Research of domestic water consumption: a field study in Harbin, China

by

Tingyi Lu

A research project report submitted in partial fulfilment of the requirements for the award of the degree of Master of Science of Loughborough University

SEPTEMBER 2007

Supervisor: I.K. Smout
BA, MSc, CEng
FICE, MIAgrE, MCIWEM

Water, Engineering and Development Centre Department of Civil and Building Engineering

Acknowledgement

The authors take this opportunity to express sincere thanks to Mr. I. Smout, the project supervisor. This project could not be completed without his guidance and suggestion.

Thanks to many other friends who took part in the study and without whose assistance this report would not have been possible.

A special word of thanks is expressed to all the households whose patience, co-operation and effort provided the necessary information to enable a better understanding of domestic water use in Harbin.

Table of Contents

Abbreviations and glossary

BWR	Basic Water Requirement
l/c/d	Litres per capita per day
l/p/d	Litres per person per day
l/min	Litres per minutes
N/A	Information is not available
OFWAT	Office of water services
RNG	Random number generator
SDPC	State Development Planning Commission
WHO	World Health Organization
WEDC	Water Engineering and Development Centre
WELL	the WELL resource centre for water, sanitation and environmental health

1 Introduction

1.1 Background

Water is extremely important for developing nations, such as China. Water is a basic resource which supports economic growth and maintains daily life. China has only eight percent of the world's fresh water to meet the demands of twenty-two percent of the world's people (Worldwatch Institute, 2006). China needs to be able to use water in a sustainable way and this presents the country with a big challenge.

A considerable amount of the total water consumption is for residential use. The increase demand for water has put pressure on water supply system, which has lead to environmental problems such as overexploitation of water resources, and breaks in the balance of the ecosystem. The increase in the demand for water has created more wastewater. It places a burden on wastewater plants. Improvements in household water efficiency could reduce the pressure upon water supply and waste water treatment. Water efficiency does not mean controlling the water supply but its sustainable water use, which will reduce wastage.

1.2 Problem statement

The majority of research projects have focused on highlighting the current water shortage and the increased use by the residential sector. Research into residential water consumption in cities has been restricted to the capital. There are a lack of studies relating to other cities especially small and medium size ones. Most of the information about household water use is reported within figures for total annual water consumption or is contained in information about existing problems. There appears to be no specific information about household water using behaviour, water using appliances and water use patterns

A review of methodologies shows that a survey will be a good way to obtain required information, household water use behaviour. After a project feasibility study, the city of Harbin was chosen in which to conduct the research. An Introduction about Harbin is shown in Chapter two Section 2.6.

1.3 Aims and objectives

Aims

The aim of this project is to understand current household water use behaviour and water use patterns in Harbin, North of China, to improve the efficiency of household water use, to encourage sustainable use and conservation of water resources.

Objectives

The top level objectives of this study were:

- To investigate household water use behaviour and water appliance characteristics
- To analyse household behaviours and appliance characteristics to water consumption
- To estimate household water consumption and pattern
- To examine the reliability of the research results
- To compare the results of this research with other Chinese cities
- To analyse any water-saving potential for the residential sector

In more detail the research should explore the following:

Household water using behaviour

- Explore personal water usage habits which include appliance use frequency and the duration of each uses e.g. shower use frequency, duration of each shower

Water appliance characteristics

- Explore appliances' flow rates e.g. showerhead and taps
- Explore the common type of water use appliance at home
- Explore the ownership of water efficient appliance e.g Dual flush toilet

Water use pattern

- Explore whether the survey results and the water pattern are reasonable
- Explore the impact of each component

Comparison analysis of water pattern

- Compare the water pattern in Harbin with other countries and other Chinese cities
- Explore the differences and the reasons for these differences in their water patterns

1.4 Overall structure of the study

The project is made up by six main Chapters

Chapter 1 Introduction: includes the reasons of this project, the project's aims and objectives

Chapter 2 Literature Review*:* it is the foundation of this project. The literature review study has determined the direction of this project. A review of domestic water use (e.g.water use pattern, water use trend) has been described in different countries.

Chapter 3 Methodology*:* describes the methodologies that are used to collect the require information. This chapter includes the methods used in field and the field work schedules.

Chapter 4 Data Analysis and Survey Results: most of raw data and summary results from field are described in figures and tables. The calculation of water consumption is shown in this chapter.

Chapter 5 Result Discussions: includes a discussion of the reliability of the results, errors of this study and a comparison the water use pattern between Harbin and other cities.

Chapter 6 Conclusions and Recommendations: the study findings and used methodologies have been summarized. A summary of limitations of the study and the possible future study areas are described.

2 Literature ReviewIntroduction

Household water use is usually the most important part of municipal water use, because it accounts for over half of the total municipal water use in many countries. It usually requires high water quality and reliability which leads to high cost. Residential water use is also directly linked to the general public health. Improving the health of the poor is one of the main goals of water and sanitation projects. Therefore, household water use is always the top priority in the municipal water supply.

The literature review is a critical review of the existing research which relates to this project. In order to achieve this purpose, the literature review of this project will go through four steps

1) Evaluate and review the relevant publications
2) Literature review of household water use in international cases
3) Literature review of household water use in China
4) Literature review of the case study area -Harbin

2.2 Finding the literature

Finding the literature is the first step in literature review. Reviewing the literature is essential , not only in providing a context for the research subject and specifically limiting and identifying the research problem, but also in providing important information for subsequent parts of the research investigation (Williman, 2005). Main sources of information include

1. Pilkington Library and WEDC resources centre: include wide range of relevant books containing background information, past theses, reports, journals and conference papers
2. Internet : electronic databases and electronic journals

The first source of relevant literature was the Water Engineering and Development Centre (WEDC) Resource Centre, including some books about research projects and research methods. The purpose of reviewing such literature was to collect ideas about the process, structure and research designs of a research project. Then a more focused review of literature followed the research question. The early literature review studied some international cases. For example, books such as "Drawer of Water" and reports such as "sustainable water use in Europe" have been used.

The other main source of information was the internet. Compared with books and reports, internet sources are update quickly, but the main concern is the quality of the information. The major information came form some reputable websites such as WHO, Environment Agency, and WELL resource centre web site.

2.3 Residential water use standard

Residential water is used for household purposes, such as drinking, food preparation, bathing, washing clothes, flushing toilets, and watering lawns and gardens. In the guidelines for Drinking Water Quality, WHO defines residential water as being 'water used for all usual domestic purposes including consumption, bathing and food preparation' (WHO, 1993).

Residential water use standards vary with climatic conditions, life style, culture, technology and economy. There is no fixed data to estimate the amount of water needed to maintain acceptable of minimum living standard (Zhang, 1999). A water use standard was identified about thirty years ago. In 1977, the United Nations determined the concept of a water use standard to meet people's basic need for water.

… all people, whatever their stage of development and their social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs.(United Nations 1977)

This concept was further developed in the 1992 Earth Summit and in the 1997 UN General Assembly.

In developing and using water resources, priority has to be given to the satisfaction of basic needs and safeguarding of ecosystems. (United Nations 1992)

… it is essential for water planning to secure basic human and environmental needs for water… develop sustainable water strategies that address basic human needs, as well as the preservation of ecosystem.(United Nations 1997)

The new concept is more towards the environment and sustainable development. Water comes from the natural environment. So the usage of water needs to be planned to make sure that there is enough for current needs without damaging the environment.

The U.S Agency for International Development, the World Bank and the World Health Organization recommend the 'basic water requirement' BWR (include drinking and sanitation needs) in the range from 20 to 40 l/p/c/d (Zhang, 1999). Gleick in 1996 estimated the basic water requirement at 50 l/p/c/d for meeting four household basic needs: drinking, sanitation, bathing and cooking.

The basic water requirement is enough to keep our alive and healthy. Now many of people choose to purchase some liquid drinking water as bottled water, juices, milk, and soft drinks. Although many of us purchase the bottled drinking water, the household water consumption is till greater than the basic water requirement

Table 2.1 Residential water use in 2000

Country	Water use(average range)
New Zealand	180-300 l/ p /d Christchurch~ 250 l/p/d (150 for internal use)

	Waitakere City ~ 200 l/p/d Auckland City~ 190 l/p/d
Australia	~ 270 l/p/d Sydney ~ 215 l/p/d Melbourne ~ 200 l/p/d Bribane~ 340 l/p/d
England and wales	~ 150 l/p/d
China	~ 230 l/p/d Beijing ~150 -104 l/p/d Shanghai ~340 l/p/d Chongqing ~170 l/p/d

Source: Parliamentary Commissioner for the Environment, 2000

China Statistical Yearbook, 2001

UK EnvironmentAgency, 2007

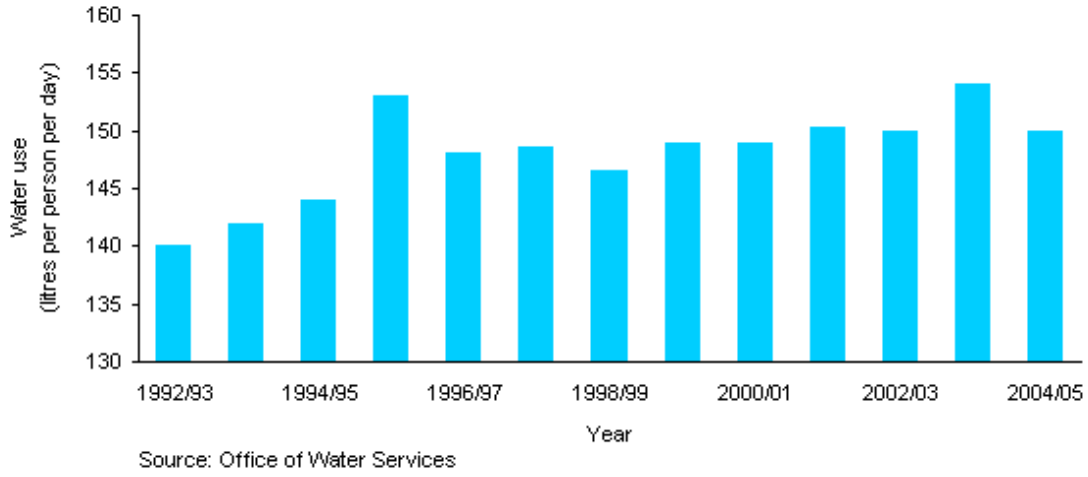
Jiang, 2004

2.4 International experiences

2.4.1 Water consumption trend

In an overview of water use in UK, about half of the abstracted water was found to be used for the domestic sector. The average trend of household water consumption has increased from 1992/1993(Figure 2.4.1).

Figure 2.1 Household water consumption in England and Wales (1992- 2005)



Source: UK Environment Agency, 2007

Individual water consumption increased by 7% from 1992 to 2001 in England and Wales. The peak demand was in 1995, due to the unusually hot weather. Washing machine ownership increased from 66% of total households to 90% by 1996 and is projected to increase further to 94% by 2010(UK Environment Agency, 2007).

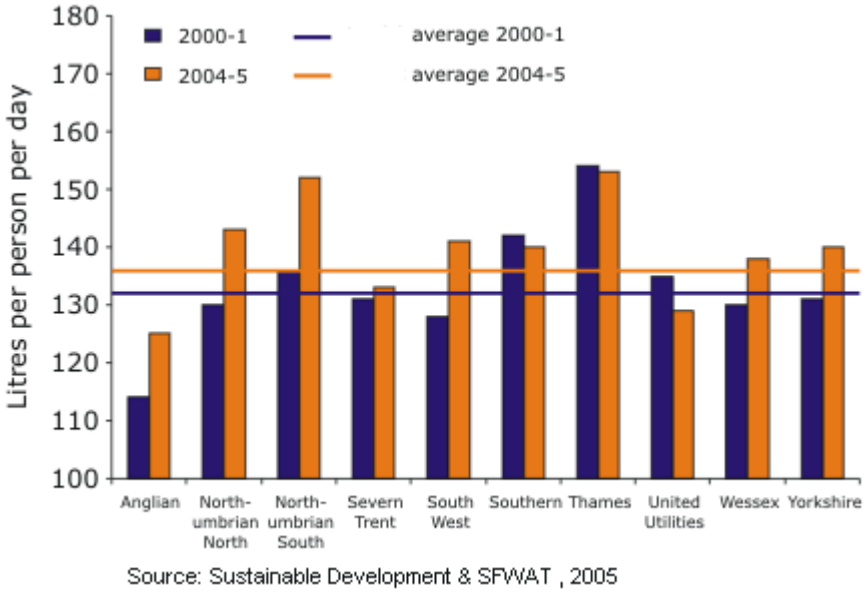
2.4.2 Water metering

Household metering is widespread in many developed countries such as, France, Germany and Portugal, Australia already has 100 per cent metering of single family houses, but the current average metering rate is 28% of total households in England and Wales (Krinner et al 1999).

In 1999 the UK use of water in metered household was estimated to be 10% lower than unmetered households (Krinner, et al 1999). Between 2000-1 and 2004-5, average household water consumption in unmetered households is still more than metered households, but there was still a high consumption growth rate is in metered households (Figure 2.2 and 2.3). Metered household water use increased by 4 litres to 136 litres per person per day(an increase of 3 percent) and unmetered households increased by 1 litre to 150 litres per person per day(an increase of 1 percent)

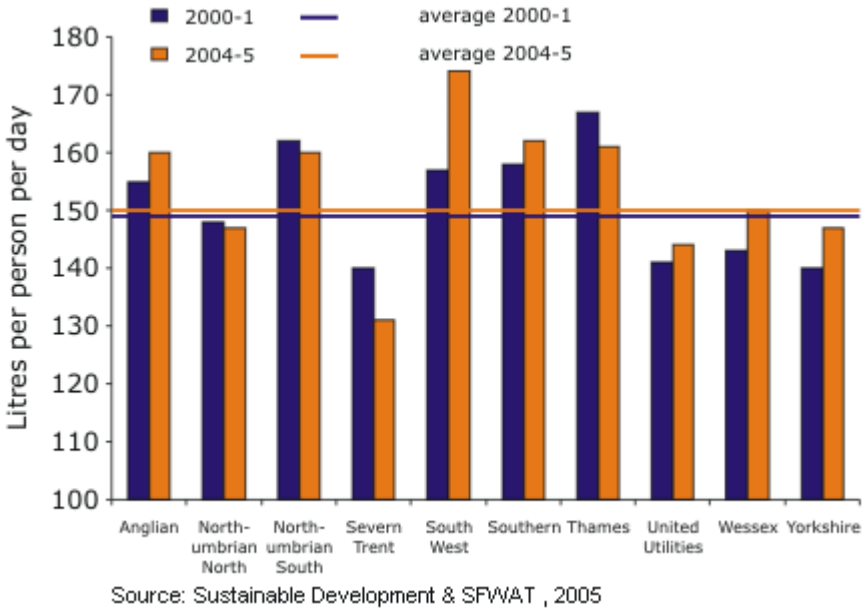
(Sustainable Development,2005). The impact of the introduction of metering on water use also links to other factors, in particular the water charges applied.

Figure 2.2. Metered household water consumption



Source: Sustainable Development & SFWAT , 2005

Figure 2.3. Unmetered household water consumption



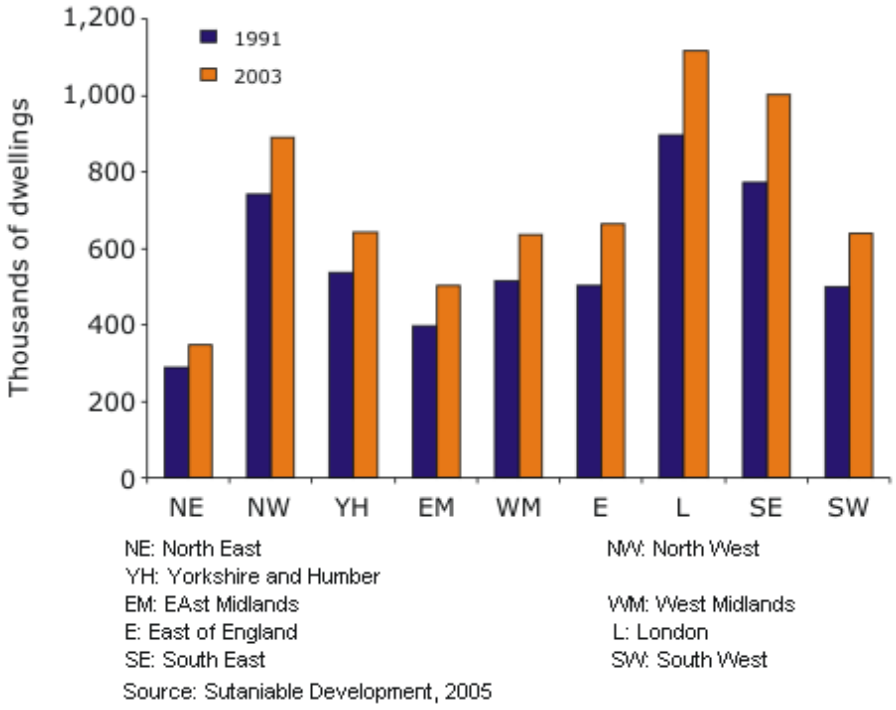
Source: Sustainable Development & SFWAT , 2005

2.4.3 Household size

The UK Environment Agency found the factors leading to growth in per capita household water consumption include reduced number of household members,

increasing use of domestic appliances, increased non-essential water use such as power showers and warmer, drier weather.

