking or flushing alternatively.
The study on the costs of fresh water supply for flushing reveals that there are over 1.3 million people using this system. Not only increasing the usage of fresh water, but also increasing the expenditure on buying Dongjiang water. The annual fresh water consumption was high at 82 million cubic meters for flushing only; and it consumed about 330 million public treasuries. If most of the Northern New Territories citizen can use recycled water instead of fresh water, the expenditure for buying fresh water can be decreased dramatically. Before taking action, we should consider how the existing water piping system and water treatment facilities could help further development.

There are limitations in using seawater for flushing, Northern New Territories, as an example, contains water treatment plant and freshwater supply pipe only. The only solution is to build up new sea water supply system, which causes financial problem. Before taking actions, there are many questions we have to consider, such as; is it cost-effective for building up a new water system for flushing? When is the return on investment? Where does the money for new water piping come from? And so on. Although the questions cannot be solved for the

moment, getting more attention of the public on conservation is good for the environmental protection. The relevant newspaper can be referred to Appendix F.

Chapter Eleven: Water Treatment Methods

The severity of world wide water shortage forces scientist to find solutions, and desalination and reclaimed water are the commonly suggested methods. The technologies used for desalination and reclaimed water include physical, chemical and biological treatment method. Reverse osmosis and membrane bioreactor are the most common methods for producing freshwater and reclaimed water.

11.1 Reverse Osmosis

A Suffolk man invented a drinkable water maker, which could remove bacteria, parasites and viruses by using a mini-filter only. This product was designed as a water bottle with mini-filtration system inside. It can handle 6,000 liters before the filter needs changing (BBC News, 17 Sept 2007). This designer bottle is useful for the soldier who cannot find clean water in the battlefield. The bottle shaped filter system is not popular due to high price and cannot solve the water scarcity in quantity.

In China, there is a desalination plant called The Yuhuan Seawater Desalination Plant to provide adequate fresh water for 2008 Beijing Olympics. The East China Sea water was used for desalination. The company that takes in charge of this project utilized a membrane which allows higher salt rejection at a higher flow rate with increased boron rejection. The membrane could reject 99.8% nominal salt and highly as 92% of boron (Wastewater International, July 2007). Reverse osmosis can remove most of the impurities, including salt, but it occupies a large area for building up a tank and accommodating the membrane. The size of the membrane is 37.16 m^2 for The Yuhuan Seawater Desalination Plant.

11.2 Membrane Bioreactor (MBR)

MBR had been invented for many years and scientists are trying to improve this technology to become more cost effective and efficient on impurity removal. The following paragraphs show two improved MBR – (i).Anaerobic membrane bioreactor and (ii).membrane bioreactor with ultra-filtration membrane.

11.2.1 Anaerobic Membrane Bioreactor

In history, membrane is used to filter out the impurities, but cleaning of the membrane is frequently needed to prevent clogging. Oxygen injection is a method to clean up the membrane. However, more energy is required to blow the membrane leading to lower profit from the wastewater treatment process. Aerobic systems use the potential energy to produce new cells, which will be formed as sludge, while anaerobic systems typically produce more energy, methane, then they consume. Therefore, Anaerobic MBR had been proposed since

less sludge generation produced from the process. (Landers, May 2008)

David Stuckey, a biochemical engineering professor, had developed a submerged anaerobic membrane bioreactor (SAMBR) for treating dilute wastewater, for which he got the Brian Mercer Award for Innovation in UK.

The field-scale test was done under laboratory conditions using three 3L reactors outfitted with two different types of submerged membranes. The pore size of membranes is 0.4 μm. Sludge collected from the sewage sludge digester was added into the process as adding micro-organisms to enhance the waste degradation. Biogas was generated during the process. The gas was collected and returned to the reactors at a point beneath the membrane units. In this way, the gas turned as bubbles to clean the membranes. SAMBRS removed 93% COD when operating at a hydraulic retention time of 3 hours.

Stuckey illustrated that energy consumption and sludge disposal problem were important aspect before promoting this method. Good treatment process needed market and should be cost-effective. Anaerobic systems totally achieved the requirements. In the process, methane generated from the process and returned to the system as energy supply, and produces less sludge to save the disposal fee.

A technology leader in Black and Veatch, which was a consulting engineering firm, said that anaerobic treatment processes was not only worked on highly concentration and warm wastewater as here and say; the processes could work at colder temperature with dilute sewage with excellent COD removal and low sludge yield.

SAMBR is a good solution for saturation of landfill sites in Hong Kong. If the disposal of sludge from waste water treatment plant can be reduced, the operation time of landfill sites can be extended.

11.2.2 Membrane Bio-reactor with Ultra-filtration Membrane

Membrane bio-reactor (MBR) can be combined with different process and can give different results of water quality. Liaoning University of Petroleum & Chemical Technology and Tokyo University had joined venture to develop the submerged membrane bio-reactor with an ultra-filtration membrane, which had a pore size of 0.08 μm, a porosity of 70 percent and an effective filtration area of 0.45 m^2. (Li Na et. al., March 2008)

The reason for choosing MBR to treat domestic wastewater was because it minimized the amount of sludge significantly and improved effluent quality. The removal was not only carbon and nutrients, but also bacteria and virus. For the submerged membrane, it reduced the energy consumption significantly compared with others.

The result of the experiment showed that COD removal is 96% while activated sludge was used. This submerged MBR wastewater system is able to handle variable impact-load conditions. However, some other things should be improved or found out in further experiments, for example, nitrification bacterium was greatly influenced by pH level.
This experiment is not totally completed, as it needs to find out more solutions to remove more nutrients. Although the COD removal reaches up to 96%, the nutrient content should be monitored and kept under the acceptable limited.

11.3 Vibratory Shear Enhanced Processing (VSEP)

Recycled water becomes more popular especially in manufacturing industry because production processes need a large amount of clean water. However, the increase on clean water consumption enhances higher cost in production. All the discharged waste-water quality should fulfill the Hong Kong legislation. Therefore manufacturers are required to add more treatments before discharge. Most of the manufacturers prefer to recycle the waste-water back to the progress rather than adding treatments for discharge.

A new product had recently developed by New Logic Research, Inc. which filtrates water into pure water simultaneously. The new technology is called Vibratory Shear Enhanced Processing (VSEP). This technology can be used independently depending on the waste-water quality. If the waste-water contains a lot of suspending solids, coarse filtration is needed as a pre-treatment. In Japan, this technology is applied for changing river water to fresh water. Another characteristic is the utilization of vibration for membrane cleaning.

Changing river water as fresh water in Hong Kong is not possible since the streams do not always carry enough water. Although this technology can be used for water treatment plant, recycling water on site is better to save water.