Figure 2.4 Single person household (1991-2003)



The total trend of single person households has increased between 1992 and 2003 in various regions. London has the most one person households. The Anglian Water survey in England found that per capita consumption decreased with increasing household size. Per capita water consumption of a single person household was 40% greater than a two-person household, 73% greater than in a four person household and over twice that in households of 5 or more people (Parliamentary Commissioner for the Environment, 2000). So in the UK, the decrease in household size could be a reason for increased per capita water use.

Table 2.2. Domestic water use in UK in 2000

	Water use (average range)
United Kingdom (England and Wales)	~150 litres per person per day Anglian Region~155 l/p/d for one person households ~130 l/p/d for a three person households(total of 390 l/d per household)

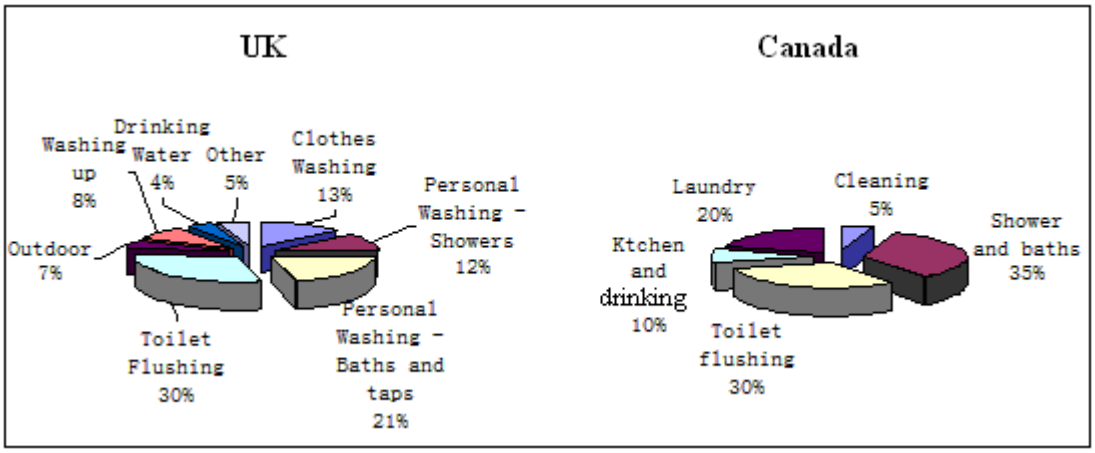
Source: Parliamentary Commissioner for the Environment, 2000

2.4.4 Patterns of water use

Higher standards of living are changing water demand patterns. This is reflected mainly in increased domestic water use, especially for personal hygiene (Krinner and Lanllana, 1999). Most European countries have indoor toilets, showers and baths for daily use. Most of urban water consumption is for domestic use. For example, in Spain, 70% of total urban water consumption is household, 24% for small industries and services, and 6% for public services (Krinner and Lanllana, 1999).

The Figure 2.5 shows the patterns of water use by households in UK and Canada. In UK, 30% of total water of a household is used in toilet flushing and about 30% for personal hygiene. The pattern of water use is quite similar in Canadian households.

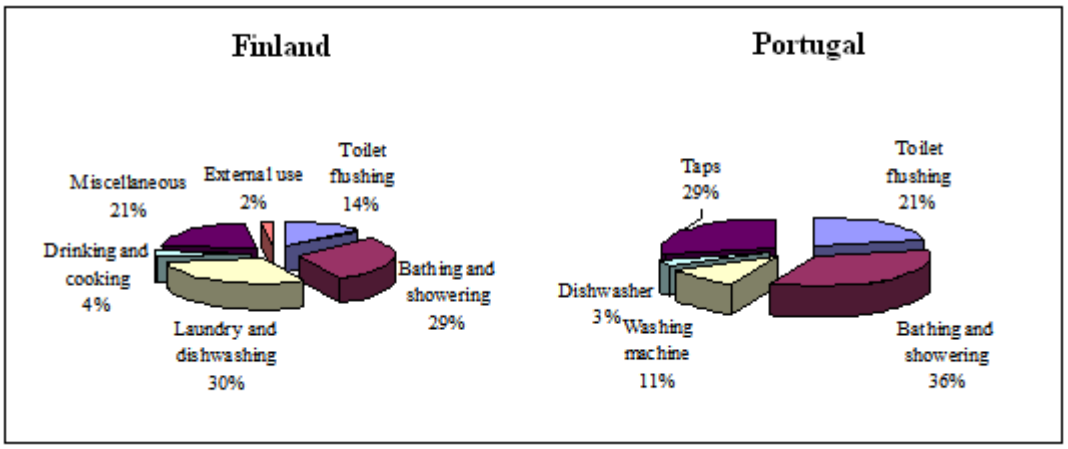
Figure 2.5 Household water consumption patterns in UK and Canada



Source: Waterwise, 2007 and Zhang, 1999

The Figure 2.6 gives the patterns of water use in Finland and Portugal. In Finland, most of the water use in households is for bathing /showering and laundry. But in Portugal, washing machines and dishwashers consume about 14% of total household water.

Figure 2.6 Household water consumption patterns in Finland and Portugal



Source: Krinner et al 1999 and Vieira et al 2007

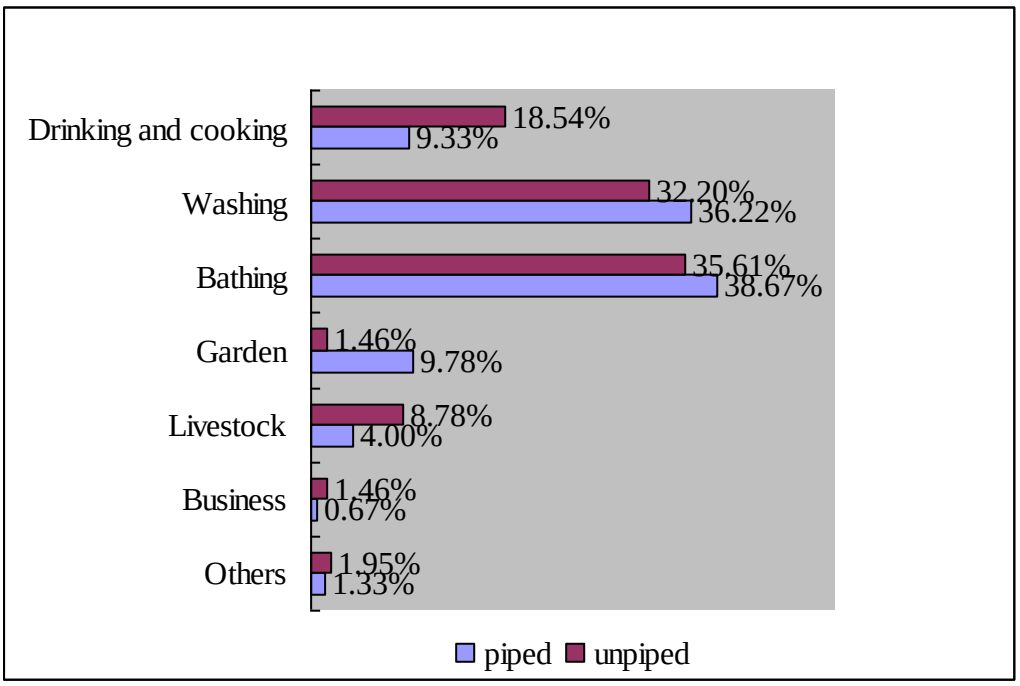
Thompson (2001) mentioned four main types of water use in a typical urban East African household:

1. Consumptive uses (i.e., drinking and cooking)
2. Hygiene uses (i.e., bathing, washing clothes, cleaning and toilet flushing)
3. Amenities uses(watering lawns, car- washing, gardens-watering and other non-essential tasks)
4. Productive uses(watering livestock, the construction of homes and beer-brewing)

The Figure 2.7 shows that the small quantities needed for drinking and cooking and the large amount water used for bathing, cleaning and washing.

There were major differences in water use quantities between piped and unpiped households in east African (Figure 2.7). Thompson and Porras (2001) indicates that one of reasons leading to the different water quantities is the presence of water appliances in piped households (e.g., flush toilet, baths and showers) which accounted for considerable quantities of water use. On average, 64 % of piped households in the study have flush toilets using an average of 19.2 litres of water per capita per day. But the figures were underestimated because not all of the interviewers were able to record their data. Types of water use in this study are shown below.

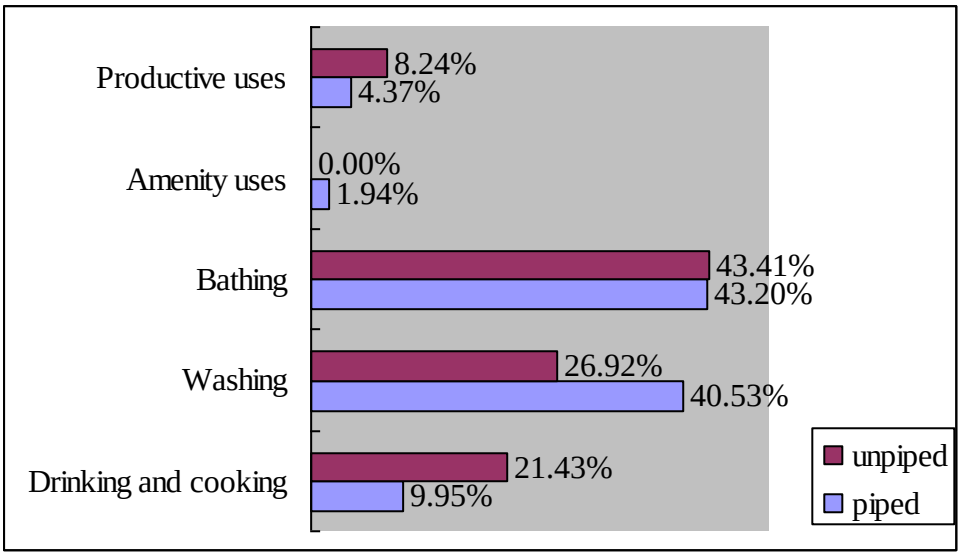
Figure 2.7 Household water use pattern in Eastern African (Tanzania, Uganda and Kenya)



Source: Thompson and Porras 2001

Thompson and Porras (2001) also highlight some typical household areas such as Uganda, Tanzania and Kenya. Piped and unpiped household water use patterns in Uganda are shown below:

Figure 2.8 Household water use pattern in Uganda



Source: Thompson and Porras 2001

2.4.5 Water efficient appliances

Statistics show that there is potential to improve the water efficiency of common water appliances at home such as toilet, showers, taps and washing machines. Demand for water can be significantly reduced through the installation of water efficient appliances and promotion of water conservation behaviours (Waterwise, 2007). In UK, there are lots of organizations (e.g. Defra, Ofwat, Environment Agency, Water UK and Waterwise) that take on the duties of promoting the efficient use of water, water conservation and sustainable development.

Some typical water consumption figures for 'traditional' domestic appliances in Europe are shown in Table 2.3.

Table 2.3 Average appliance consumption in UK, Finland, France and Germany

Appliances	UK	Finland	France	Germany
Toilet	9.5 l/flush	6 l/flush	9 l/flush	9 l/flush
Washing machine	80 l/cycle	74-117 l/cycle	75 l/cycle	72-90 l/cycle
Dishwasher	35 l/cycle	25 l/cycle	24 l/cycle	27-47 l/cycle
Shower	35 l/shower	60 l/shower	16 l/shower	30-50 l/shower
Bath	80 l/bath	150-200l/bath	100 l/bath	120-150 l/bath

Source: Krinner and Lanllana, 2001

1. Toilet cisterns and taps

The quantities of water used for flushing the toilet could be reduced by three ways:

- Install water saving toilet cisterns
- Install cistern displacement devices
- Fix leaking toilet immediately

McKenzie and Buckle indicate four most basic measures to reduce water use in toilets in Africa including low-volume toilet cisterns, dual flush toilet cisterns, and toilet retrofit devices (McKenzie et al, 2003). Waterwise list typical toilet cisterns from1940 to 2001 and more details are shown in Appendix 1. Some water saving toilets and taps, which can be used in the home are described in Table 2.4.

Table 2.4 Water efficient appliances in UK

Water efficient appliances	Description	Water saving
Toilets		
dual-flush toilet	two split push buttons give user the choice of pressing a small button or large button depending on how much water is required for cleaning	~6 litres for a full flush (for solids) ~4 litres for half flush (for liquids).
Taps		
Taps with air devices	Introduction of air bubbles into the water, increasing flow water volume with reduce flow but producing the same effect	Flow reduction of around 50%
Taps with infrared sensors	Water is available only when an object is underneath	Reduction of between 70-80%
Taps with thermostats	They keep the selected temperature	Reduction of around 50 % of water and energy

Source: Krinner, 1999 and Waterwise, 2007

2. Washing machine and dishwasher

In recent years, the EU has established conditions required for the 'ecological labelling' of washing machines and dishwashers. Dishwashers can not use more than

1.85 litre of water per cutlery item. Washing machines can not use more than 15 l/kg of clothes in a cycle of 60^{o}C and both machines must give clear instructions about water and energy saving (Krinner and Lanllana, 1999).

A typical water-saving washing machine only uses about half the water and energy of the average 10-year-old machine. Many of the most efficient washing machines use less than 50 litres of water per wash (Waterwise, 2007).

3. Showerhead

An inefficient showerhead can use more than 20 litres of water per minute but a water efficient showerhead only uses about 8 litres per minute. A water efficient showerhead can save a significant amount of water without reducing the quality of service to the user. The common measures to save water use by showerheads include using of low volume showerheads, shower adjustments.

2.5 General facts on China

2.5.1 Water issues of China

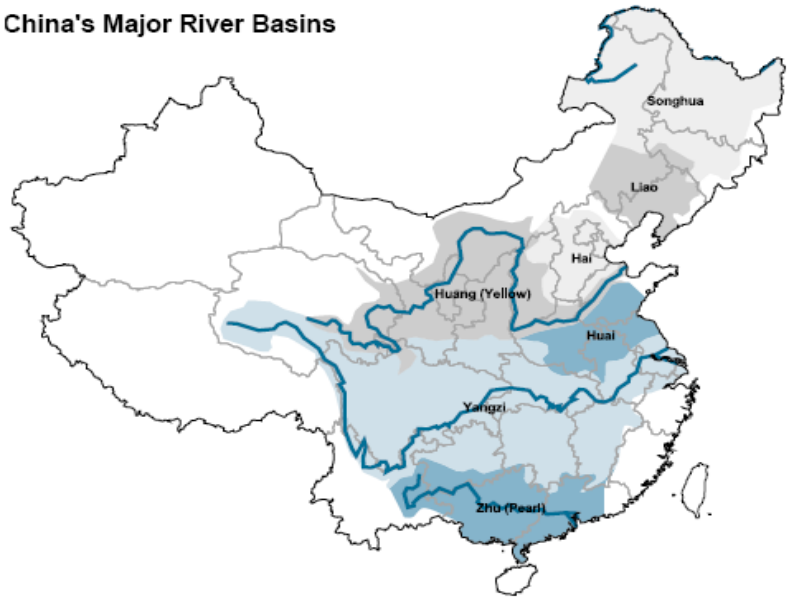
Natural water resources of China are distributed unevenly in the north and south of China. The main rivers and runoff are shown in the Figure 2.9. It shows that water resource of southeast China are quite rich, compared with the north and northeast China. Annual runoff from the Yangzi(also called Chang jiang) river is about 1 billion cubic kilometres of water, compared with 0.028 billion cubic kilometres of runoff of the Hai river Located in north China. Figure 2.9 below

Figure 2.9 China's stream runoff for water supply varies by water basin

China's Stream Runoff for Water Supply Varies By Water Basin

Major river basin	Area	Population	Cultivated land	Annual stream runoff: Total volume	Share of nat'l total	Per cultivated ha	Per capita
	1,000 sq km	Million	Mil. ha	Cu km	Percent	Cu meters	Cu meters
Dry region:							
Hai	319	92	11.3	28	1.0	2,505	308
Songhua	528	46	11.7	76	2.9	6,450	1,650
Liao	232	28	4.5	15	0.5	3,375	540
Huang (Yellow)	752	82	13.1	56	2.1	4,290	683
Wet region:							
Huai	262	125	12.5	53	2.0	4,230	424
Yangzi	1,807	346	24	1,000	38.2	41,700	2,890
Zhu (Pearl)	415	74	4.4	307	11.7	69,750	4,150

1 hectare (ha) = 2.471 acres.



Source: Crook and Diao, 2000

Northern China has only one-fifth of the per capita water resources of southern China. But around 34 percent of China's population[1] lives in this dry region (north, northeast, and northwest China). The dry region includes several large urban centres, includes seven cities with populations of more than 2 million people and 81 cities with 200,000-500,000 people, such as Beijing and Harbin (Crook and Diao, 2000). Available water resource is merely 750 cubic meters per capita for northern citizens. In 1998, China's per capita fresh water reserve was 2500 m3, about a quarter of the world's average (Table 2.5) (Hou and Hunter, 1998.P1). The population in China is the biggest in the world; it has already increased to 1.3 billion people in 1997.

[1] Total population was 1.2 billion

Obviously, the huge amount of population greatly contributes to the current water scarcity.

Table 2.5 China's water resources per capita compared to other countries

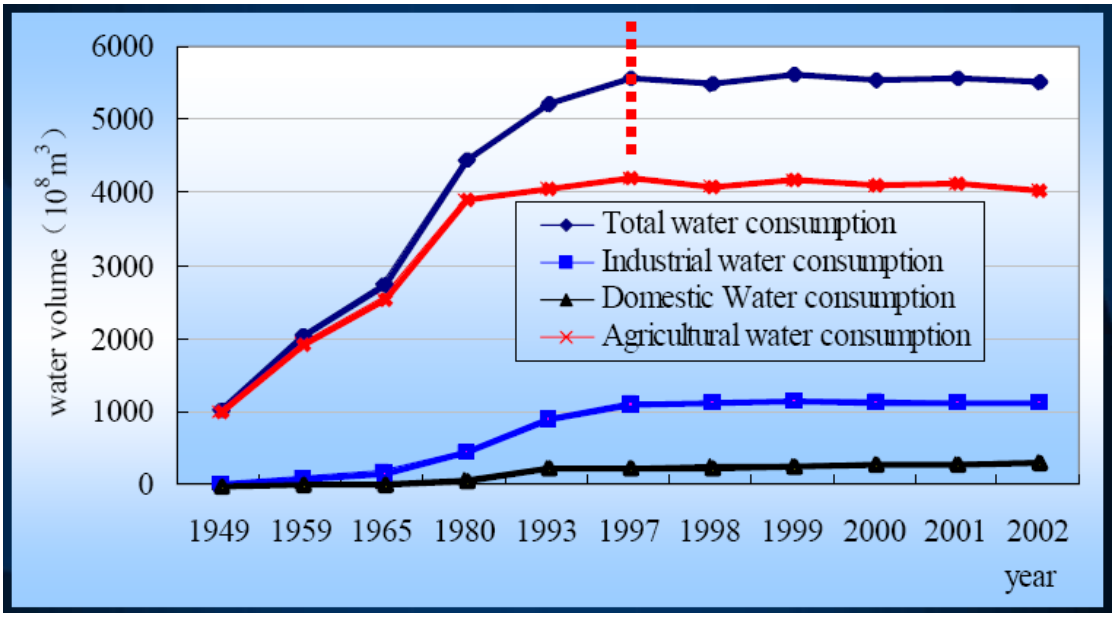
Country	**Water per capita (cubic meters)**
Canada	98,462
Brazil	42,957
Russian Federation	30,599
United States	9,413
China	**2,292**
Northern China (*Beijing, Harbin areas*)	**750**
Southern China(*Guangzhou areas*)	**3,440**
India	2,228
World	7,176

Sources: Hou and Hunter (1998) Beijing Water: Causes, Effects, Solutions *P1*

2.5.2 Municipal water supply

Total water consumption has increased from about 100 billion m^3 in 1949 to 557 billion m3 in 1997 and remained stable since then. Total water consumption was around 550 billion m^3 in 2002(Figure 2.10).

Figure 2.10 Water consumption in China (1949-2002)



Source: Zhang, 2002

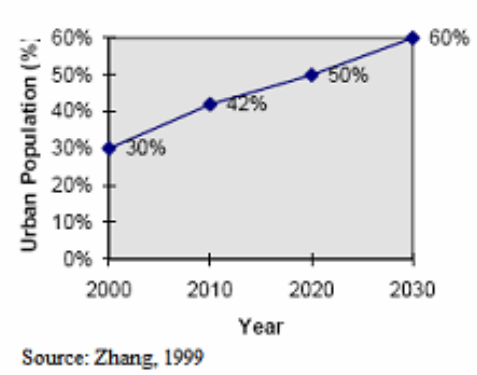
1. Industrial water use

Since the 1980s, Chinese economic reform has led to a significant increase in total water consumption, particularly in the industrial sector (Figure 2.10). By the beginning of the 1990s, industrial water use had been more than 22 times greater thant in 1949.

2. Agriculture water use

Agriculture in China has a long history and plays an important role in the Chinese economy. Agriculture water use has accounted for around 80 percent of total water consumption in the past 20 years (Figure 2.11). But due to the low efficiency of irrigation methods, only about half of this water has been actually used.

Figure 2.11 Demographic index ofurbanization



Source: Zhang, 1999

3. Domestic water use

From 1985- 1997, the number f Chinese cities increased from 324 to 668. Urban population grew at an annual average rate of 4.8 percent (Zhang, 1999). Demographic index of urbanization

estimates that the Chinese urbanization level will reach around 43 percent by year 2010 and 60% in 2030(Figure 2.11). Chinese urban residents use at least 200 percent more water than rural inhabitants. With increased urbanization and raised living standards, water demand for urban domestic use will be in a strong growing pattern in the coming decades (Zhang, 1999).

Currently, agricultural water use is tending to decrease, industrial water use has been quite stable since 1997, but domestic water use still rises incrementally. Beijing has a similar water use trend during the past twenty years (Table 2.6).

Table 2.6 Proportion of water use in Beijing (2002) (unit: 100 million m^3)

Year	Total water consumption	Industrial water use		Agricultural water use		Domestic water use	
		Consumption	Percentage	Consumption	Percentage	Consumption	Percentage
1980	42.08	13.5	32.08	24.46	58.13	4.12	9.79
1990	41.12	12.34	30.01	21.74	52.87	7.04	17.12
1996	43.21	12.64	29.25	19.68	45.55	10.89	25.2
1997	40.26	11.00	27.32	18.12	45.01	11.14	27.67
1998	40.47	10.84	26.79	17.39	42.97	12.24	30.24
1999	41.71	10.56	25.32	18.45	44.23	12.7	30.45
2000	40.40	10.52	26.04	16.49	40.82	13.39	33.14

Source: Cai& Ji, 2007

2.5.3 Water price in China

2.5.3.1 History of water pricing in China

From the founding of New China in 1949 until 1964, both surface and groundwater were free. In most cases, water was not metered in households and people did not pay their own bills. The cost of water supply and maintenance was completely subsidized by central authorities. Then residents have believed that water should be free goods.

In 1964, the Ministry of Water Resources held the first meeting on water resource management and discussed the implementation of water tariffs. Tariffs were applied to cover water supply infrastructure construction, operation and maintenance costs.

But they failed to provide an institutional process through which water supply companies should raise water prices. This has led to a very low water price for more than a decade because water supply companies were not empowered to raise water fees.

"In the 1980s, the national water conservancy meeting set a draft water management regulation that endorsed a shift in emphasis from the construction of new facilities to the improved management of existing installations. That involved setting fees according to volume of usage and reallocation of water in time of scarcity from less valuable agricultural uses to industry" (Hou, 2000). But in the late 1980s and early 1990s, many cities had overexploited or polluted nearby raw water sources. Some cities realized an imminent water crisis and began tariff increases in the late 1980s.

Although water prices increased considerably in the early 1990s, the principles behind water price did not change until 1997 (Hou, 2000). In 1998, based on the price law, the State Development Planning Commission (SDPC) and Ministry of Construction established the Management Method for Pricing Urban Water Supply. His method was based on the principles of full cost recovery, reasonable profit margin, and sector-based pricing. It acts as the foundation for all water pricing reforms within all provincial price bureaus since1998.

2.5.3.2 Current water price in China

In 2000, the average water price for industrial use was 1,136 yuan/m^3 (about 8 pence), domestic use 0.853 yuan/m^3 (about 6 pence), commercial use 1,527 yuan/m^3, and tourist hotel use 1,692 yuan/m^3 (Hou, 2000). The water price varies between different regions. But general speaking water price is lower. Table 2.7 shows the tap water price in some Chinese cities in 2000.

Table 2.7 Tap water prices in various Chinese cities, 2000(unit: yuan)

	Industry	Residential	Commerce	Hotel
Beijing	1.19	0.99	1.65	1.50
Tianjin	1.47	1.17	1.67	1.87
Guangdong Province				
Guangzhou	1.17	0.70	1.50	1.85
Shenzhen	1.90	1.35	2.40	2.40
Zhuhai	1.45	1.02	1.52	2.17
Sichuan Province				
Chengdu	1.15	0.85	1.55	1.55
Chongqing	1.19	0.94	1.96	1.96

Water price in Harbin (unit: Yuan)

Year	Industry	Residential	Commerce	Hotel /restaurant
2003	2.4	1.8	2.5	4.0
2001	2.0	1.3	n/a	n/a

Source: Hou, 2000 and Harbin China, 2003

Tap water companies provide the most reliable data, but the prices are limited to tap water and exclude self- extracted ground and surface water. Self – extracted water is mainly used in rural Beijing, and most of this water is used for irrigation. Water price for irrigation is very low in China. By the late 1997, it was only 0.024 yuan/m^3.

For the most Chinese cities, water is charged at constant rates (flat) rather than increase block rates, however there are some cities applying increasing block prices. For example, in Tianjing[2], domestic water users are charged 2 yuan/m^3 for any block of water in excess of 8 m^3/person/month. Water within the amount of 8 m^3/month is charged at only 1.4 yuan/m^3 (China Daily, 2005).

2.5.4 Residential water consumption in Chinese cities

Zhang compared residential water uses among three cities in China (Table 2.8). In Beijing, more than one third of water is used in the kitchen and almost one third used for flushing the toilet. The water use pattern in Hebei province is slightly different from Beijing. But in the southern city Shenzhen, a small percentage of total water is used for drinking, cooking and kitchen. Large volumes of water are used for baths and washing basins (Table 2.8).

[2]City of Tianjing is located 130 kilometers southeast of Beijing

Table 2.8Household water use composition (%)

Regions	Drinking/ cooking	Kitchen sink	shower and washing basin	Clothes washing and wash machine	Toilet and cleaning	Other	Consumption(l/p/d)
Beijing	32		26.7	12	29.3	N/V	150
HeBei[3]	2.1	18.5	27.2	12.7	32	7.5	138
Shengzhen[4]	17		31	25	25	2	N/V

Source: Zhang , 1999

Beijing water saving organization did a household water consumption survey during July and December 2003(Jiang, 2004). The survey shows average household water consumption was 104.14 l/p/d (Table 2.9). Table 2.8 shows water consumption was 150 l/p/d in 1999, a recent research mentioned consumption was about 165 l/p/d in 2006(Ouyang, 2006). The different water consumption number may be due to the different research year and research sample. In general, water consumption is around 150 l/p/d.

The findings from Jiang (2004) indicate large percent of household water was used for flushing toilet, personal hygiene uses, and washing clothes. Household water use was divided into six main categories:

1. Hygiene uses: include shower, washing (e.g. washing hand, face , brush teeth)
2. Drinking water
3. Flushing toilet
4. Washing machine
5. Kitchen uses: include cooking, washing dishes
6. Amenities: watering flowers and fish

[3] HeBei is located next to Beijing
[4] hengzhen is the southern city and Chinese economic reform started in that area.

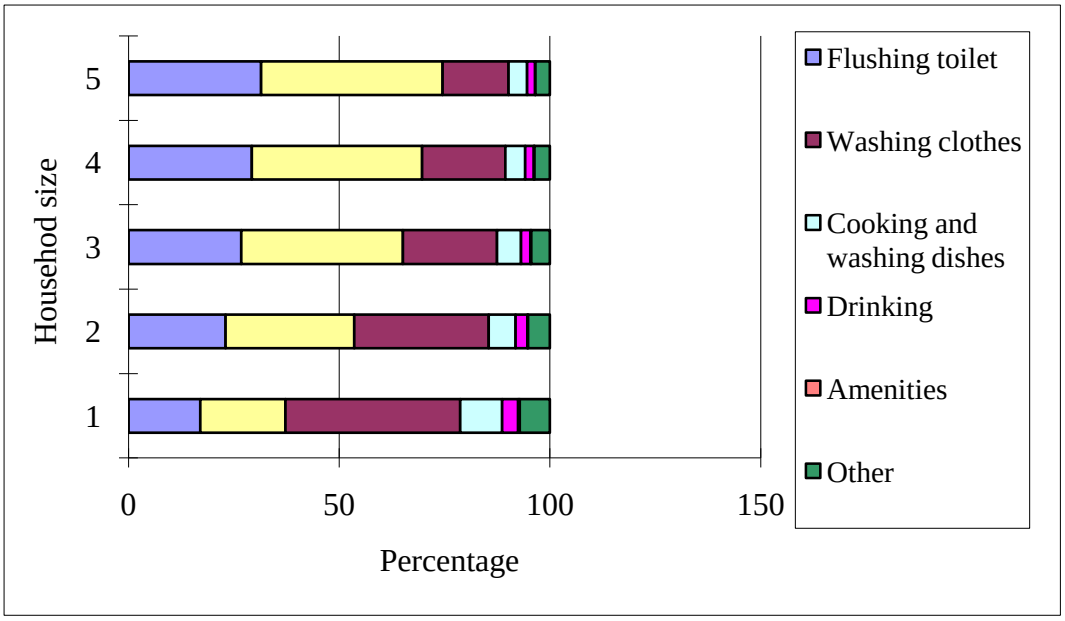
Table2.9 Household water use pattern in Beijing, 2003

Types of water use	Water consumption(l/p/d)	%
Flushing toilet	27.00	25.93
Hygiene uses	42.51	40.82
Washing machine	22.53	21.63
Kitchen uses	5.43	5.21
Drinking	2.25	2.16
Amenities	0.17	0.16
Others	4.25	4.08
Total	104.14	100.00

Source: Jiang, 2004

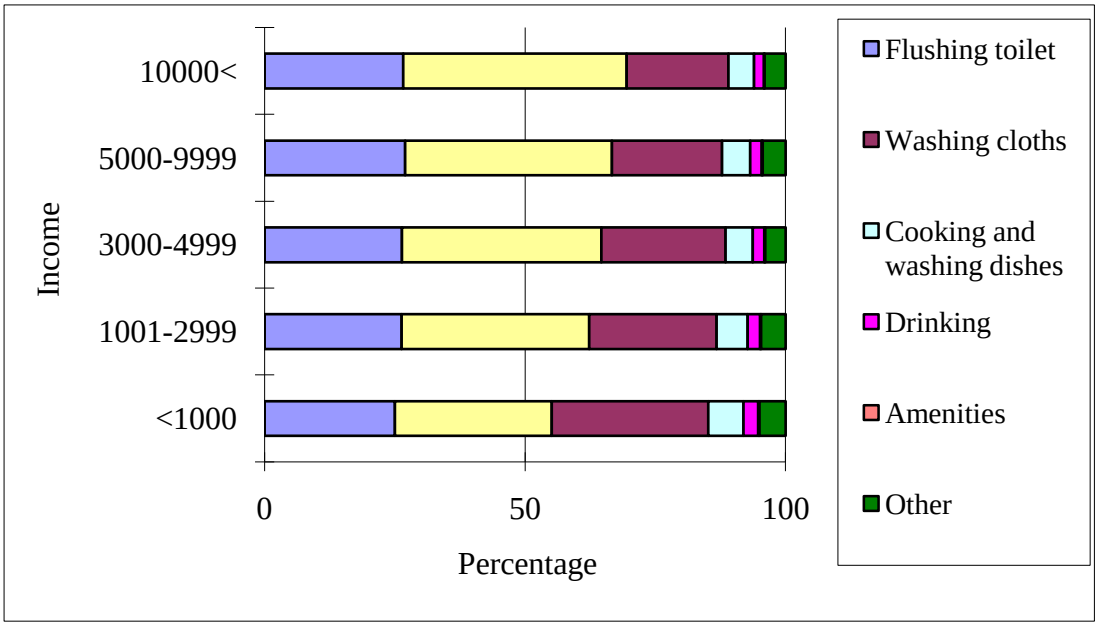
The survey also found that the per capita volume of water decreases with increasing household size. Per capita volume of water used in a one person household is nearly twice that used in a five people household (Figure 2.9). This figure also shows that the amount water used for hygiene purposes grows slightly with increase household size. But other types of water use by households are decrease with increased household size.

Figure 2.12 Household water use composition in different household size, Beijing (%)



Source: Jiang , 2004

Figure 2.13 Household water use composition in different income group, Beijing(%)



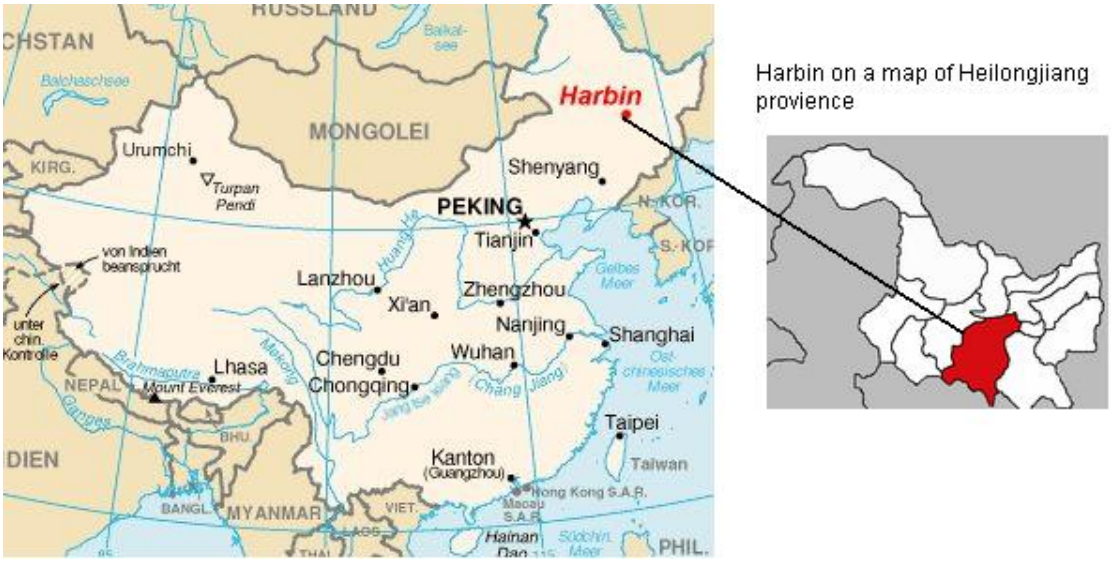
Source: Jiang , 2004

2.6 Review of Harbin

2.6.1 Background information

Harbin is the provincial capital and largest city of Heilongjiang province, located in the northeast of China (Figure 2.14). Total population is around 10 million, about 4 million people in the city area. Urban area is about 7086 km^2 (Wikitravel, 2007).