In Japan, there is an electronic disk manufacturing facility at Hokkaido Island in Northern Japan for which requires pure water for rinsing. Since the requirement of water quality for electronic disk product is high, additional treatment is needed in order to guarantee the rinse water in high quality. The additional treatment is called Vibratory Shear Enhanced Processing (VSEP), which is invested by NEW LOGIC RESEARCH, INC. and the information below is found from its website.

The manufacturer has been using traditional technologies since the opening, and it had applied VSEP Treatment System since 1997. The traditional technologies included:

- sand filtration,
- cross flow membrane filtration, and
- poly-aluminum chloride (PAC) for coagulation.

Whereas, the VSEP Treatment System include:

- preheat,
- equalization/pH adjustment,
- VSEP units, and
- heat recovery.

The weaknesses of the traditional technologies are insufficient power for colour removal by sand filtration; and easy occurrence of membrane fouling by cross-flow membrane systems since the humic substances contents in river water is high. VSEP enables to lower the turbidity and eliminate the problem caused by humic substances.

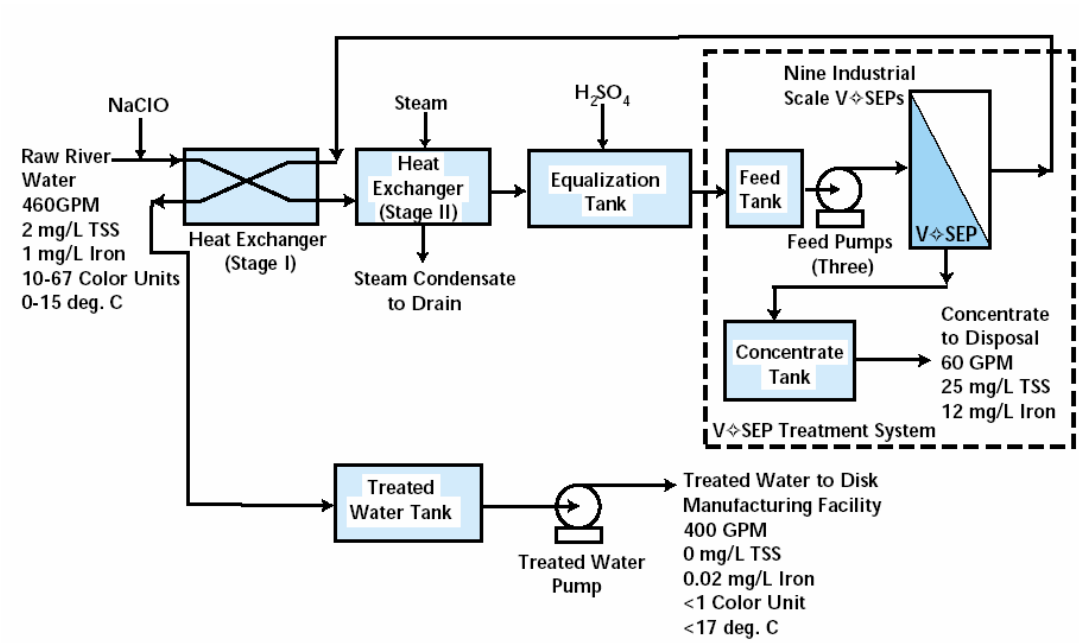


Figure 26. Integration of VSEP with ultrapure water production at electronic disk manufacturing facility

The river water treatment process in the electronic disk manufacturing facility is shown in Figure 26. The processes surrounded by dotted line represent the VSEP Treatment System. At the beginning of the process, sodium hypochlorite (NaClO) is added into the raw river water for coagulation before entering the heat exchanger (Stage I). The original temperature of raw river water varies from near 0℃ in winter to 15℃ in summer, therefore the temperature control is needed to stabilize the condition of feed water. After crossing two heat exchanger (Stage I and II), the temperature is raised to 30℃. It is because high temperature can improve the permeate flux through the membrane in VSEP unit and provides the energy drive for the first exchanger. The following step is to adjust the pH value by using sulfuric acid (H_2SO_4). On the other hand, other chemicals may be added to help coagulation, such as

poly aluminum chloride (PAC). One feed tank and three feed pumps are used to maintain constant feed rate into the VSEP unit. The products from VSEP are concentrated water, which is disposed into the holding ponds and then sewer; while the treated water is delivered back to the disk manufacturing facility as rinse water.

The treated water is found to meet the water criteria in different parameters as shown in Table 7. Membrane osmosis is applied in VSEP unit. The VSEP unit is designed as a cylinder and contains many sheets of membrane which are arrayed as parallel disks separated by gaskets. Referring to the Figure 26, the river water is fed from the columns on left and right while the center column is used for collecting pure water. The flow of pure water and concentrated water are in opposite directions.

Parameter	**Raw River Water**	**Treated Water**	**Designed Water Quality**
Temperature ℃	0-15	<17	<17
pH	7.1	6.0-6.7	5.8-6.9
TSS, mg/L	2	<1	<1
TS, mg/L	94-117	98-116	-
Color, units	10-67	<1	<1
Turbidity, NTU	4-16	<0.1	<0.1
Permanganate ($KMnO_4$) Consumption, mg/L	2-7	<1	<1
Total Iron, mg/L	1	0.01-0.02	<0.05
Total Manganese, mg/L	0.012	0.009	-
Aluminum, mg/L	0.02	0.01	<0.05
Total Organic Carbon (TOC), mg/L	0.7	<0.5	-
Humic Group, mg/L	<0.4	<0.4	-
Electrical Conductivity, μS	-	82-88	-