Figure 2.14 Location of Harbin



Source: Wikipedia, 2007

Harbin is one of the important industrial cities in northeast China. The city is located in the northern temperate continental climate zone, at the same latitude as Montreal. Winter is very cold and dry, while the short summer is hot and humid. The annual average temperature is about 5.9 °C (Table 2.10). The ground is frozen during winter time (November to March). The annual average rainfall is about 526 mm, with over 70% of which falls in the June to August period.

Table 2.10 Climate in Harbin

City	Annual Avg Temp (°C)	Monthly Avg Highest Temp (°C)	Monthly Avg(Lowest Temp°C)	Annual Avg Precipitation (mm)
Harbin	5.9	29.1	-20.6	526.2

Source: Harbin Statistical Yearbook, 2004

2.6.2 Water resource

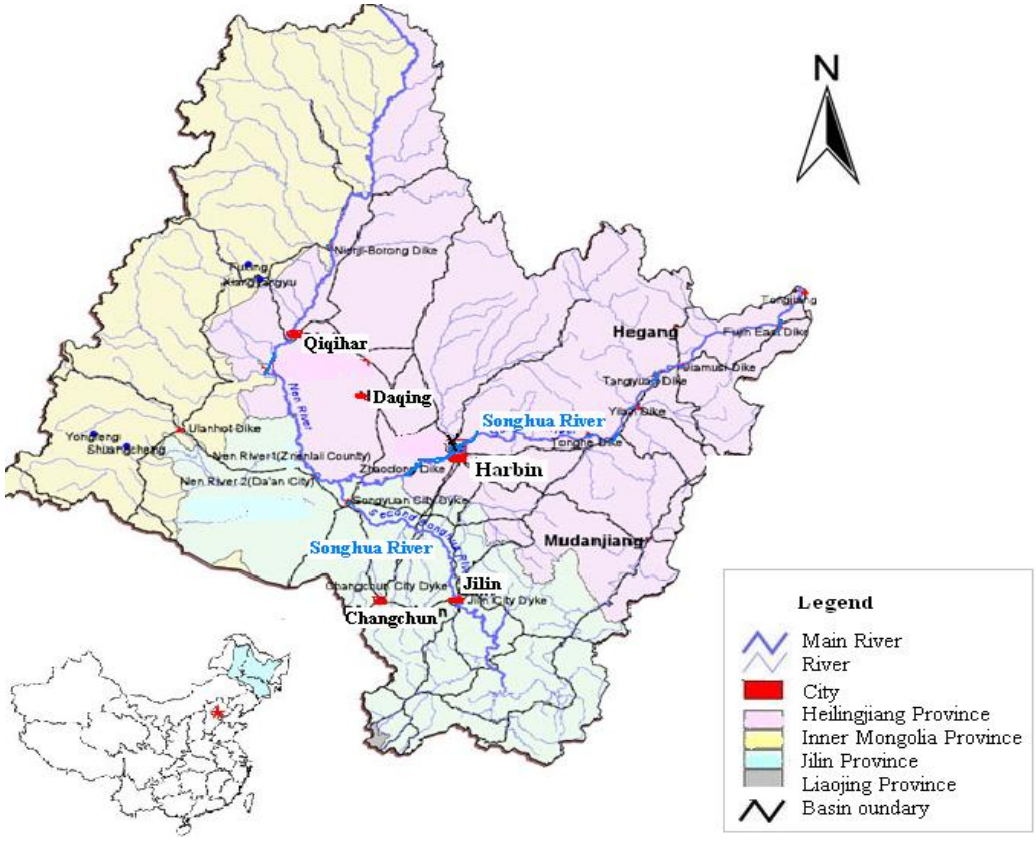
Songhua River passes through the city, and is the major water source for 1 million m^3/day of water used in Harbin (Black and Veatch, 2006). It provides the main source of drinking water for the residents in Harbin, the location of the Songhua River is

shown in dark blue (Figure 2.15). Harbin is located on the down stream of the Songhua River. The Songhua River basin covers about 400,000 km^2 of drainage area upstream from Harbin, and receives pollution from several major upstream cities- Jilin, Changchun, Daqing and Qiqihar (Figure 2.15).

Recently Harbin is forecast to has been a shortage in water supply capacity of at least 450,000 m^3/day by 2010, increasing to at least 950,000m^3 /day by 2020 (Black and Veatch, 2006). A new water source (Mopanshan reservoir) is being developed under the Harbin Water Supply Project to address the urgent needs of Harbin to improve the existing inadequate water supplies to the urban communities.

A Flat water tariff is used currently, but after the new project an increasing block tariff model will be implemented in Harbin. Current water price is shown in Section 2.5.3 Table 2.7. Local government hopes the new tariff model can be used to improve water shortage and reduce waste (Harbin China, 2005).

Figure 2.15 Songhua River and surrounding cities



Source: ADB Financed Songhua River Flood Management Project, 2007

2.6.3 Residential Water consumption

Harbin Tap Water and Sewerage Company is the main residential water supplier in city. There are eight administrative districts in Harbin, and each district has been set one branch water company. Recent water records show Harbin household water consumption has increased steadily during the past ten years (Table2.11). Water payment depends on the water meter. The household meter is read by staff in the local water company. Normally number is read every three months.

Table 2.11 Basic statistics on Harbin tap water

Year	Annual Volume of Tap Water Supply (100 million ton)	Annual volume of Water leakage	Water Consumption for Residential use(100 million ton)	Residents with Access to Tap Water (10 000)	Percentage of Population with Access to Tap water (%)
1995	29443	2855	8213	252	94.3
1997	35634	2694	16732	245	95.4
1999	36181	2075	19380	255	91.7
2000	34422	2192	19717	255	91.7
2002	34078	5530	21796	260	91.7
2004	35481	4869	20796	294	93.4

Source: Harbin Statistical Yearbook, 2004

Harbin Tap water and sewerage Company, 2007

The literature review of Harbin (Chinese and English documents) indicates that information of household water use in Harbin is very limited. Harbin Tap Water and

Sewerage Company is the main water supplier in Harbin, but most of residential water data is not available on the website and some past years data are confidential or not public. Through the local investigation, there is no practical environment agency or organization that has recorded the past years information, especially detailed information such as household water use patterns, current household water use behaviour, water use appliance and water bills. Therefore, this study will focus on understanding the general household water use behaviour, situation and water use pattern. The main required information included

- Household water use behaviour e.g. appliance use frequency and duration
- Water appliance characteristics and ownership
- Water use pattern e.g. water use proportion of water appliance and per capita daily consumption

The required information will be collected through different methodologies. More detail information is shown in Chapter three Methodology.

3 MethodologyLiterature search

In order to gather accurate information, research methodology literature and past theses have been used as references. Some literatures although not directly relevant to this study, provided helpful ideas on structure. The main literature sources included:

- Accessing past year theses in the WEDC Resources Centre and the University of Loughborough library catalogues
- Relevant research method books, such as Social Research Methods in WEDC Resources Centre
- Conference papers from an IWA conference on efficient use and management of urban water supply

3.2 Data collection method

Primary data

The primary data were collected in three ways:

A survey questionnaire (Paper-pencil-questionnaire) and face- to- face interview (semi-structured interview) were designed to gather required information on household's perception and behaviour on water use. More detailed survey and interview information are shown in Section 3.4.

A simple flow rate experiment was conducted to gather required data on tap and showerhead flow rates. The test procedure is shown in Section 3.5.

Secondary data

Secondary data were an important part in this study, especially in the literature review. Three main ways for the secondary data collection included:

- Some of secondary data were from China's Statistical Yearbook and Harbin Statistical Yearbook of various years
- Due to the limited availability of data in governmental publications and lack of relevant literature on household water use, some sources and regional data

were also obtained from Chinese and English websites. Some authoritative Chinese websites are Harbin China, China Statistical Yearbook only

- Through the literature research, some useful journal papers and PDF files have been found online. Also some Chinese journal papers have been purchased online.

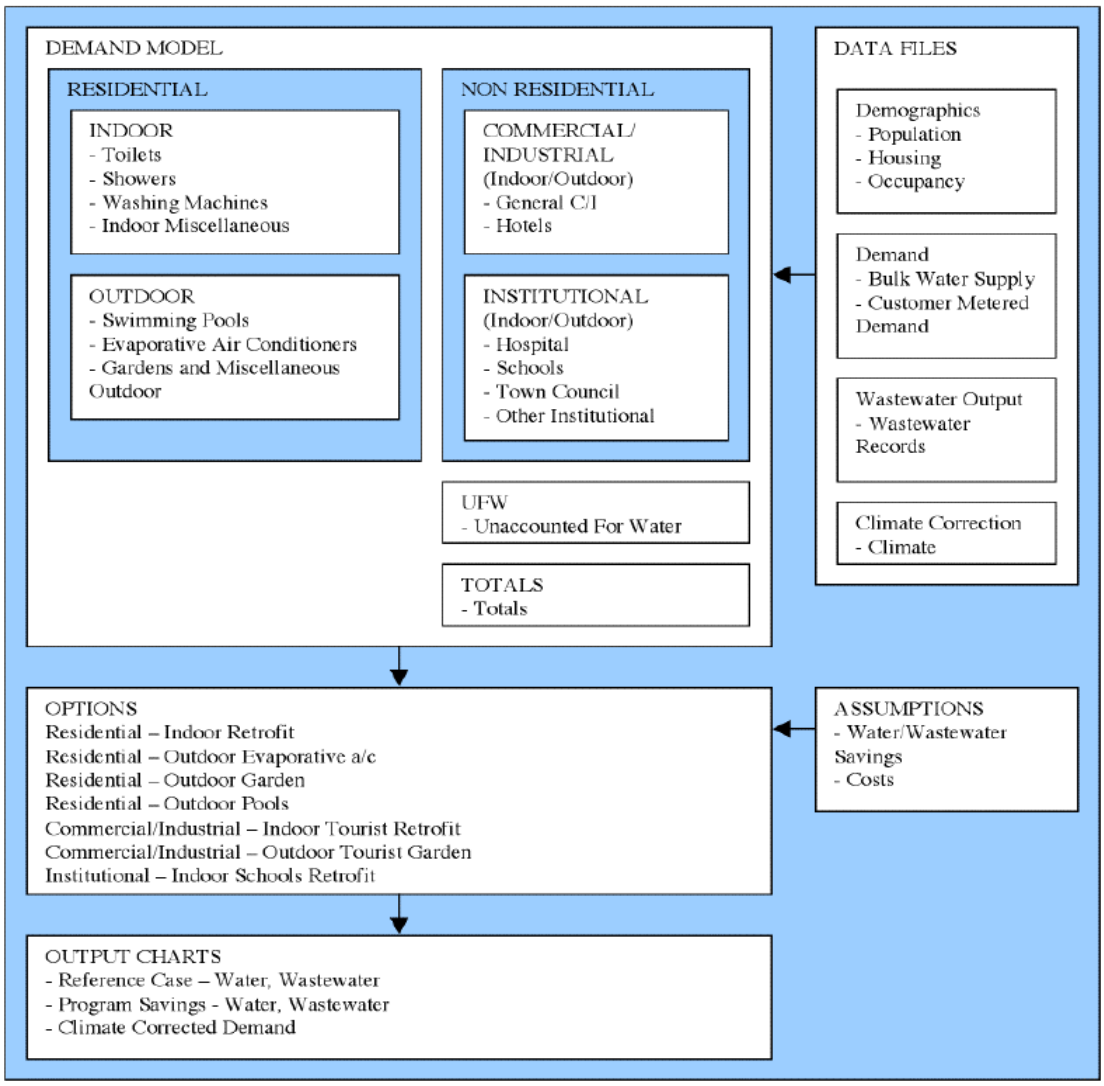
3.3 End use analysis method

End Use Analysis (EUA) is the initial step to understand the components of household water use. It has been used for water demand management in Australia. The literature review shows that it is also an appropriate method for this study.

3.3.1 Basic principle

End Use Analysis (EUA) is one of a number of techniques that can assist water utilities to understand the demand for water, to enable projections of water demand and to design effective demand management programs(White and Milne,2004). "EUA involves the disaggregation of water demand by customer sector and ultimately by end use within each sector. It focuses on the factors and technologies that affect water use, including emerging trends, so historical patterns are less relevant" (Turner and Campbell, 2003). A typical urban community would normally be disaggregated into residential, commercial/industrial and institutional customers. The residential sector could be further disaggregated into single and multi residential customers and into specific end uses such as toilets, showers, baths and washing machines for the indoor component (going to sewer) and garden irrigation and car washing for the outdoor component. By disaggregation of water use in this way could a detailed understanding of water demand for each end use. The typical end use model is shown in Figure 3.1.

Figure 3.1 Typical end use model



Source: Turner and Campbell, 2003

3.3.2 End-uses selection

The definition of 'end-use' varies within different literature sources depending on the scale of the investigation. Due to the limited time and information, in this study end use analysis will only consider the residential sector and water demand is based on tap water services for in- house water usage.

Household water use is defined as that within a house and surrounding area within the residential property boundary. Normally residential end- use is divided into two components: indoor use and outdoor use. Different regions will have different end

uses. For example, in Australia, swimming pools and air-conditioners could be significant outdoor end uses.

The selection of end uses is focused on indoor use in this study, because the water use for outdoor activities is small for Chinese households. In European countries and Australia, the main outdoor end use is garden and lawn watering. But in the study city, most of residents live in flats or high rise apartments. The garden area is shared by several households so it seems like a public area. Normally households do not need to water the garden area. In this study, the selection of end-use is based on two factors:

- Literature review of end-use: those end –uses have indicated or agreed by most of the literature sources
- Water consumption: those end-uses with relatively significant water demand or wastewater flow in Harbin

The end-use model for Harbin is shown below:

Table 3.2 The components of the residential end-use model for Harbin

Indoor	Bathroom	Shower Basin taps
	Toilet	Cistern
	Kitchen	Sink taps
	Laundry	Washing machine

3.3.3 End- use model

The end-use methodology requires the incorporation of all available data in relation to appliance stocks, efficiency levels, usage patterns, occupancy rates, and population and building types. Estimates of the water consumption for each of these uses are based on parameters such as

- Water using equipment: water efficient appliances
- Water using behaviour: frequency of use , duration of use, occupancy

- Water usage patterns: affected by income, socio-cultural factors and demand management (e.g. pricing, regulation, knowledge or awareness and consumer behaviour)
- Demographics: housing size (people per household) , housing type
- Climate: temperature

Table 3.3 End use model for Harbin

Residential water use	Parameters	Source
Indoor - toilets - showers - washing machines - taps(kitchen, basin)	**Demographics** - housing size - housing type **Climate correction** - temperature **Water usage pattern** - income - demand management(e.g. water price, users' awareness **Water using appliances** - water efficient appliances **Water using behaviour** - frequency of use - duration of use	Literature review Social survey

3.4 Social survey methodology

3.4.1 Introduction

The previous literature review showed that the relevant data on household water use are very limited in Chinese cities, especially in small cities such as Harbin. Due to the lack of available information in the study, social survey is considered as an appropriate methodology for this study.

The aim of the survey method was to understand households' water use behaviour, the water use pattern in the Harbin city area of China and to be aware of current

household water use characteristics. The survey was made up of questionnaires and interviews. Two types of survey were considered in this study:

1 Semi-structured interviews for the water appliances market

2 Questionnaires for household weekly surveys and face- to- face surveys

Main steps were used to conduct the social survey including:

1. defining the objective of the survey
2. determining the sampling group
3. writing the questionnaire
4. conducting the pilot questionnaire
5. feedback collection from the pilot and revise questionnaire
6. recording the answers
7. data analysis

3.4.2 Questionnaire survey

3.4.2.1 Sampling

"Sample is the segment of the population selected for investigation. The selection of the units to which the data relate is an important phase in the collection of data" (Bryman, 2004). It is difficult to do a direct observation and survey every individual family in Harbin. Instead, the select data (sample) from the population was used to make inferences about the overall households in Harbin. Based on the literature review, the following methods were employed in this study.

- Convenience sampling for household weekly survey and face- to- face survey

In total household data was collected from 40 volunteer households across Harbin city area which involved:

- A pilot sample of five households was questioned between 5th -6th July 2007
- A convenient group sample of four weekly household surveys was recorded from 9th July 2007
- The main group household survey was conducted from 15th July 2007

3.4.2.2 Pilot sample

Five pilot surveys were employed in the families of friends, to assess the feasibility of the questionnaire and to clarify the questions. The results of the pilot showed the weakness of the survey, such as the wording of questions and unclear questions. After the pilot some of the questions were revised. For example, the first question in the pilot survey was ‘How many showers are taken every week? ’. The first respondent asked ‘is it for summer or winter? ’ After the pilot, the question was revised and clarified. Shower frequency in summer was requested. The pilot survey was very helpful in modifying the questions and also indicated the direction of results that could be expected.

3.4.2.3 Convenience sample

In convenience sampling, the selection sample from the population is based on easy availability and accessibility. Probability sampling (e.g. random sampling) involves much more preparation so that is often avoided because of the time and cost constraints. The major disadvantage of convenience sampling is that the likelihood of the sample being unrepresentative of total households is high. Convenience sampling was employed for the weekly record survey, because this survey takes one complete week and needs good participation from households. From the point of view of data reliability and response rate, it is difficult to collect data through a random sample. Therefore, a voluntary participation in the study was made within kind households, relatives and friends.

The first group of convenience sampling (weekly survey) is made with friends and relatives. The second group of sampling (questionnaire) was made with households in a different area in Harbin. A random number generator (RNG) was used for sample selection. this is a computational software to generate a sequence of random numbers.

These random numbers were the house numbers in a target department, RNG shows which household should be investigated. In total about twenty households were visited but only five households opened their doors for the researcher. The respondent rate was quite low when the sample was generated from RNG. The possible reasons for this are that this method seems like an indoor survey and during survey time, some households are not at home, feel unsafe or embarrassed when a stranger knock the door to ask for a survey. Because of theis low respondent rate the rest of the respondents were collected in a public area such as outside of apartment and shopping centre.

3.4.3 Semi -structured interview

The semi-structured interview was one of qualitative methods used in this study. Qualitative data was be collected by setting up an interview that allowed respondent the time and scope to talk about their opinions on a particular subject (Sociology central, 2007). The aim of the interview was to understand the respondents' opinion (sale staff in water appliances shop) about household water appliances in Harbin. Two water appliance markets were visited in Harbin. The focused questions were based on:

- The awareness of the flow rate of the common showerhead and tap
- The understanding of the average water capacity of the common toilet and washing machine

Open-ended questions were used. Some suggested questions were "tell me about ……"and some arise naturally during the interview such as "You said this is water efficient toilet…can you tell me more." The semi-structured interview was like a kindly conversation with respondent and questions were asked when the respondent agreed and felt it was appropriate. The summary of strengths and weakness is shown below.

Strengths / Uses of Method	Weaknesses / Limitations of Method

-Complex questions and issues can be discussed / clarified. -Plenty of information can be collected - High Validity. People are able to talk about something in detail and depth.	-Time consuming -Validity a. no real way of knowing if the respondent is lying. b. respondents try to sell water appliances in the shop, so they always give positive messages. c. During the interview, unconscious signals / leading questions may cue respondent to give answers which are expected

3.4.4 Questionnaire

Questions were divided into sections asking the respondents about water usage by shower, toilet, washing clothes, washing up and some general water use questions. About seventeen questions were closed questions because closed questions are more specific than open ones, and could detect differences among respondents more accurately. Some questions asked respondents what kind of water appliances are used at home. Closed questions and picture options were provided which could be easy for the respondent to answer. The questionnaire is available in Appendix 2.

- Semi- structured interview: there was no specific set of questions for interviewers. The interview was like a natural conversation with the respondent to talk about water appliances (detail is shown in 3.4.3).
- Weekly survey: the weekly survey was divided into two parts. In this part three questions were asked of households about the types of water- using appliances. Questions of part two referred to household water using behaviour. These questions were divided into different household water using purposes which included shower, flushing toilet, washing clothes and washing up. The weekly

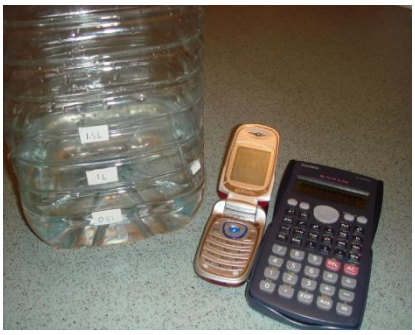
survey is available in Appendix 3.

- Face to face questionnaire: the face to face survey consisted of 21 questions which were also divided by different water use purposes. Most of questions were closed questions .The age, family income, different districts and type of house were also set up and reflected the different groups of households (questionnair in Appendix 2).

3.5 Flow rate experiment

The results of the semi-structured interview showed that the sales assistants in water appliances shops were not sure about the flow rate of taps and showerheads. They identified some water efficient products, but were not sure how much water could be saved. Product instruction only showed the size and features of the product, not including the flow rate. The varying flow rates of different appliances could affect water consumption in different households. So flow rate is an important indicator to understand the amount of water use at home. From the literature review it was found that the flow rate (tap and showerhead) could be measured through a simple experiment. The test procedure was based on Green Venture website: how to conduct a flow rate test, 2007(Green Venture, 2007).

The test instruments included stopwatch (Mobile phone), a container and a calculator. The container had measurements on the side, the maximum measurement being 1.5 litres (right picture). The main procedures were as follows:



1) Place the empty container under a tap or showerhead, turn on the tap or showerhead to its highest flow rate. At the same time start the stopwatch, when water reach 1 litre, stop the watch and record the time.

2) Calculate the flow rate. For example, to fill one litre container takes 5.8seconds, 5.8 sec= 0.1 min, the flow rate = 1 litre/ 0.1 minute= 10 litre / minute

3) This procedure was repeated twice for each test and the average number was used.

4 Data Analysis and Survey Results

Semi-structured interview results

During the appliances market interview, most of staffs were very cooperative. They sell various water appliances on the market. Some information from the interview was not used, because several staff only provided positive messages and tried to sell the appliances. The findings of the interview were evaluated and main results are:

1. Toilets

- Dual-flush toilet (3 /6 litres model) is very common on the market. About 80% of toilets are dual-flush but the conventional toilet is still on the market.
- Conventional toilet water consumption varies. It depends on the manufacturer year. Toilet water consumption for conventional modern toilets is 6 litres while for toilets ten years old the average water consumption is around 8-12 litres.
- Most of the consumers choose dual-flush toilets currently
- The average cistern volume for a dual flush toilet is about 4.5 litres per flush, for conventional toilets it is about 8 litres per flush.

2. Showerheads and taps

- Sale assistants are not sure about the flow rate. Staffs think there is not a big difference between different types of showerheads or taps.
- Water efficient showerheads and taps are not common in the market.
- Manufacturers' books only introduce the size and the features of the appliances not their flow rate.

3. Washing machines

- Front loading washers consumer less water than top loader washing machines but consume more energy and not popular on market
- Energy consumption was mentioned more frequently than water consumption during interview
- Average water consumption per wash for front loading washing machines is 70-90 litres, for top loading washers is about 130-150 litres.
- Most consumers preferred automatic top loading washing machines.

4.2 Flow rate experiment results

Due to the difficulty of access to all the households, the water flow rates were measured in four feasible houses. Background information on the research households is shown in the table below 4.1

Table 4.1 Research households' characteristics

	Type of housing	Average family income(Yuan)	Household size	Year of moving in
Household 1	High- rise department	6000-7000	3	2006
Household 2	7 floors mulity-story department	5000-6000	4	2002
Household 3	5 floors mulity-story department	4000-5000	3	2000
Household 4	7 floors mulity-story department	4000-5000	3	2005

The maximum appliance flows were conducted in this study. For greater accuracy the same experiment was repeated twice in all households and tested appliances and the average values been calculated. The experiment procedure was described in Chapter 3.5. Experiment results are shown below.

Taps

Table 4.2 Kitchen tap flow rate (unit: litres/min)

Type of tap	First test	Second test	Average
Household 1	10.33	8.32	9.32
Household 2	10.64	8.81	9.72
Household 3	6.01	4.13	5.11
Household 4	11.76	8.78	10.27

Test taps

1. 

2. 

3. 

4. 

Table 4.3 Basin tap flow rate (unit: litres/min)

Type of tap	First test	Second test	Average
Household 1	8.21	6.58	7.39
Household 2	5.81	4.82	5.32
Household 3	5.80	4.63	5.22
Household 4	6.76	5.67	6.22

Test basin taps

1. 

2. 

3. 

4. 

Showers

Table 4.4 Shower flow rate (unit: litres/min)

Type of shower	First test	Second test	Average
Household 1	4.12	5.61	4.86
Household 2	6.88	9.22	8.05
Household 3	2.12	2.03	2.07
Household 4	4.67	7.03	5.85

Test showers

1. 

2. 

3. 

4. 

The results show that basin taps and showers have similar flow rates, with average values of 5.75 litres/ min and 5.21 litres /min respectively. In the tested taps, the highest flow was 9.72 litres/min (kitchen tap) and the lowest flow is 5.11 litres/min (kitchen tap). The average flow rate of kitchen tap is about 8 litres /min.

Table 4.5 Appliances flow rate summary (unit: litres/min)

	Average	Minimum flow	Maximum flow
Kitchen tap	8.61	5.11	9.72
Basin tap	5.75	5.22	7.39
Shower	5.21	2.07	8.05

4.3 Questionnaire survey results

4.3.1 Household appliances ownership

Showers

The results show that most households were using high flow rate showerheads; only three households (7.5%) used water efficient showers (Table 4.6). Showerheads are divided into high flow, low flow and water efficient. Before the respondents answered the questions researcher explained the differences and characteristics of these types of showers. Water efficient showers are a type of shower that have a water efficient label or flow controller (adjustable flow rate). High flow showers have a high pressure or user feel powerful flow. After the explanation, some respondents mentioned the flow rate of their shower head was adjustable, but they preferred the high flow.

Table 4.6 Shower ownership

Type of shower	Number of owner	%
High flow	28	70
Low flow	5	12.5
Water efficient	3	7.5
Not sure	4	10
Total	40	100

Toilets

Respondents were asked about the type of toilet, after the explanation respondents could reliably identify the dual flush toilet or conventional toilet. The most common toilet is single flush, about 50 % of total respondents.

Table 4.7 Toilet ownership

Type of toilet	Number of owner	%
Conventional toilet(single flush)	21	52.5
Dual flush toilet	17	42.5
Communal toilet and	2	5
Total	40	100

Washing machines

95% of study households owned a washing machine. Two households did not have washing machine, the highest machine ownership for the rest households was one. Table 4.8 shows the main types of main washing machine. The top loading washing machines are the most popular machine at home.

Table 4.8 Washing machine ownership

Type of washing machine	Number of owner	%
Automatic top loading single tube	18	45
Automatic top loading twin tube	16	40
Automatic front loading	4	10
No washing machine[5]	2	5
Total	40	100

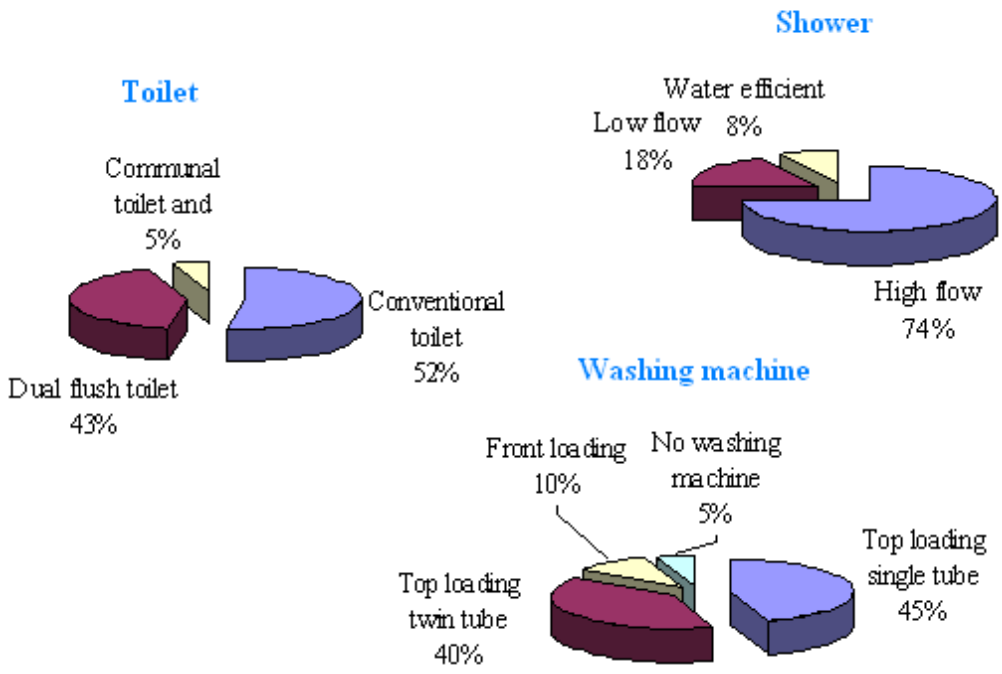
Other appliances

Dishwashers and baths were not popular in Harbin. Only one respondent said that they own a dishwasher but it was not used. Householders mainly washed dishes by hand. Householders did not bathe at home and most of households did own bath basin. The experimental households did not have private gardens or swimming pools.

Three households that were studied had two or three toilets. They felt it gave more convenience. The widespread appliances include top loading washing machines, single flush toilets, and high flow showers. The summary of appliances ownership is shown in Figure 4.1.

[5] includes households which used a communal washing machine

Figure 4.1 Household appliances ownership (%)



4.3.2 Household appliances use frequency

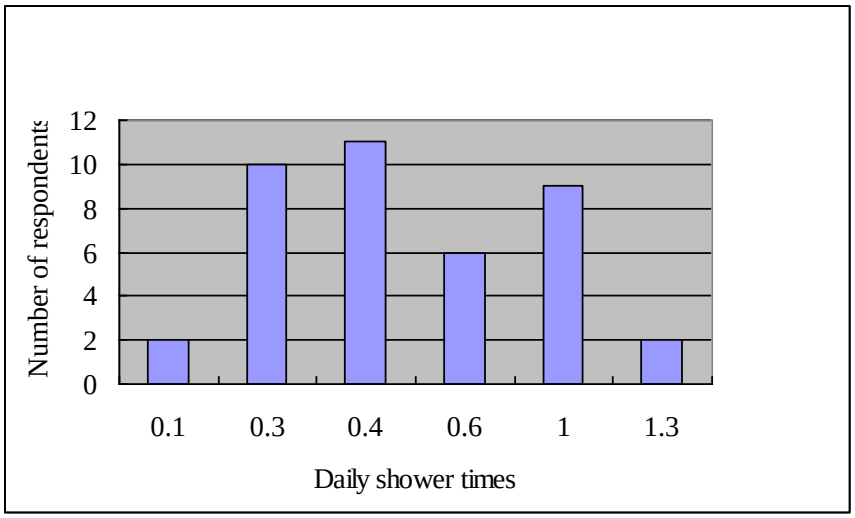
Appliance use frequency could be a good indicator of household hygiene and to understand household water use pattern. The average household size is 3.6 people per household, appliances use frequency is discussed below. Some appliances (showers, toilets and taps) are used very frequently each day and for these appliances daily use frequency per respondent is discussed below. Washing machines were not used each day, so monthly use frequency per respondent is discussed below.

Shower frequency

As Figure 4.1 shows most of respondents (28%) took a shower about 3 times per week (0.4 times per day), 23% of respondents took a shower everyday. Showers were used frequently during summer time. The highest frequency of shower use is 1.3 times per day, but the lowest shower frequency is 0.1 times per day. So the frequency of shower use varies in different households. The study shows that households owned

at least one shower at home. The temperature remained nearly the same during the survey time so the reason for the variations in shower frequency could be personal habits.

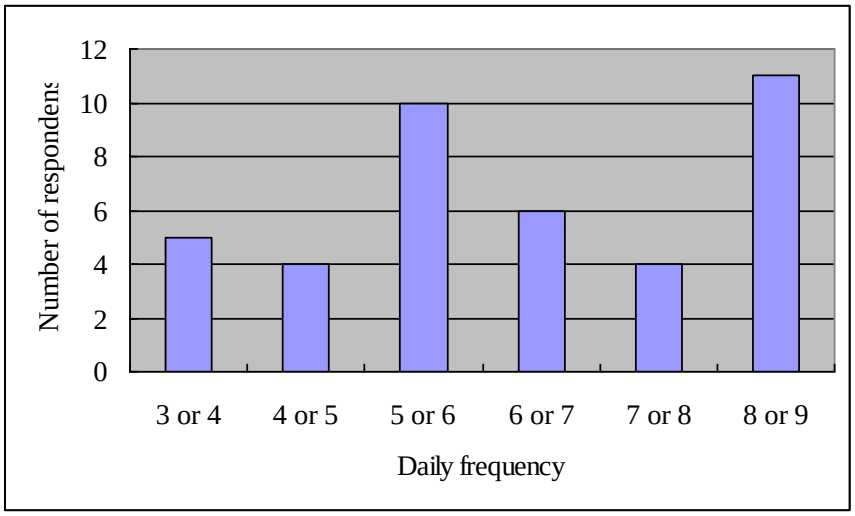
Figure 4.2 Daily frequency of use shower in Harbin (unit: person/day)



Toilet frequency

Daily frequency use of the toilet was in the range from 3/4 times to 8/9 times per day per person (Figure 4.3). The main group of households (78%) used the toilet between 5/6 times and 8/9 times per day. Flushing toilet frequency was assumed by respondents. The households did not have an accurate count of toilet frequency use. People used the toilet frequently but not regularly. The result may affect by personal habits and are not very accurate.