Table 7. A comparison of raw and treated river water using VSEP

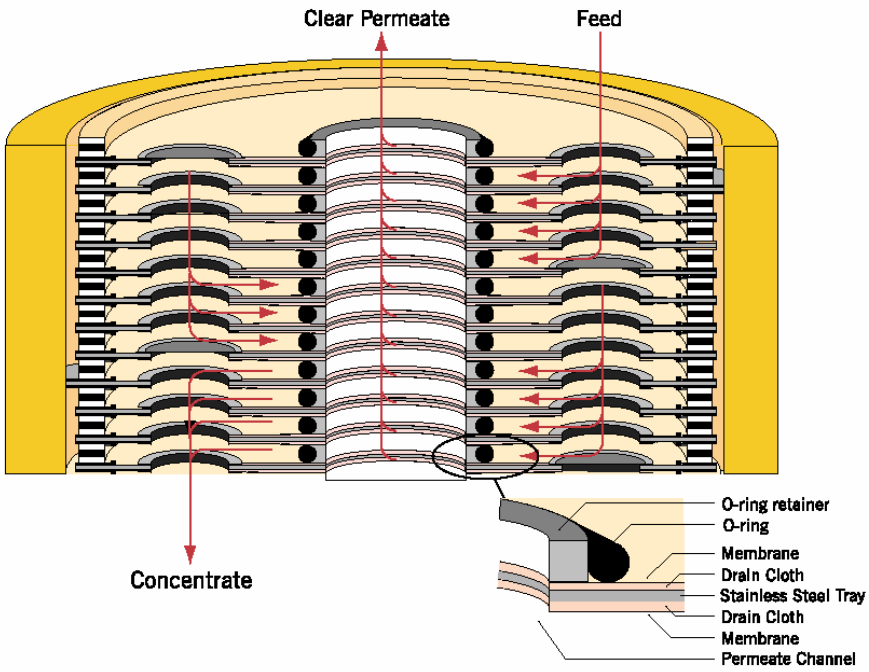


Figure 27. - Cross section of VSEP pack

VSEP has another model, which is known as the “Series I system”. It only occupies 20 square feet only but possible to treat 5-200 U.S. gallons river water per minute. Although the system works for 24-hours a day, the packing required to clean once a month only. This system can convert river water to pure water as well as greywater recycling.

VSEP is able to efficiently remove suspended particulates, color and other elements as listed in Table 7. The designed purpose of VSEP is to recycle the wastewater from manufacture facilities, which contains high metals and color. The testing result shows that this system is able to produce high quality pure water, so it is believed that it can be applied to domestic grey water recycling.

Sewage contain too much impurities and require large area to do the sedimentation and aeration, therefore turning it into grey water is the best choice to re-use water in a cost-effective way. Before the recommendation, some considerations are discussed in the following paragraphs, based on the analysis about the actual application of VSEP system in an estate. The first issue is the production rate of grey water in an estate, Sunningdale Garden.

Chapter Twelve: Conclusions and Recommendations

Water shortage is a global issue as it affects all the living being in the World. Reduction on fresh water consumption and utilization of reclaimed water are effective methods to minimize the pressure on fresh water supply. Since most of the fresh water is bought from Kangdong, the less water people used in Hong Kong can save the cost on buying water. Besides, a part of China is facing water shortage, where they need water to maintain a sustainable life. People make all effort to save water in anyway, whether to change the living habit or to apply new technologies.

The first step to achieve the water saving purpose is education. People who understand the reason and method to save water can do it actively. The tips on water saving can refer to the government website. Second, people are appreciated to use water saving device to prevent water loss, such as infra-red sensor water tap, mushroom-button water tap and two-button flushing system. Third, regular plumbing system check is essential since the leakage causes waste up to 70 litres of water per day. Lastly, water recycling is appreciated because most of the water consumption works do not need fresh water and instead of reclaimed water.

Reclaimed water is suggested to be a viable method to conserve water usage because non-drinkable needs can use reclaimed water. Three methods had been suggested in this report, they are reverse osmosis, membrane bio-reactor and a new technique called vibratory shear enhanced processing (VSEP). Reverse osmosis and membrane bio-reactor are popular in use on water treatment process and obtain different weaknesses and strengths during the treatment process. Anaerobic membrane bio-reactor is recommended for reclaimed water production since the anaerobic environment does not lead the sludge generation after the process. It is not only reducing the treatment cost on sludge, but also convenient for on-site treatment, especially in a housing estate. Another recommended method is VSEP, which is possible to produce pure water for drinking. For example, for Sunningdale Garden, two VSEP units can be equipped to recycle the water used for flushing. However, the area required for such a device is a concern for tightly spaced Hong Kong housing estate.

Water retains in a housing estate for recycle is proposed in this report. This suggestion directly reduces the waste water treatment pressure in public waste water treatment plant and the water piping system, and also reduces the cost for treating waste water from governmental facilities. However, a pilot scale test is suggested to be done for testing the technologies with accurate data. Besides, the costs on the system, maintenance, operations and so on, are needed to find them out in the next project.

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Appendix A: Capacity of Impounding Reservoirs in Hong Kong (香港水塘容量)

Name of Impounding Reservoirs	水塘名稱	Capacity[1] 容量[1]
Aberdeen Lower Reservoir	香港仔下水塘	0.486Mm^3
Aberdeen Upper Reservoir	香港仔上水塘	0.773 Mm^3
Pok Fu Lam Reservoir	薄扶林水塘	0.233 Mm^3
Shek Pik Reservoir	石壁水塘	24.461 Mm^3
Tai Tam Byewash Reservoir	大潭副水塘	0.080 Mm^3
Tai Tam Intermediate Reservoir	大潭中水塘	0.686 Mm^3
Tai Tam Tuk Reservoir	大潭篤水塘	6.047 Mm^3
Tai Tam Upper Reservoir	大潭上水塘	1.490 Mm^3
High Island Reservoir	萬宜水庫	281.124 Mm^3
Kowloon Byewash Reservoir	九龍副水塘	0.800 Mm^3
Kowloon Reception Reservoir	九龍接收水塘	0.121 Mm^3
Kowloon Reservoir	九龍水塘	1.578 Mm^3
Lower Shing Mun Reservoir	下城門水塘	4.299 Mm^3
Plover Cove Reservoir	船灣淡水湖	229.729 Mm^3
Shek Lei Pui Reservoir	石梨貝水塘	0.374 Mm^3
Shing Mun Reservoir	城門水塘	13.279 Mm^3
Tai Lam Chung Reservoir	大欖涌水塘	20.490 Mm^3
Total capacity:	**總容量:**	**586.050 Mm^3**

Appendix B: Eight Sewage Treatment Plant effluent in Hong Kong on April 2008

Plant 1: Shatin Sewage Treatment Works 沙田污水處理廠
Plant 2: Tai Po Sewage Treatment Works 大埔污水處理廠
Plant 3: Shek Wu Hui STWs 石湖墟污水處理廠
Plant 4: Yuen Long STWs 元朗污水處理廠
Plant 5: Sai Kung STWs 西貢污水處理廠
Plant 6: Stonecutters Island STWs 昂船洲污水處理廠
Plant 7: Siu Ho Wan STWs 小濠灣污水處理廠
Plant 8: Stanley STWs 赤柱污水處理廠

(a) Daily Flow (x10^3 m^3/day) 每日流量 (千立方米/日)								
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
Min.	212	85	72	12	6.8	1257	35	8.1
Max.	306	130	106	21	15.5	1369	58	13.1
Ave.	227	92	77	14	8	1315	42	9.2

(b) Design Dry Weather Flow (x 10^3 m^3/day) 設計旱天流量								
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
DWF	236	88	80	70	8	1725	180	11.6

(c) BOD5 (mgO_2/L) 生化需氧量(毫克/升)								
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
Ave.	<5 (20)	<7 (20)	<5 (20)	<5 (20)	<5 (20)	53 (75)	80 (180)	<3 (20)

(xx): License Standard (Percentile)

(d) TSS (mg/L) 總懸浮固體 (毫克/升)								
	Plant 1	Plant 2	Plant 3	Plant 4	Plant 5	Plant 6	Plant 7	Plant 8
Ave.	<7 (30)	<16 (30)	<8 (30)	14 (30)	<5 (30)	36 (55)	21 (120)	<4 (30)

(xx): License Standard (Percentile)

(e) Total-N (mg/L) 總氮量 (毫克/升)			
	Plant 1	Plant 2	Plant 5
Ave.	<10 (25)	<8 (25)	<4 (12)

(xx): License Standard (Percentile)

(f) NH_3-N (mg/L) 氨-氮 (毫克/升)		
	Plant 3	Plant 8
Ave.	<0.52 (2)	<0.1 (5)

(xx): License Standard (Percentile)

(g) NO_x-N (mg/L) 硝酸鹽+亞硝酸鹽-氮 (毫克/升)		
	Plant 3	Plant 8
Ave.	8.2 (12)	3.4 (8)

(xx): License Standard (Percentile)

(h) E. coli (count/100mL) 大腸桿菌 (個/100 毫升)			
	Plant 3	Plant 5	Plant 8
Ave.	16 (1500)	2 (1500)	<5 (15000)

(xx): License Standard (Percentile)

Remarks: All the tested results are summarized in the above tables. Some of the boxes are missing because that plant did not do such test.

Appendix C: Design criteria of small sewage treatment plant

A portable submersible pump should be provided in order to allow flexibility in operation. This pump can be used to recycle the plant effluent to maintain the STP in a working condition when incoming flow is low.

General headroom of 3m should be maintained for enclosed or underground STP with artificial ventilation. This may be reduced to 2.5m at localized points, e.g. under beams.
For enclosed STP, a minimum air volume of $14m^3$ should be provided. Artificial ventilation should be provided with not less than 10 air changes per hour. Ventilation exhaust pipes should be carried up to a height not less than 1m above the roof of the building at which the STP is located.

Access walkways of MIN. 0.75m clear width should be maintained within the STP for access to all areas requiring maintenance and operation. Walkways should have safety rails (preferably stainless steel) and toe boards. Walkways should be laid to a 1:25 crossfall to prevent ponding if of solid construction and they should not be obstructed by crossing pipework.

Where levels vary, staircases should be provided and not catladders or step irons.

All tanks should be provided with stainless steel ladder or step irons for access. Mild steel should not be used. Step irons should be spaced at 300mm c/c horizontally and 250 mm c/c vertically.

If a tank has to be covered, stainless steel or aluminium alloy open mesh flooring should be used (aluminium should however not be used in chlorination facilities located in confined space). Open mesh flooring should be designed for 5kPA uniformly distributed load.

Provision of an emergency by-pass to the STP is not allowed under normal circumstances.

Fresh water taps for hoses and hand-washing should be provided in the STP at convenient locations and should be shown on the drawings.

Electrical distribution boards and control panels should be installed in locations not liable to flooding and the locations shall be shown in the drawings. Panels should have a dehumidifying heater.

The control panel should incorporate a mimic/schematic diagram and all labels should be in both English and Chinese. All valves, penstocks, pumps etc. should be appropriately labeled.

Hours run meters should be provided for all major equipment to record the total hours of operation. They should be of the non-resettable type.
Coarse screens should be provided to precede pumps. Fine screens should be placed downstream of equalization tanks equipped with air ejectors so as to minimize organic solids content in the screenings.

Mechanical screens should be the static type or of the type having the rakes moving in the bar openings and not on the bar. Either manual or mechanical by-pass screens should always be provided. The duty screen channel should have a high level overflow into the standby screen channel so that the flow diverts automatically through the standby screen in case the duty one is blocked.

Excessive screen channel width which results in shallow depth of flow should be avoided. In case of small developments where the smallest mechanical screen commercially available is still too wide, a manual screen may be used.

Bars of screen should be extended to the invert of the channel. For manual screens, consideration should be given to:

- Access by operator;
- Ease of removal of screenings by operator, including provision of suitable rake;
- Draining of screenings;
- Bagging and storage of screenings

A perforated/mesh type drain tray (of stainless steel or plastic material) should be provided to allow the screenings to drain prior to packaging.

Pump sumps (including equalization tanks) should be designed to limit the pump starts to not more than 10times/hour.

Electrical voltage for level sensors in pump sumps should not exceed 24V to avoid electrical hazard.

High level alarms should be provided in all pump sumps. This should be in the form of visual and audio alarms connected to a suitable constantly manned location.

Pumps should be carefully chosen to correspond to the design duty point. Flow regulation tanks with control weir should be used if only bigger pumps are available.

Comminutors, especially the enclosed type, are discouraged as they often cause operational problems in the STP.
Sedimentation tanks should be designed either as rectangular horizontal flow tank, or as square/circular upward flow tank. For horizontal flow tank, the length to width ratio should not be less than 2. The use of tanks with length to width ratio between 1 and 2 should be avoided.

Upward flow sedimentation tanks should be provided with minimum 60° hopper wall slopes to facilitate easy sludge collection and removal.

Horizontal flow sedimentation tanks should be provided with a mechanical scraper system on a nominal floor slope, discharging to a sludge hopper. Twin tanks should preferably be used. If single tank is used, the scraper should be of the type that allows the underwater parts to be maintained without the need of shutting down the tank.

Adjustable weirs should be used for sedimentation tanks to enable fine leveling. V-notch weirs should be used where wide flow variation occurs. The side-wall height should be not less than 1m in order to avoid sludge carryover. The layout should be such that inlet arrangement never becomes submerged in sludge.

A chamber should be provided at the final sedimentation tank outlet after the weir for installation of recirculation pump in the event that the actual initial flow is much lower than the design flow.

Sludge in sedimentation tanks should be removed as frequently as possible, at least once per day by a suitable sludge withdrawal device such as submersible sludge pumps, airlifts or valves. A scum removal device should also be provided. The sludge and scum removal device should have independent adjustable control. Inspection trough should be provided at the discharge end for inspecting the quality of sludge withdrawn so that adjustment to the withdrawal system may be made accordingly.

Chlorination facility should include a flash mixing device followed by a plug low contact tank. Baffles should be provided in chlorination tanks to prevent shout-circuiting. Lateral baffling should be used for shallow tanks and up-and-over baffling should be used for deep tanks. Dechlorination facility may be required in situations where the residual chlorine poses

hazard to fisheries or shellfisheries.

Sludge storage tanks should be provided with aerators when they are located in enclosed plant rooms to maintain the aerobic condition of the sludge. However, sludge storage tanks should preferably be ventilated separately to the exterior. Decanting facilities should be fitted to sludge storage tanks. Supernatant should be returned to the equalization tank.