Figure 4.3 Daily frequency of use toilet (unit: person/day)



Washing machine frequency

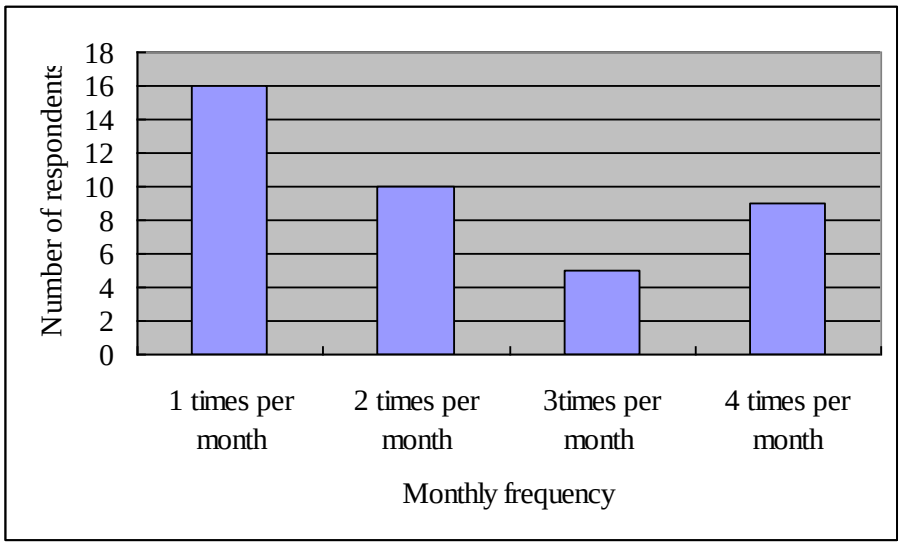
95% of households owned a washing machine, but only 23% of households used the machine for washing clothes every time. Most of households washed cloth by hand and by machine together (Table 4.9). They washed clothes quite frequently but not lots of clothes for each time. Lots of respondents mentioned that they hand wash clothes every one or two days. They only hand washed clothes that were worn daily e.g. T-shirts or socks. They seemed to like hand washing, because they thought the machine used more water. They thought that it was not necessary to use machine to wash small loads. The washing machine was only used to wash large loads of clothes or large sheets and curtains. The washing machine was used only one or two times a month by most of households (65% of households), about 0.25-0.5 times per week (Figure 4.4.). Therefore, despite the ownership of washing machines being high, they are not used very frequently in the households in Harbin.

Table 4.9Clothes washing habits

Type of clothe washing	Number of respondents	%
Hand washing	7	17.5
Washing machine	9	22.5
Mix[6]	24	60
Total	40	100

[6] mix- includes hand washing and machine washing

Figure 4.4 Monthly washing machine use frequency (unit: person/month)



Kitchen tap frequency

About 60% of households washed dishes three times per day. Washing up frequency was did not vary in the study households. Households all used hand washing but hand washing in some households was more efficient than other. 53 % of households used running water for washing up. No respondent chose washing in a bowl or sink. But 47% of respondents said 'mix washing', running water and sink wash were both used at home

Basin tap frequency

The basin tap use frequency was recorded in four households. Basin tap water was frequently used for several households' activities e.g. hygiene uses (hand, face, tooth cleaning) and hand washing clothes. In order to obtain the reliable data, weekly tap use frequency was requested in these households. The result shows average basin tap frequency was nine times per day (Table 4.10).

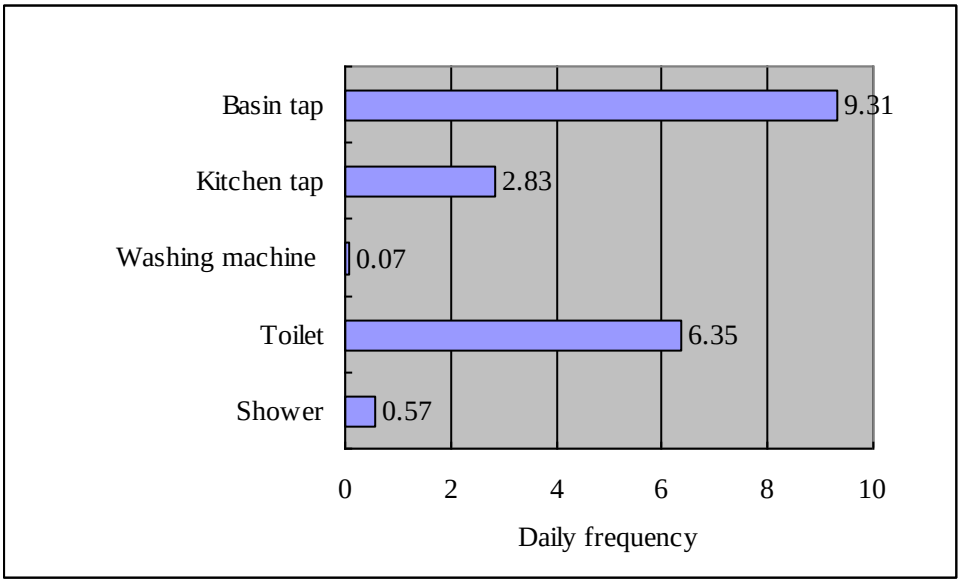
Table 4.10 Daily average basin taps use frequency (unit: person/day)

	Household1	Household2	Household3	Household4	Daily average
Hand washing	5.3	4.6	3.7	6.2	4.95

Face cleaning	1.8	2	2	1.5	1.83
Tooth cleaning	1.5	2	2	2	1.88
Hand washing clothes	0.6	0.3	1	0.7	0.65
Total	9.2	8.9	8.7	10.4	9.31

Summary of daily frequencies of use for several appliances obtained in this study is shown in Figure 4.5. Higher frequencies of appliances usage were basin tap and toilet, 9.3 times per day and 6.4 times per day respectively. Average frequencies for shower and washing machine were only 0.57 and 0.07 times per day respectively. These use frequencies were significantly lower than use frequencies for basin tap and toilet.

Figure 4.5 Daily average frequencies of appliances usage (person/day)



4.3.3 Household appliances use duration

Appliance use frequency and duration are two key factors that influence household water consumption and an understand water use. If people do not know the answer, they may assume it. ‘When fairly precise estimates of the amount of time spent in different forms of behaviour are required, the diary may provide more valid and

reliable data than questionnaire data (Bryman, 2004).' Weekly appliance use duration was recorded in four households. They were the same households that were conducted the flow rate experiment. Basic household information is shown in Section 4.2.1 Table 4.1

Before the data was recorded each household had been showed how to record how long each appliance was in use every time for one week. Owing to the constraints of time observations did not go through the whole week. Observation was conducted only on one random set of data per household. The observed together with the non-observed data are shown in Table 4.11.

- Tooth cleaning: This was not included in the observation, because research households used water in cups for tooth cleaning. The quantities of water which were used for cleaning depended upon the size of cup. Average tooth cleaning required about two cups of water that is about 0.5 litres per use.
- Hand washing clothes: normally households washed clothes in the basin (sink). The duration per wash was about half an hour but major quantities of water were used in filling the basin and rinsing the soapsuds from the clothes. Usually three or four basinfuls water were used per wash. Households usually used the maximum tap flow or high flow to fill the basin so that the basin could be filled very quickly. Roughly a normal size basin could be fully filled in about one minute, three or four minutes running water is assumed per wash.

Therefore, the time of basin tap use did not include hand washing clothes and tooth cleaning. Because the amount of water used for hand washing clothes and tooth cleaning did not depend on the duration per wash, but on the time (minutes) for filling the basin or cup.

- Shower: It was quite difficult to directly observe households' shower duration.

Family members could observe each other but not by the researcher.

Table 4.11 Average water use duration (unit: minute/ per wash)

	Average observation data	Average non-observation data	Average
Basin tap			**1.0**
Hand washing	0.4	0.5	0.5
Face cleaning	0.9	1.0	0.95
Kitchen tap			**3.7**
washing dishes	3.3	4.2	3.7
Shower	18.4	22.5	**20.5**

4.3.4 Household water use characteristics

According to the End- use model, household indoor water use includes water used for shower, toilet, washing machine and taps. The calculation of household water consumption is based on the water use frequency, use length and flow rate which have done in prior sections. Water use characteristics are summarised in Table 4.12.

Table 4.12 Household water use characteristics (per person/ per day)

		Average	Minimum	Maximum
Toilet				
Average flushes per day		6.35	4.5	8.5
Average toilet cistern volume	Single flush	8	6	12
	Dual flush	4.5	3	6
Shower				
Average numbers of showers per day		0.57	0.1	1.3
Average length per shower(min.)		20.5	12	30
Average shower flow rate(L/ min)		5.21	2.07	8.05
Washing machine				
Average number of uses per day		0.07	0.03	0.13
Average water consumption(l/cycle)	Top loader	140	130	150
	Front loader	80	70	90
Kitchen tap				

Average number of uses per day	2.83	1	4
Average flow rate(L/min)	8.61	5.11	9.72
Average time per use(min.)	3.2	2	5
Basin tap			
Average number of uses per day	9.3	8.7	10.4
Average flow rate(L/min)	5.75	5.22	7.39
Average time per use(min.)	1.0	0.3	1

4.3.5 Household water use pattern

Per capita water consumption was calculated by two ways: water bills and appliances consumption. The required data for calculations were both collected from the questionnaire results. Water consumption for the households was calculated as follows:

4.3.5.1 Water consumption from bill

The amount of the monthly water bill was questioned in the questionnaire. The results show that on the average it was about 22 Yuan[7] per house. The current residential water tariff is1.8 Yuan / m^3 (see Chapter Two Table 2.7). The calculation shows that the average water consumption is 407.5 litres per day per house. The water bill was read through the house meter so the per capital water consumption includes leakages, such as tap leakage and toilet leakage. The problem associated with the questionnaire result is not related to the leakage.

4.3.5.2 Water consumption from appliances

According to the household Melbourne Water, Water Use Calculator (2003) and Ernst (2005) the water used for different appliances can be calculated through simple equations. These equations can be specified as follows:

- Shower water use = the shower length * the shower frequency *Constant (shower flow of the household's shower head)

[7] 1 Yuan = 15 pond (Exchange rate for 2007)

- Toilet water use = toilet cistern volume * number of flushes per day
- Washing machine water use = machine water consumption * number of uses
- Kitchen tap water use = time of each use * tap use frequency * tap flow rate
- Basin tap water use = water use for washing hand/face + assumed water use for tooth cleaning + assumed water use for hand washing clothes

Water use for face/ hand washing = time of each use * tap use frequency * flow rate
Assumed water use for tooth cleaning = tooth cleaning frequency* assumed water use per cup* assumed number of cup per use
Assumed water use for clothes washing = washing frequency * assumed time for using water * tap flow rate

Calculation for water consumption is shown is Appendix 4. Data which require in these equations are extracted in Table 4.13 above.

In the survey households, the minimum water consumption is 51.7 l/p/d, the maximum is 667.4 l/p/d (Figure 4.6 below). There is big gap between the minimum and maximum water consumption. Water use for the shower was the component which showed the greatest variation. High flow rate showerhead was used by70% of the respondents, but shower frequency varied from 0.1- 1.3 times per day (Table 4.12). Shower frequency should be the main reason that causes variations in shower water use. Compared with single flush toilets, dual flush toilets save half amount of water per flush. The difference in water consumption for toilets is the main reason that causes variation in toilet water use in Figure 4.6. It indicates that water-saving appliance (e.g. dual flush) reduce water consumption efficiently.

The average household water consumption is 223 l/p/d. Most of the water used in the households was tap water. 35% of total daily water was used by the basin tap and 27 %, by the kitchen tap. This is because the basin tap is used for several daily activities (e.g. hand washing clothes and for hygiene). The washing machine was not

used very frequently in the research households. It only consumed 3% of the total water. The rest of the household water consumption is apportioned as follows: 21% for showers and 13.5 for toilet flushing.

Figure4.6 The estimated household water use pattern in Harbin

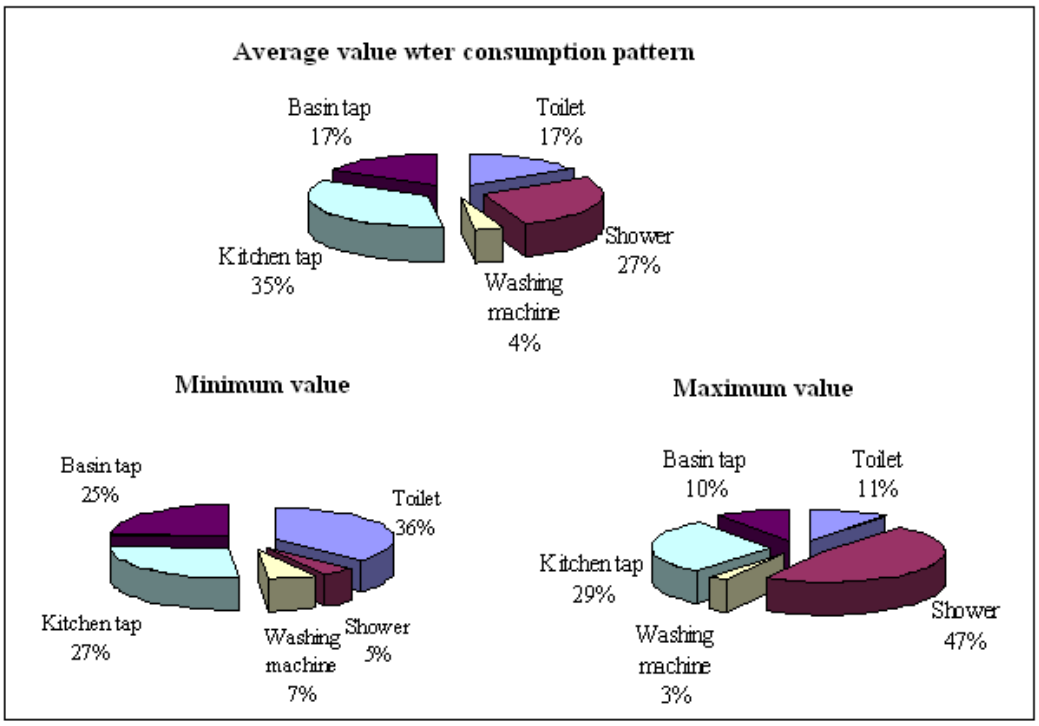


Table 4.13 Appliance water consumption (litres per capita per day)

Appliance	Average	Minimum	Maximum
Toilet	37.5	19.2	72.7
Shower	60.9	2.5	313.9
Washing machine	8.9	3.5	17.5
Kitchen tap	77.9	13.8	194
Basin tap	38.1	12.7	69.3
Total	223.3	51.7	667.4

5 Results DiscussionDiscussion of water consumption results

One of the questions in the questionnaire asked about the cost of the water bill per month per family. In fact, water payment was collected every three months. Some respondents provided the annual water payment. Daily water consumption is about 407.4 litres per family, and the average household size is 3 members. Therefore, per capita per day water consumption is about 135.8 L.

However, the water consumption is about 233 l/p/d for the same household if it is calculated by appliances consumption data in the survey (see Section 4.3.5.2).For the same households, the estimated water consumption from survey is about twice the metered water use.

The possible reasons influence the high water consumption in the survey could be:

1. Flow rate: Maximum tap/shower flow rate was recorded in the experiment and has been used for calculating water consumption. In fact, households may not use maximum flow every time. The survey result is made up from the maximum flow rate. Household water use pattern show that the tap and shower water account 79% of the total (Figure 5.1). Therefore, the higher number could be caused by using maximum flow rate.
2. Flow rate was measured in four households. By contrast data from water bills were collected from forty households. the small sample size could also cause the higher number. So meted water consumption could be more accurate than one derived from flow rate.
3. Although the respondents answered the question about their water bill, the response may not have been accurate. The amount they provided may be either a recall of a recent bill or an estimated average bill.

4. Hot climate: The survey was conducted in July which is the hottest time. Climate data in Harbin is mentioned in Section 2.61. Due to the hot climate the amount of water use for hygiene (shower, clothes washing and cleaning) may greater than the rest of the year. This means that water consumption could be at a peak but it needs further study to support.
5. The reliability of water meters is uncertain.
6. Survey error: The accuracy of the results also relates to the reliability of the respondent's answers. Sampling and data collection error is exacerbated affecting the results. Errors in the questionnaire are discussed in Section 5.4.

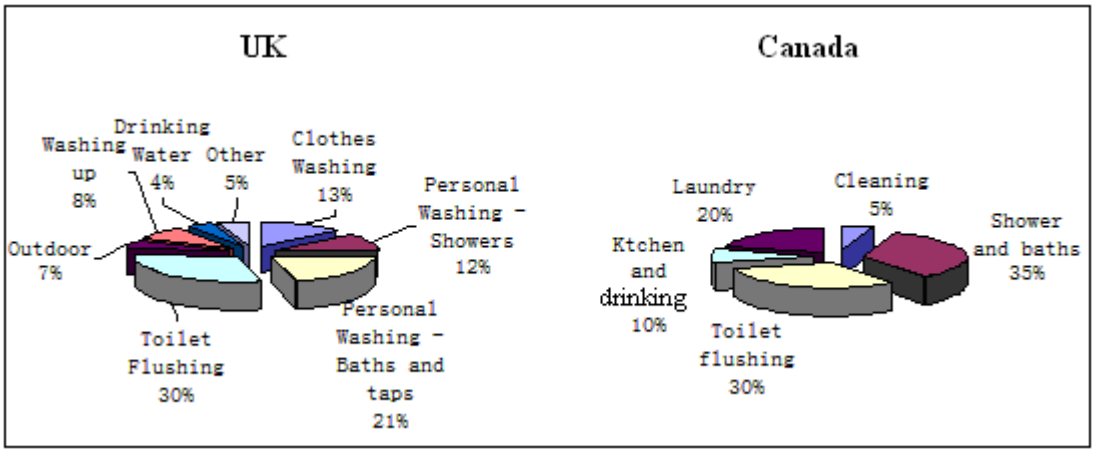
There are number of reasons to cause the difference in water consumption values. The water consumption from the bill (136 l/p/d) seems more reliable and realistic, because the metered results are quite similar with the 2001 average urban household water consumption being 149 l/p/d and 106 l/p/d for rural household(China Water Service, 2001).

During the survey time, the researcher found that most of households realised they consumed large amounts of water. They would like to save water but they felt there was a lack of information about ways of saving water. Some respondents mentioned that sometimes they used the water from clothes washing to flush their toilets.

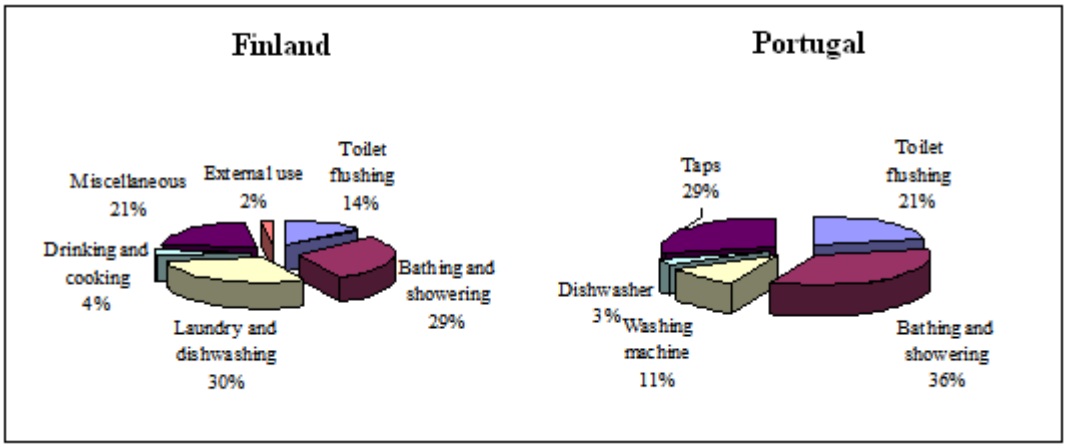
5.2 Discussion of water use pattern between Harbin and international countries

Water consumption components vary between different countries. For example, the household water component in Canada consists of laundry, cleaning, kitchen and drinking, toilet, shower and bath, but it is different in UK. Household water consumption pattern in different countries is shown in Figure 5.1

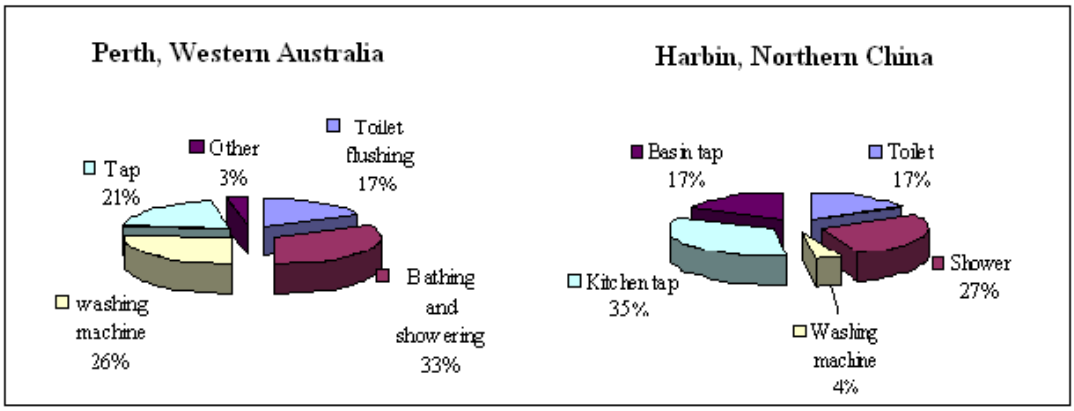
Figure 5.1 Comparison of water consumption pattern in different countries



Source: Waterwise, 2007 and Zhang, 1999



Source: Krinner et al 1999 and Vieira et al 2007



Source: Loh and Coghlan, 2003

Taps consumed more than half of the total daily water in Harbin. Approximately one-third of the total daily water is used by kitchen tap. The proportion of water needed for washing machine compare with the rest of the uses is minimal. The reasons that affected the water use patterns in Harbin include:

1. kitchen tap

The proportion of water used by the kitchen tap is not clearly shown in water pattern use in international data. In Harbin, the largest proportion of water is used in the kitchen. Three factors affect this figure: dishes washing habits, washing duration and high flow rate.

More than half of the respondents used running water for hand washing up. The average kitchen tap flow rate is about 8 L/min. The average duration of per washing up is about 3 minutes. If running water is used, the amount of water for each occasion will be about 24 litres. The average number of dishes washing is three times per day. This is a large amount of water. However, if households wash dishes in a sink or a bowl then half amount of water could be saved. Resent research in UK shows that daily hand washing typically uses about 63 litres and if the dishes are rinsed off under a running tap the total water used can be 150 litres (Waterwise, 2007).

In this study, kitchen tap water use is only concerned with washing dishes, because this the major water consuming activity in the kitchen. The amount of water for cooking and food preparation could be small. In Finland 4% of total water is use for cooking and drinking. The corresponding percentage for Harbin could be similar but it requires further study. Water used for cooking and food preparation is both are accounted for in kitchen tap use. The proportion of kitchen tap use will increase.

Usually public think dishwashers use more water than hand washing. Washing up by hand always uses less water than a dishwasher. Bu a modern dishwasher can use as little as ten litres of water per cycle if the dishes washer is filled full. Therefore a rise

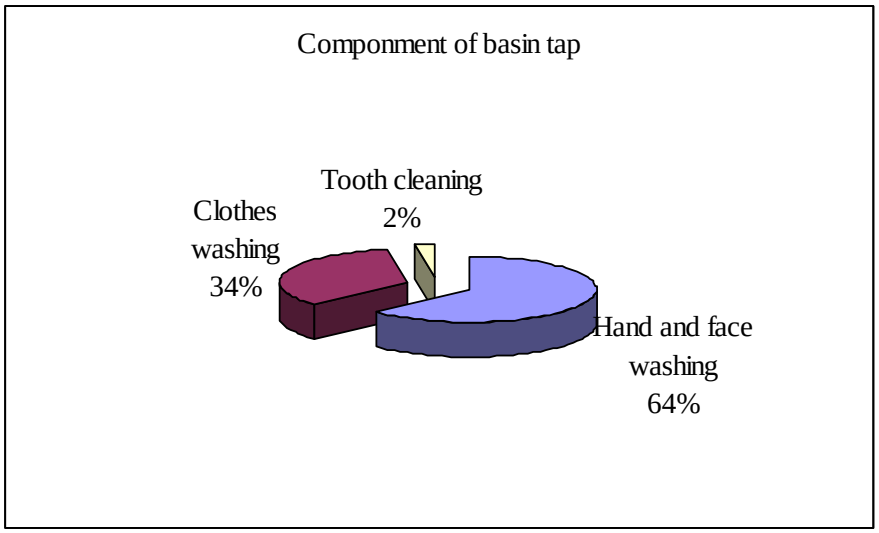
in hand washing efficiency could reduce large amount of water for washing up. The increase in dishwasher ownership and the efficiency of dishes washers in the future will have a positive impact on water reduction at home.

2. Basin tap

The basin tap uses about 17% of the daily water. The amount of water used by the basin tap includes hand and face washing, tooth cleaning and hand washing clothes. Most of the household used basin taps water for hand clothes washing. The high frequency of washing greatly increased the amount of daily water use by the basin tap during the summertime. The use frequency of washing machine was, therefore, very low. The average machine use was about two times per month and led to the small proportion of water used by the washing machine.

The amount of the basin tap water use component is shown below (Figure 5.2) and calculations for the component are available in Appendix 4. A large proportion of water is used for daily hand and face washing. In a comparison of use frequency, hand washing clothes is about 0.65 times per day but hand and face washing frequency is around 6 times per day. Hand and face washing is very frequent activity in the households. The different use frequency could be the main reason that caused the different water use proportion.

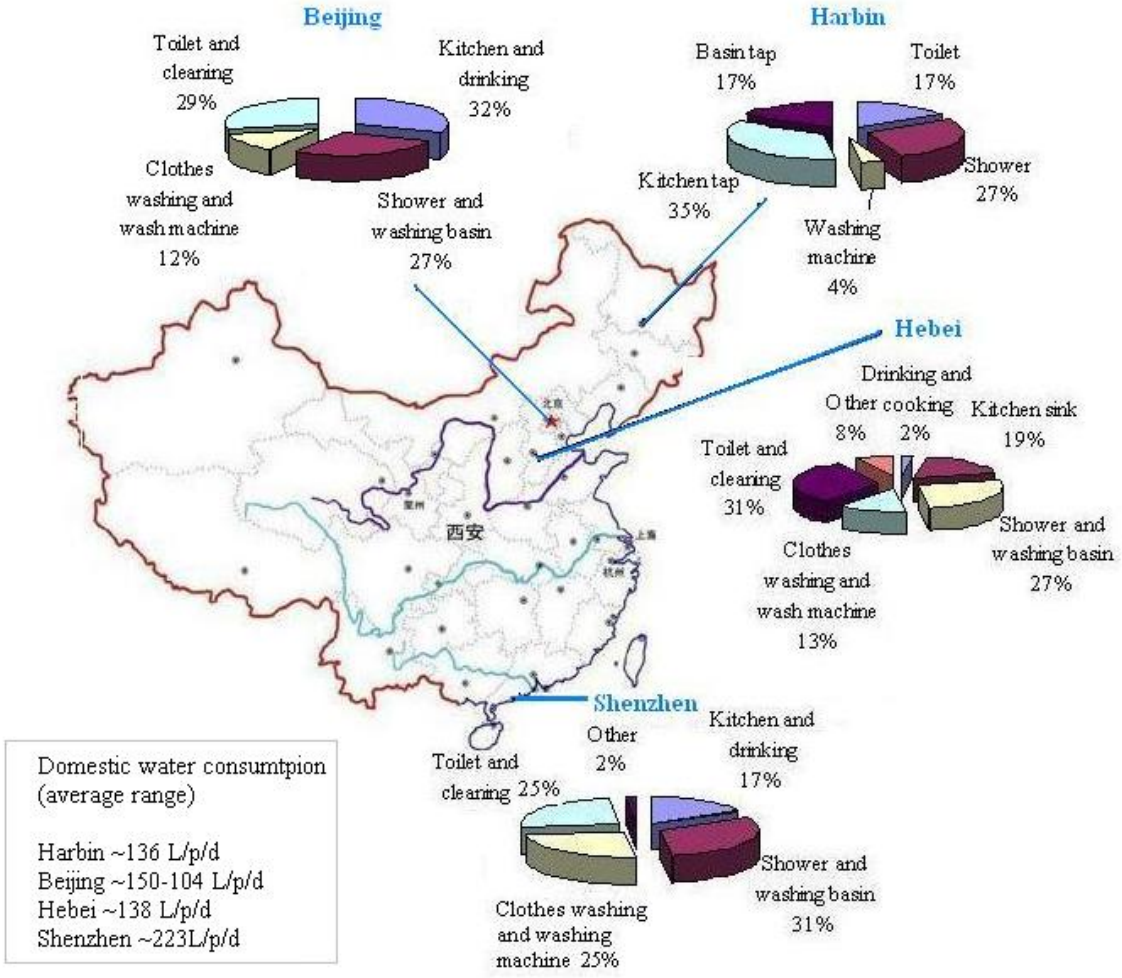
Figure 5.2 Component of basin tap water use (%)



5.3 Discussion of water use pattern between Harbin and Chinese cities

The comparison of the water use pattern in Harbin and other Chinese cities is shown below.

Figure 5.3 Household water use pattern in Chinese Cities (%)



Source: Zhang , 1999 , Jiang ,2004 and Xinhua News, 2004

Toilet and shower

This component is made up by different uses in different cities. But generally, the proportion of shower use is quite similar in these cities. In Harbin, 17% of daily water is used for flushing toilets compared to about 25-31 % of total water for toilets in other cities (Figure 5.3).In the research households dual flush toilet ownership is quite high (43%) and could account for the low amount of toilet water used in Harbin. The research households moved into their current property over the past ten years. Half of the respondents moved in year 2000-2002. New property does not provide water use appliances such as showers, toilets, basin sinks and taps but sewage pipes are available. Occupants need to choose the type of appliance from market by

themselves. In addition, most of Chinese families like to decorate their new house before move in and although sometimes the tap or sink is available the household may still replace it. In these cases, the type of appliance which is chosen will directly influence the household's water consumption. In Harbin the dual flush toilet is very common and the quantities of dual toilets on the market could influence consumer decisions. A lot of dual flush toilets on the market could influence consumers to choose dual flush not conventional toilets. Therefore, Households' water appliances characteristics and ownership are influenced by the household's perception, availability in the market and the year of construction of the building.

Clothes washing

Water consumption for hand clothes washing is 13.1 l/p/d while by washing machine is 8.9 l/p/d in Harbin. In total, the amount of water which is used for clothes washing is 22 l/p/d, about 10% of the total daily water consumption. Compared with (Figure 5.3) the northern cities of Harbin, Beijing and Hebei they have a similar water use component for hand clothes washing and washing by machine of approximately 10% of total water consumption. The southern city (Shenzhen) has a big proportion for clothes washing. It may due to hot climate which lasts throughout the year. Water consumption for hygiene use is also large

Kitchen tap

The proportion of kitchen tap is very similar in Harbin and Beijing, around 30% of total consumption. The proportion decreased from north to south cities. It may due to different way of washing dishes, tap flow rate or frequency of cooking at home.

5.4 Errors in the Study

5.4.1 Errors in flow rate experiment

1. Sampling error: Convenience sampling was used in the experiment, because it

was feasible. Data was only collected in four households. So the results may not be representative of all the households in Harbin. The error can be decreased as the sample size increases. A large sample would more representative of the overall population. Increasing the size of sample also increases the precision of the sample.

2. Experiment processing error: The experimental procedure was based on Flow Rate Test Procedure" (Green Venture website, 2007). Only a one litre container was used. The error could be decreased by increasing size of container and repeating experiments until concordant results were obtained.

3. During the experiment the water container should be placed under a showerhead or tap. One showerhead was not removable and in order for it to catch the water the container had to be positioned some distance away from the showerhead while with removable showerheads the test was conducted quite close to the container. The results could be affected by the distance between container and appliances.

4. Water flow of number three household was quite low and not constant compared to the rest of households (see Section 4.2).The flow tests were conducted in the lunch time which was the peak demand time. Number three household lived on the top floor of the apartment block and the low flow rate that was experienced may be due to a combination of peak time demand and location.

5.4.2 Errors in questionnaire survey

Although the existing errors are pointed out in this section, some errors may be not be apparent or recognised by the researcher. Error exists and is impossible to eliminate. Errors could identify potential problems in the research that may lead to inaccurate

results. If errors could be identified it will help the researcher to become aware of the reliability of results. So it is crucial to be aware of error during the research.

Sampling error

- Random sampling involves a lot of preparation due to time and feasibility constrains, so convenience sampling was used in this study. The sampling error in the questionnaire is similar as the error in the flow rate experiment (see section 4.2.2).The biggest disadvantage of convenience sampling is that it is not clear how much of the sample is be representative of the overall population. The likelihood of error can be reduced with an increase in the size of the sample.

Bias answer

- The sample size is 40 in the questionnaire. Some answers were estimated by respondents and may not be accurate. For example, one of questions asked about shower frequency per week. The answer that was provided by respondent was an estimated answer or a rough average frequency. So the accuracy of the frequency result was influenced by respondents' perception.

- A face to face questionnaire was employed. Respondents' answers may be affected by the researcher. If the respondents realized that the results were for a thesis then the real answers may not have been provided. They may think that their faults would have been revealed, so they might not have presented the real information. For example, question eleven is "if you wash dishes, do you use running water or wash in the sink or mix (includes running water and sink water)." No respondent answered "wash dishes in sink", but 47% of respondents choose "mix washing". Some respondents may only use running water, but they choose 'mix washing'. They think that is the right way to wash dishes. They choose this answer just to cover real activity.

Data collection error

- The average duration for the use of each appliance was requested in the four households. The researcher expected the households to time their daily activities for a week but it is uncertain whether use duration was timed or not.

6 Conclusions and Recommendations

6.1 Introduction

Understanding domestic water use is vital for effective management of water saving at home. Domestic water consumption has been described by the types of water use in Harbin which is based on an End-Use Analysis method (see Section 3.3). Typically these are the use of appliances such as washing machines, personal washing by shower, toilet use and taps use. Study was carried out in Harbin, China during July 2007. The appliance data of use frequency use duration and appliance water use volume has been colleted through a questionnaire, interviews and flow rate experiment. Household water consumption and pattern were estimated and analysed from the survey results. A brief review of the study findings is presented as follows. This chapter addresses the research objectives as set out in Chapter one.