Sludge pumps should be designed with positive suction head to minimize the possibility of clogging.

The diameter of the sludge draw-off pipework should be of a minimum diameter of 80mm in order to prevent pipe blockages.

A sludge dewatering machine capable of attaining 30% w/w dry solids content for landfill disposal and a sludge tank for emergency storage of 14days sludge volume should provided. For small STP serving less than 100population, it may be acceptable to provide only a sludge storage tank for wet disposal provided that:

- A storage tank capable of holding 60days sludge volume be provided,
- Vehicular access is maintained for desludging tankers,
- Written confirmation is provided from a desludging contractor undertaking to carry out the work and specifying the ultimate disposal site for the wet sludge.

An automatic flow measuring device with non-resettable type totalizer should be provided at suitable location for measuring the flow for STP serving a population of more than 50.

An easily accessible sampling point should be provided for taking samples of the treated effluent.

A minimum lighting intensity of 300lux should be provided in the STP. Lights should be located where they are accessible for maintenance and replacement.

Appendix D: Number of public estates in different district

District	Number of Public Estate
North	9
Tai Po	6
Yuen Long	14
Tuen Mun	12
Tsuen Wan	6
Kwai Chung & Tsing Yi	23
Sha Tin	17
Sai Kung & Tseung Kwan O	8
Islands	8
Sham Shui Po	14
Kowloon City	5
Wong Tai Sin	20
Kwun Tong	27
Yau Tsim Mong	1
Central & Western	1
Wan Chai	0
Eastern	14
Southern	8
Total	193

Appendix E: Tips for Water Saving

I. Saving Water at Home

The most obvious place to start saving water is at home. There are a few simple tips that will allow you to conserve fresh water by only changing your habits slightly.

- Don't use or store more water than you immediately require.
- Never rinse your hands, clothes or vegetables under a running tap – do so in a bowl or sink.
- If your take a shower instead of a bath, you will only use 20% of the water.
- If you do have a bath, try using the water left over to wash the floor or to water plants.
- Only use your washing machine or dishwasher when you have a full load, and cut down the rinse cycle if possible.
- Fix dripping taps immediately, because they can waste up to 70 litres of water a day.

II. Saving Water at Work

Water can also be saved in the workplace with a little forethought and planning.

- Use manufacturing processes and equipment that are efficient in water use.
- Determine water requirements for each unit of production and check usage frequently.
- Ensure that hot water pipe runs are as short as possible and that cold water pipes are laid away from heated areas.
- Reduce water pressure to the lowest practical level.
- Carry out regular leakage tests on concealed piping and check for overflowing tanks, waste worn tap washers and other defects in the water supply system.
- Pump cooling water to a condenser or heat exchanger for re-use.
- Collect, dilute and recycle rinsing water.
- Re-use steam by collecting condensation.
- Collect used water for cooling purposes, floor cleaning and yard washing.
- Ensure that bottles, cans, churns and other vessels are fully emptied before they are washed.
- Reduce spillage by keeping the water level in rinsing and washing tanks to a minimum.
- Turn off the water supply system at night and on holidays.
- Place posters and other publicity materials in prominent places to encourage water conservation.

Appendix F: Newspaper for flushing water in Northern New Territories

From Ming Pao on 10th March 2008

130 萬人每年「沖走」3.3 億公帑 再生水代食水沖廁擬擴大範圍

【明報專訊】全港仍有 130 多萬人口以淡水沖廁，年耗水量高達 8200 萬立方米，即白白沖走 3.3 億元公帑；環保署於 06 年秋季展開示範計劃，每日向上水的住宅、學校及安老院，提供經處理污水作沖廁用，

若計劃年底完成時效果理想，當局考慮擴大應用範圍。

北區再生水示範計劃原定今年初屆滿，但環保署回覆查詢，指計劃今年底結束，亦未有交代示範計劃成本。但該署曾以昂坪污水處理廠的再生水爲參考，1 立方米再生水成本僅 1 元，較東江水約 4 元（07 年價格）及海水化淡約 7 元比較，認爲相當具吸引力。

擴大應用視乎試驗計劃成效

環保署表示，已制訂監察計劃，以判斷再生水的水質和處理設施的成效。政府會於今年底前，一併檢討北區再生水示範計劃，以及昂坪污水重用計劃的運作成效，若結果顯示整體運作理想，政府會再考慮擴大應用範圍，在本港其他地區使用再生水。

不過，該署表示，北區目前只有由水務署營運的唯一一個公共供水系統，若要在區內應用再生水，便需建設全新的供水網絡，這是在決定再生水是否可以更廣泛應用時其中一個考慮因素。

鳳溪公立學校行政總裁馬紹良表示，使用再生水，可減少耗用食水，該校及轄下幾間安老院使用再生水後，節省六七成沖廁水費，由於該校參加示範計劃，可免費使用再生水。他說，如廣泛使用，基於用者自付原則，相信便要繳費，認爲政府在推廣環保之餘亦要平衡市民的負擔能力，若較水費更貴便不化算。

試用學校省七成沖廁費

另外，水務署表示，該署計劃於屯門安排興建海水抽水站，有關工程已於去年底動工，預料於 2012 年竣工，到時屯門、元朗及天水圍就可用海水沖廁，不用再交淡水沖廁費用，但北區則未有時間表。06 年，用作沖廁的淡水達 8000 立方米，

以去年的東江水價計算，市民白白沖走 3.3 億元公帑(public treasury)。發言人稱，全港所有地區都有兩套水管系統，以淡水沖廁的地區，只要有海水供應，隨時可轉用海水。

明報記者 馬耀森

斥資 1500 萬 設再生水設施

【明報專訊】新加坡早已引入再生水技術，將「屎水」變成飲用水，但本港仍停留在試驗階段。環保署於 05 年斥資 1500 萬元，爲石湖墟污水廠加建再生水設施，以薄膜滲濾及加氯消毒等程序，將污水淨化，供自願參與的北區用戶作非飲用用途。

本港是少數使用雙重供水系統的沿海城市，自 50 年代後，水務署開始供應海水，初期主要提供政府建築物使用，後來擴展至市區及新市鎮，但目前本港仍有 130 多萬人口使用淡水沖廁，每年用水量 8200 萬立方米，包括南區、山頂、西貢、粉嶺、上水、天水圍、元朗、屯門東及離島區居民。

對於市民，海水與淡水　廁的最大分別是前者免費，後者卻要繳費，除了首 30 立方米用水免費，超過該用量，每立方米收費 4.58 元，較飲用的食水更貴。

Appendix H – Refuse Chute Master Details for Hong Kong Public Rental Housing Estates

The following Refuse Chute Details are master details for public rental housing. They are acquired from the Housing Authority.

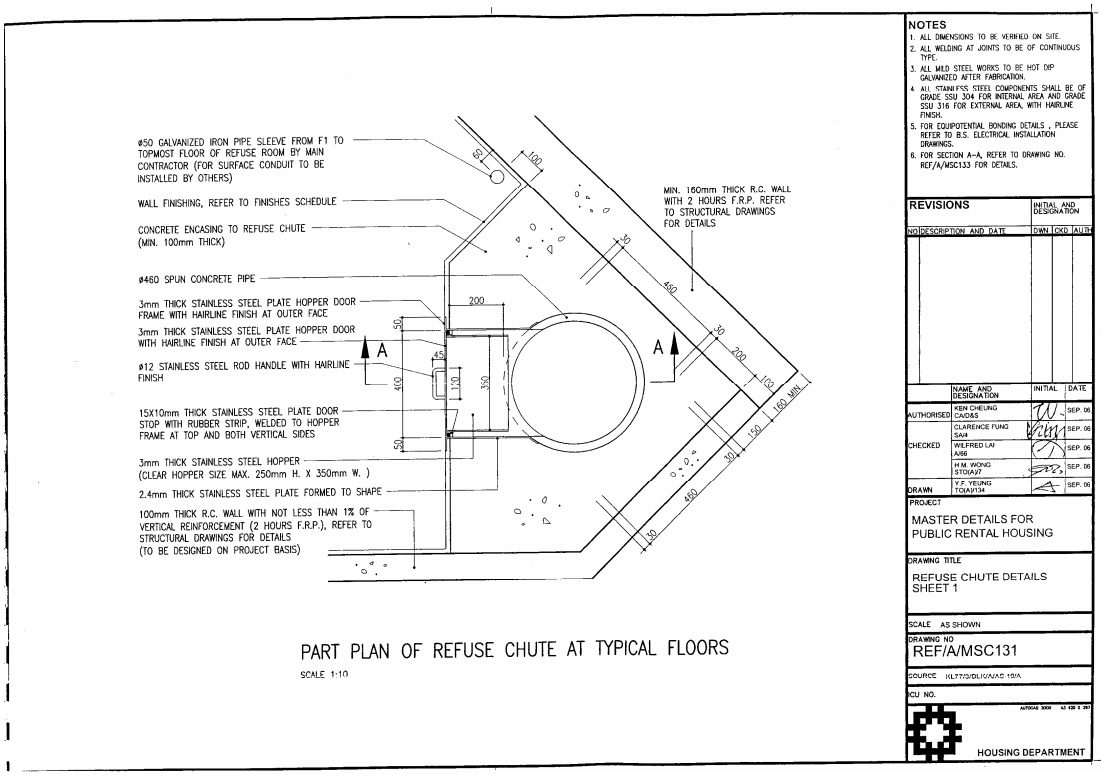

Figure 29 – Part Plan of Refuse Chute at typical floors

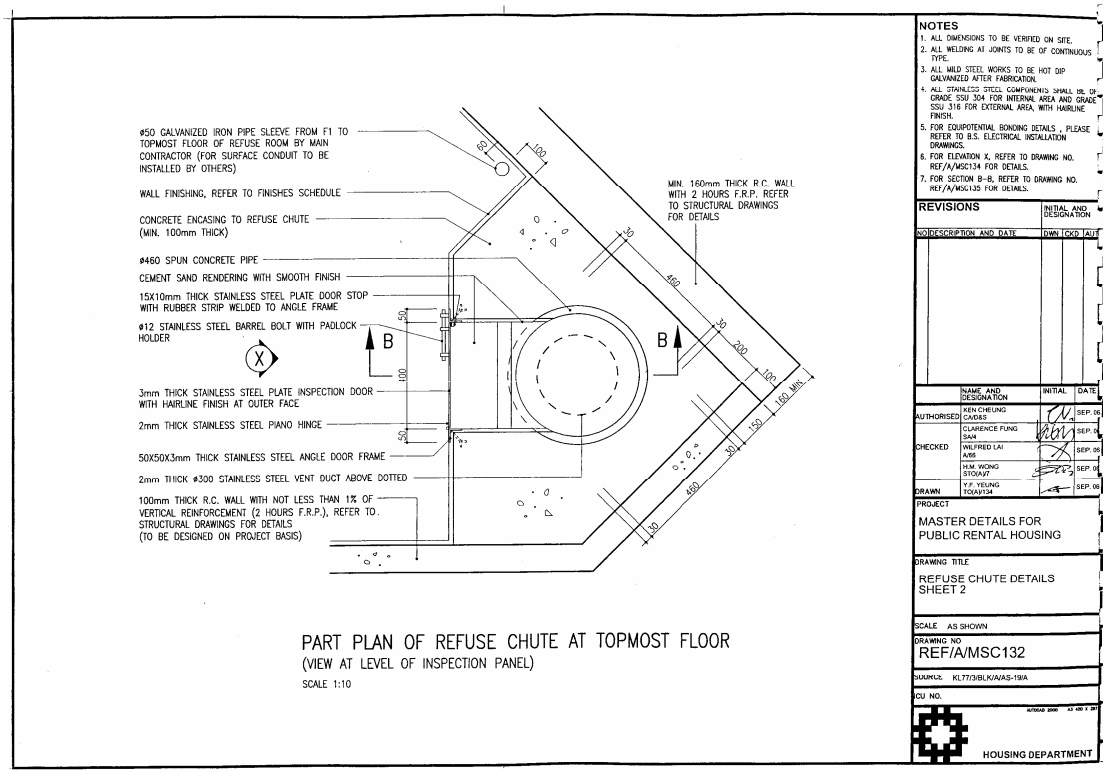

Figure 30 - Part Plan of Refuse Chute at topmost floor

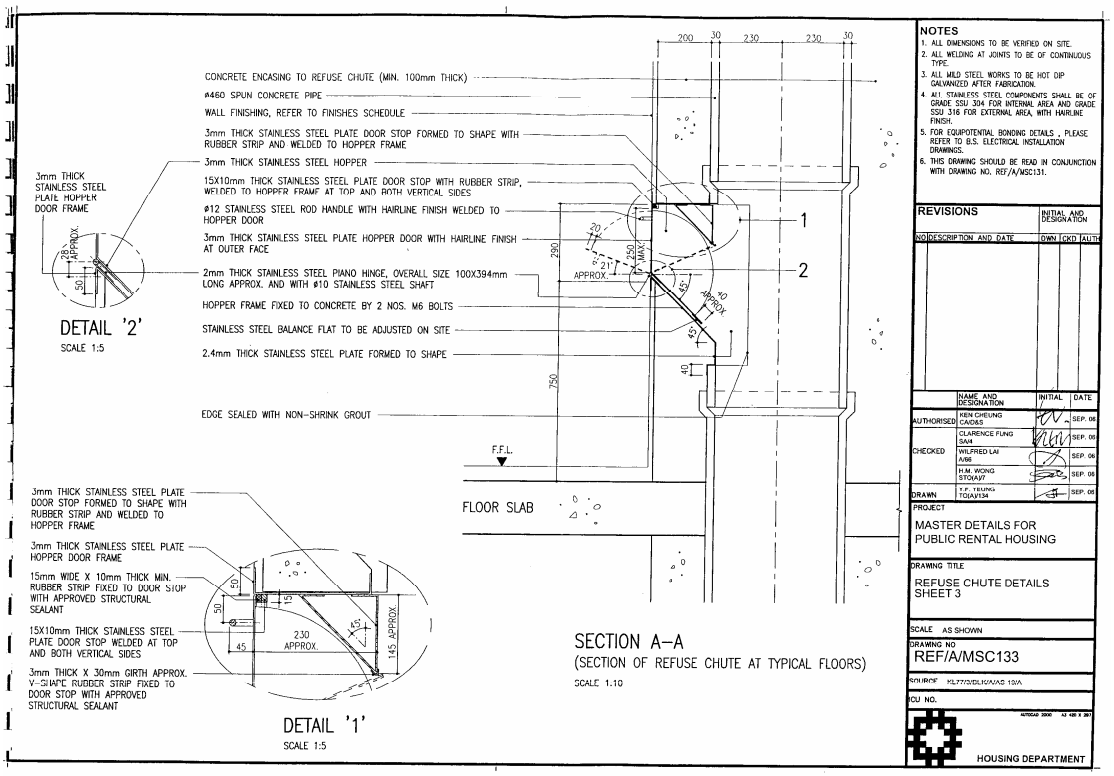