The project objectives were:

- To investigate household water use behaviour and water appliance characteristics
- To analyse household behaviours and appliance characteristics to water consumption
- To estimate household water consumption and pattern
- To examine the reliability of the research results
- To compare the results of this research with other Chinese cities
- To analyse any water-saving potential for the residential sector

6.2 Study findings

1. Estimated water use pattern

Most of the water used in households was by kitchen taps (35%) and by showering (27%). The lowest percentage of residential use is for washing machine (4%). Water use pattern is quite similar between Harbin and Beijing (see Chapter five Figure 5.3).

2. Per capita water consumption

Daily per capita water consumption is around 136 L in Harbin, also see Section 5.1 Per capita water consumption in most of northern cities is similar (e.g Beijing, Harbin and Hebei).

3. Water using habit

The frequent water use appliance was basin taps (9.3 per day) and toilets (6.3 per day). The least frequent use appliance was the washing machine (0.071 per day). The average washing machine ownership is one per house but is infrequently used. In the majority of households clothes are washed by hand.

4. Water- saving appliances

The most popular efficient appliance is dual flush toilet.

Other domestic water saving appliances is available on market but is not very widespread in the home. Perhaps because public is still lack of information on then or their relatively high price. The promotion of water-saving appliances would have a positive impact in reducing household water consumption. Ownership of water efficient appliances is influenced by household perceptions and the year when the building was constructed.

Household water consumption could be reduced after installing water-saving appliances. Toilets use 17% of the total water in Harbin because half of the respondents using dual flush toilets. Taps with air devices (introduction of air bubbles into water) could reduce water flow by 50%. (Krinner and Lanllana et al, 2001). If the households of Harbin installed air devices taps, half amount of water which is used in kitchens and basins could be reduced. Household water patterns will be completely different. In 1977 a third of washing machines were top loaders or twin-tubs in UK and average water used per cycle was about 140 litres. This type of washing machine has almost disappeared. A water efficient machine only used around 50 litres/cycle in 1998(Waterwise, 2007).

The new technologies have a positive impact on water use by water appliances. Currently, most of the households still wash clothes by hand and use a top loader machine but the future trend of the washing machine market will be for front loader water-saving machines. If washing machines are more water efficient then machine use will rise. The household water use pattern will change. There is great potential for household water conservation and water-saving appliances in Harbin.
Household environmental awareness, attitudes and behaviour towards water could greatly influence water consumption but technological improvement (water-saving appliance) is necessary. Improvement of public awareness and technology can not be separated.

6.3 Review of methods

The following methods were used in this study for the collection of information.

- Literature review
- Semi-structured interview
- Flow rate experiments
- Questionnaire survey and a weekly survey

Literature review

The preliminary study was a necessary step for this study. It was difficult to collect adequate information for domestic water use study in Chinese cities. If further studies are carried out in other Chinese cities, it should be more focused on field work. But it is necessary to have a good literature review which contains international studies..

Semi-structured interview and questionnaire

Semi-structured interviews are particularly useful to collect general information. In this study, it was helpful as some interesting and unexpected information was obtained. Some interviews are not formal, more like a natural conservations. When a household felt that they were not doing a formal survey for a project, their answer was

more natural. The interview and questionnaire technique was quite good for collecting data and information in this study but the problem with questionnaire was that sometimes the accuracy of the collected information was suspect. Good questionnaire design is a vital part of a successful survey. A few pilot samples followed by revision are necessary before conducting the actual research. Piloting is a very effective way of discovering mistakes, unclear questions, inappropriate questions or any additional questions which need to be added to the questionnaire.

Weekly survey

The original idea of a weekly survey was to collect more reliable data by recording daily water use activities in a week. In this study, a pilot was conducted in each household just to show them how to record data. The majority of the data that was recorded by the households was unobserved by the researcher and the household may not have done the recording very seriously. So the structured observation could be the better method for a further study. More reliable data can be obtained by observation.

Flow rate experiment

It was difficult to obtain flow rate data from the market so the flow rate experiments were used to gather the required data. Only one test method was used but if a variety of techniques could be used for the same appliance test to produce averaged results then this result would be more accurate.

6.4 Study limitations and further study

Sampling

Convenience sample was employed in survey and the flow rate experiment. This method can lead to sampling bias because it means that there is a greater chance that sample is not representative of the overall population.

Further study area: Employ random sampling or improve the accuracy of the results by increasing the size of the sample.

Flow rate experiment

The flow rate test was only conducted in four households. The test instruments and procedures were very simple and will contain errors. The result was constrained by sample size, test method and number of tests.

The flow rate test was an indoor test. It required a good relationship with research household. It is necessary to communicate with household first and get permission. It was hard to a collect large sample or employ random sampling in such a short time.

Further study area: In a further indoor study should plan to communicate with the sample group as early as possible and then plan the experimental activities well with them. This will improve efficiency. A more detailed literature review of test procedures and methods is recommended. The accuracy of the results could be improved by increasing the sample size, using different test methods and increase the number of experiments.

Season variable

Due to the time allowed, this study was conducted in July (summer time). The survey results only indicated water consumption and household using behaviour during summertime. However, use frequency (shower, clothed washing) could be different during winter time due to the big temperature various in Harbin. Marshallsay, 2003 mentioned current demand estimation used in UK originated from work of Herrington who examined the change in water use components as a result of climate change (Marshallsay, 2003). So the climate could influence household water use.

During the survey time, there was no public holiday. Normally, Chinese public holidays are about a week long, such as Spring Festival in winter time (in January or February), National Day in October. Some households may stay at home or go out. The public holiday also may influence household water consumption but it needs a future study. If surveys could be conducted during other months then results will be

more accurate and differences in water use consumption, patterns and behaviour between different seasons will be discovered

Future study area: Conduct surveys during different seasons to obtain more reliable results and analysis the relationship between climate and household water using behaviour, patterns.

Kitchen tap component

In this study, water use for the kitchen only considered the amount of water involved in washing dishes, because the author feels that dish washing consumes the major amount of kitchen tap water.

Further study area: Studies are being carried out in cooking and food preparation to investigate whether dish washing accounts for the major amount of water use in the kitchen. However, the volume per use for cooking and food preparation needs to be measured in actual type of use e.g. using running water or using water in a bowl.

Water awareness and attitude

This study focused on household water using behaviour and estimating water consumption. It did not include much information about household awareness and attitudes toward water use but they could be reasons that influence household water consumption.

Further study area: Work should be done to obtain household awareness, views and attitudes towards water and water using appliances.

Geographic constrain

Due to the time and feasible consideration, the study was only focus in one northern city. North and south of China have big differences in temperature, culture and personal habits.

Further study area: Conduct research in different locations, to discover if water use patterns may be different.

References:

ADB Financed Songhua River Flood Management Project (2007) *Project Introduction* Available at< http://www.slwrcpco.cn/English/index.htm>. (Accessed on 19/07/07)

Bryman, A (2004) *Social research methods***,** Part two, samplingp83-108 Oxford: Oxford University Pres

Black and Veatch (2006). *PRC: Harbin Water Supply Project*, Asian Development Bank, Available at< www.adb.org/Documents/SEMRs/PRC/33177/33177-01-PRC-SEMR.pdf>. (Accessed on 19/07/07)

China Statistical Yearbook, (2001). Available at< http://www.stats.gov.cn/tjsj/ndsj/index.htm> （Accessed on 06/06/07）

Cai,J and Ji,W (2007).*Beijing Water Resource*, Sustainable water management improves tomorrow's cities' health (SWITCH)

China Water Service (2001). *Usage of water resource in China* (Chinese website)<available at http://www.cws.net.cn/cwsnet/gazette/songliao/2001/4.html>.(Accessed on 25/07/07)

CIDA Funded Project Team (1999). *Sustainable Water Resources Management in Beijing and Tianjin Region Water Demand Estimation*, published by School of Urban Planning, McGill University, Montreal, Canada

Crook, F.W and Diao, X(2000). *Water pressure in China: growth strains resources* Economic research survey/USDA, special article

Ernst, Andreas (2005). *Shallow and deep modeling of water use in a large, spatially explicit, coupled simulation system* Available at < http://www.pst.ifi.lmu.de/~janisch/pub/ShallowAndDeep-ESSA2005.pdf >.Produced by: European Social Simulation Association (ESSA) (Accessed 19/07/07)

Gleick, P.H. (1996). "*Basic water requirements for human activities: Meeting basic needs*." Water International Vol. 21, No. 2, pp. 83-92

Green Venture (2007). *How to conduct a flow rate test,* Available at http://www.greenventure.ca/ecohouse/tours/wisewateruse/003/printer.html>. (Accessed on 22/07/07)

Harbin Statistical Yearbook (2004).Available at< http://www.stats-hlheb.gov.cn/more.jsp?page=2&type=204>. (Accessed on 17/07/07)

Harbin China (2003). *Harbin water price standard* , Available at< http://www.harbin.gov.cn/hrbzfw/hrbnews_search/index.php>. (Accessed on 21/07/07)

Hou, E and Hunter, G.(1998). *Beijing Water: Causes, Effects, Solutions* *A*vailable at< http://www.chs.ubc.ca/china/beijing.pdf> (Accessed on12/06/07)

Hou, E(2000). *Nine Dragons, One River: The Role of Institutions in Developing Water Pricing Policy in Beijing, PRC*. 3x3 Beijing Tianjing water resources management project

Jiang, X(2004). '*Household Water Consumption Pattern in Beijing'*. Economical information centre –department of economic research and consultancy, Beijing. (Chinese Version).Available at<

http://report.drc.gov.cn/drcnet/corpus.nsf/c5941e2eb286283448256538000d3426/ab21db56814d49a648256f0a000826c6?OpenDocument>. (Accessed on 05/07/07)

Krinner, W.and Lanllana,C et al (1999). *Sustainable Water Use in Europe part 1: sectoral use of water.* European Environment Agency

Krinner, W.and Lanllana,C et al(2001). *Sustainable Water Use in Europe part 2: Demand management.* European Environment Agency

Loh,M and Coghlan,P(2003). *Domestic water use study in Perth,Western Australi*a, Water corporation

McKenzie, R. S. Bukle, H. Wegelin, W. A and Meyer,N (2003). *Water Demand and Management Cookbook ,* Available at <www.unhabitat.org> (Accessed on 11/06/07)

Marshallsay, D (2003). *Understanding Domestic Water Use in the Context of Demand Management and Forecasting*, Availbe at< http://www.idswater.com/Common/Paper/Paper_13/Dene%20Paper.pdf>. (Accessed on 26/07/07)

Ouyang, M (2006). *Change our Life styles to Build Green Beijing*. (Chinese website). Available at < http://kgzc.hdavec.org/news_show.asp?f_id=53&wt_id=255>. (Accessed on 05/08/07)

Sustainable Development (2005), *Regional Indicators Summaries*. Available at< http://www.sustainable-development.gov.uk/regional/summaries/index.htm>. (Accessed on 02/06/07)

Sustainable Development (2006). *What is Sustainable Development?* Available at< http://www.sustainable-development.gov.uk/what/index.htm>. (Accessed on 11/06/07)

Sociology Central (2007). *Focused semi-structured interviews*
Available at< http://www.sociology.org.uk/methfi.pdf>. (Accessed on 21/07/07)

Thompson, J. and Porras, I (2001). *Drawers of Water II Summary*. International Institute for Environment and Development

Turner, A., Campbell, S. & White, S. (2003). *Alice Springs Water Efficiency Study*. Institute for Sustainable Future (ISF), University of Technology, Sydney

Turner, A., Campbell, S. & White, S. (2004). *Methods Used to Develop an End Use Model & Demand Mangement Program for an Arid Zon*e. Biennial World Water Congress, Marrakech, Morocco 19-24 September 2004.

Parliamentary Commissioner for the Environment. (2000). *Ageing Pipes and Murky Waters- Urabn water system issues for the 21st century* .Wellington,Parliamenraty commissioner for the Environment, June 2000

UK Environment Agency (2007). Household Water Use-background and data. Available at < http://www.environment-agency.gov.uk/yourenv/432430/432434/432453/434390/?lang=_e#> (Accessed on 02/06/07)

Waterwise (2007). *At Home- Indoors.* Available at< http://www.waterwise.org.uk/reducing_water_wastage_in_the_uk/house_and_garden/save_water_at_home.html> (Accessed on 04/06/07)

Williman, N (2005). *Your Research Project* SAGE publications Ltd, second edition

WHO (1993). *Guildelines for Dringking Water Quality*, Volume 1 Recommendations 2nd edition

White, S. Milne,G and Riedy, C (2004). *End use analysis: issues and lessons*. Water supply vol 4 no3 pp57-65, IWA publishing 2004

Zhang, henry(1999). *Nine Dragons, One River: The Role of Institutions in Developing Water Pricing Policy in Beijing, PRC***.** Published by: McGill University,

Zhang , J (2003). *Towards the Health Wataer Cycle of China* . Key lab of water quality science & water environment recovery engineering Beijing University of Technology

Vieira, P and Almeida, M. et al. (2007). *Household Water Use: A Portuguese Field Study* . International Water Association

Wikitravel(2007) *Harbin*, Available at< http://wikitravel.org/en/Harbin> (Accessed on 17/07/07)

Wikipedia(2007).*Songhua River*, Available at< http://en.wikipedia.org/wiki/Songhua_River> (Accessed on 17/07/07)

Xinhua News (2004). *Water saving in Shenzhen.* Available at<http://news.xinhuanet.com/comments/2004-12/21/content_2360877.htm. >(Acces sed on 22/08/07)

Appendix 4

Table4.13 Household water use characteristics (per person/ per day)

		Average	Minimum	Maximum
Toilet				
Average flushes per day		6.35	4.5	8.5
Average toilet cistern volume	Single flush	8	6	12
	Dual flush	4.5	3	6
Shower				
Average numbers of showers per day		0.57	0.1	1.3
Average length per shower(min.)		20.5	12	30
Average shower flow rate(l/ min)		5.21	2.07	8.05
Washing machine				
Average number of uses per day		0.07	0.03	0.13
Average water consumption(l/cycle)	Top loader	140	130	150
	Front loader	80	70	90
Kitchen tap				
Average number of uses per day		2.83	1	4
Average flow rate(l/min)		8.61	5.11	9.72
Average time per use(min.)		3.2	2	5
Basin tap				
Average number of uses per day		9.3	8.7	10.4
Average flow rate(l/min)		5.75	5.22	7.39
Average time per use(min.)		1.0	0.3	1

Households water consumption (litres per capita per day)

Household water consumption = water use (toilet + shower+ washing machine +kitchen type + basin tap)

Average water consumption = 37.5+60.9+8.9+77.9+38.1=223.3
Minimum water consumption =19.2+2.5+3.5+13.8+12.7= 51.7
Maximum water consumption =72.7+313.9+17.7+194+69.3=667.6

The **toilet** water use = toilet cistern volume * number of flushes per day
Average value = 6.35* (8*0.5+ 4.5*0.425) = 37.5

Minimum value= 4.5 *(6*0.5+3*0.425)= 19.2

Maximum value= 8.5*(12*0.5+6*0.425) =72.7

The **shower** water use = the shower length * the shower frequency *Constant (shower flow of the household's shower head)

Average value = 20.5 * 0.57*5.21=60.9

Minimum value= 12*0.1*2.07=2.5

Maximum value= 30*1.3*8.05=313.9

The **washing machine** water use = machine water consumption * number of uses

Average value = [140 * (0.45+0.4)+80*0.1] * 0.07=8.9

Minimum value= [130 * (0.45+0.4)+70*0.1] * 0.03=3.5

Maximum value= [150 * (0.45+0.4)+90*0.1] * 0.13=17.7

The **kitchen tap** water use = time of each use * tap use frequency * tap flow rate

Average value= 3.2 * 2.83*8.61=77.9

Minimum value= 2.7*1*5.11=13.8

Maximum value= 5*4*9.72=194

The **basin tap** water use = water use for washing hand/face + assumed water use for tooth cleaning + assumed water use for hand washing clothes

Average basin tap water use = 24+0.95+13.1= 38.1

Minimum basin tap water use =7.6+0.4+4.7= 12.7

Maximum basin tap water use =37.7+2+29.6= 69.3

Hand and face washing

*Water use for face/ hand washing = time of each use * tap use frequency * tap flow rate*

*Average = (0.5*4.95*5.75)+(0.95*1.8*5.75)= 14.2+9.8=24*

*Minimum = (0.4*4.6*5.22)+(0.9* 1.5*5.22)= 0.6+7=7.6*

*Maximum= (0.5*6.2*7.39)+(1*2*7.39)=22.9+14.8=37.7*

Tooth cleaning

*Assumed average water use for tooth cleaning = two cup water * average tooth cleaning frequency= 0.5 *1.9=0.95*

*Assumed minimum water use for tooth cleaning = one cup water * minimum tooth cleaning frequency=0.25 *1.5=0.4*

*Assumed maximum water use for tooth cleaning = two cup water * maximum tooth cleaning frequency = 1*2=2*

Clothes washing

*Assumed water use for clothes washing = washing frequency * assumed time for using water * tap flow rate*

*Average= 0.65*3.5*5.75=13.1*

*Minimum =0.3*3*5.22=4.7*

*Maximum=1*4*7.39=29.6*