Figure 31 – Section of refuse chute at typical floors

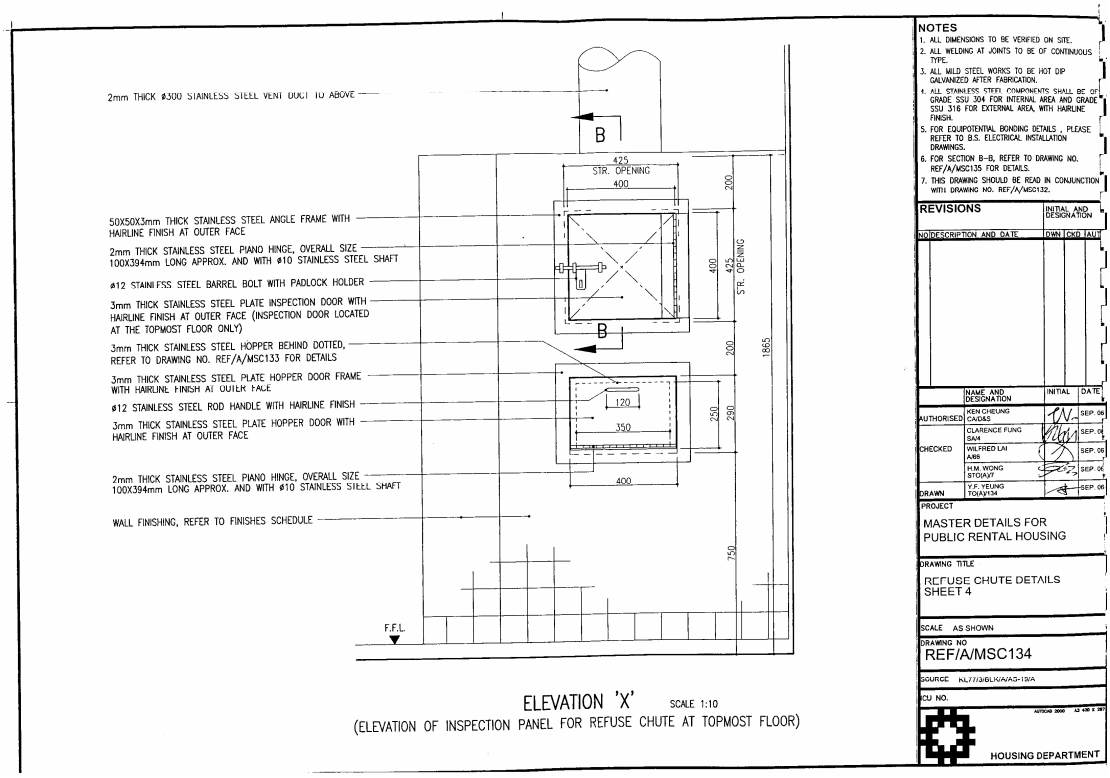

Figure 32 – Elevation of inspection panel for refuse chute at topmost floor

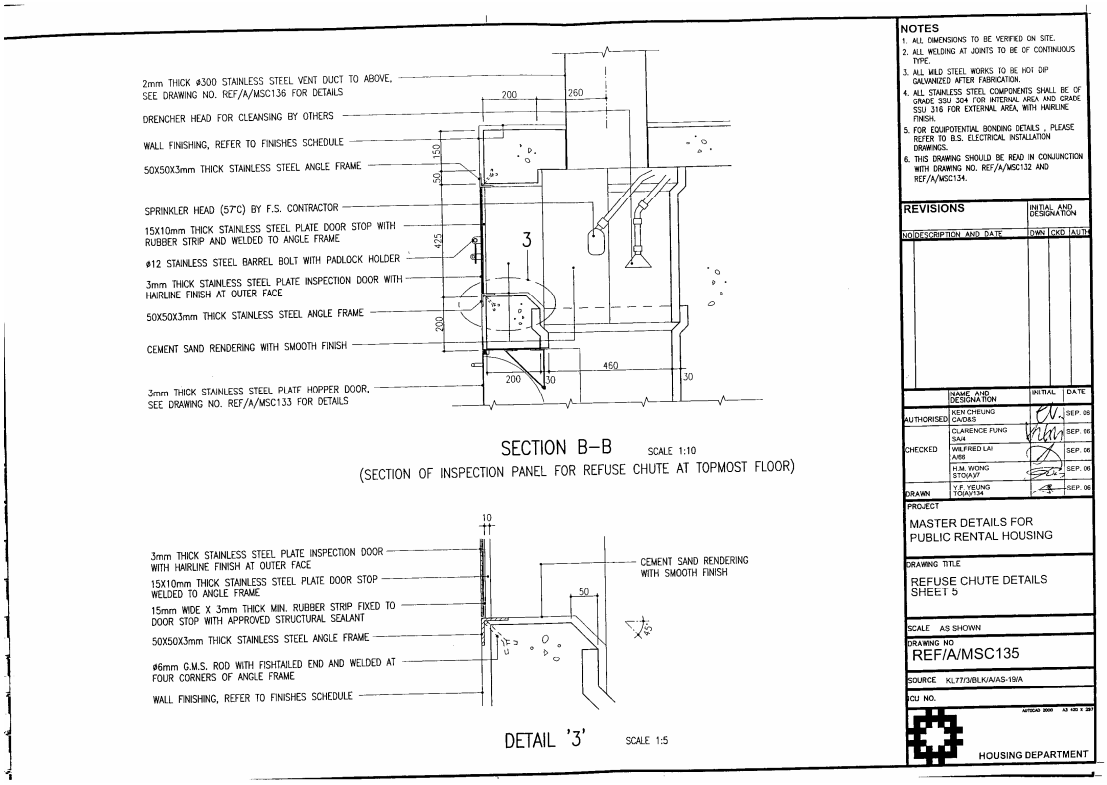

Figure 33 – Section of inspection panel for refuse chute at topmost floor

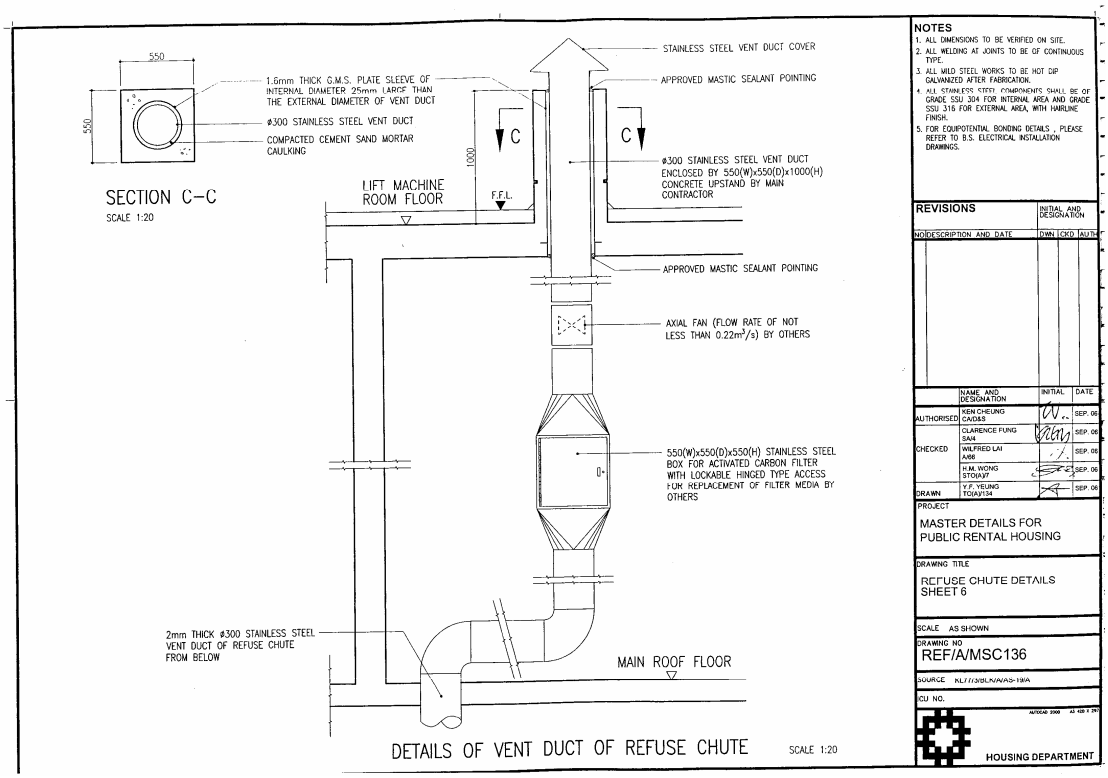

Figure 34 –Details of vent duct of refuse chute

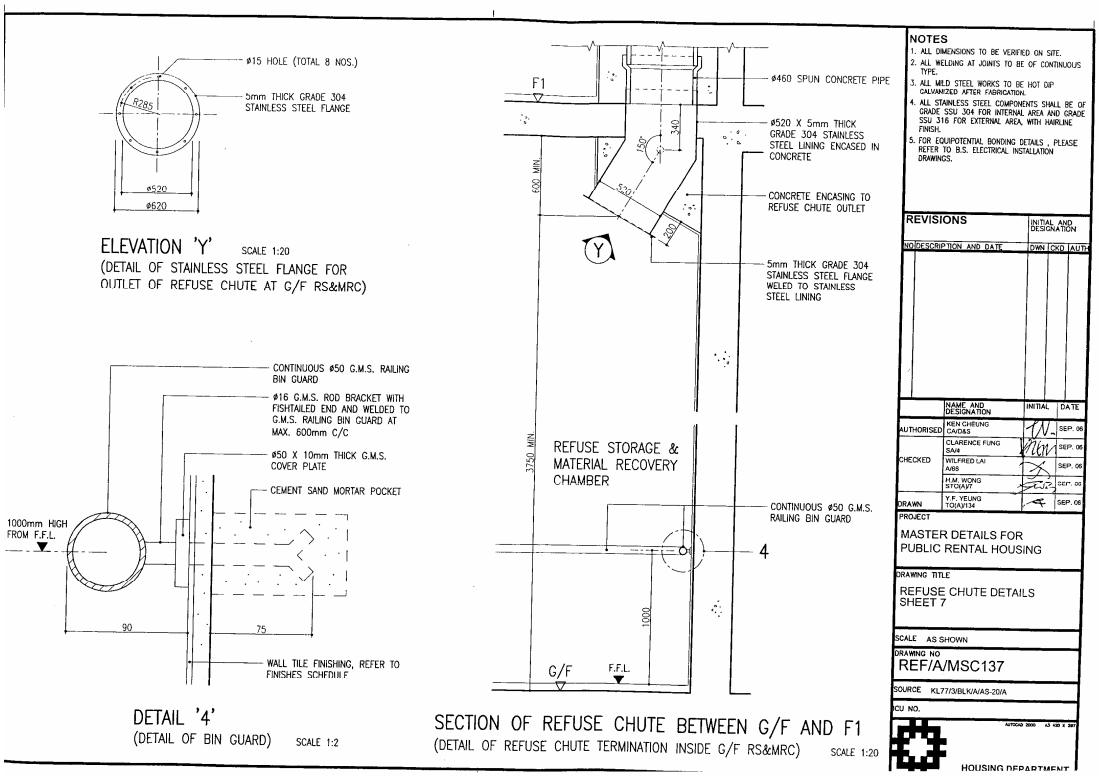

Figure 35 – Details of refuse chute termination