

COMPARATIVE EVALUATION OF ENERGY AND WATER EFFICIENCY OF WASHING MACHINES

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Introduction

Domestic technology is the incorporation of applied science into the devices such as appliances and automations that are used in homes. It plays the role of a facilitator of the production and consumption processes and has radically altered the way we maintain and manage our households (Ironmonger *et al.*, 2000). As such, modern technological devices have become commonplace in and around the home presently. These electric and electronic devices require energy and specific for laundry appliances, water is needed in addition to operate.

However, the world is currently facing both water and energy crises as a consequences of unsustainable production and consumption pattern. Shortage of safe and accessible drinking-water will become a major challenge in many parts of the world as fresh water supplies are further stretched to meet the demands of industry, agriculture and an ever-expanding population (WHO, 2000). Global Water Outlook to 2025 reported that an individual used about 30 cubic meters/person/year in 1995 and projected to almost 38 cubic meters/person/year in 2025. Due to rapid population growth and rising per capita water use, total domestic consumption alone will increase by 71 percent of which more than 90 percent will be in developing countries (Rosegrant *et al.*, 2002). Hence, it is estimated that a quarter of the world's population (nearly 1.4 billion) or a third of the population in the developing countries live in regions that will experience severe water scarcity within the first quarter of the twenty-first century (Seckler *et al.*, 1999). This implies that there is insufficient water to cater for the reasonable per capita water needs of the growing population. Water scarcity is significant as it will lead to problems with food production, human health, economic development and well-being of the ecosystems (Chiramba, 2010). One of the strategies that can be used to address the challenge posed by water scarcity by consumers is to

conserve water and improve efficiency use through either adoption water saving technology appliances or modification of behavior.

Another important component that plays a significant role in human and economic development of a nation is energy. Studies have shown that there is a direct correlation between energy usage and economic development (Aqeel & Butt, 2001) and energy consumption with Human Development Index (UN,2005). The quality of social environment of a country is improved when the consumption of energy surpasses two toe (ton of oil equivalent) per capita (Goldernberg & Johansson,1995). Energy is required for man to meet the basic needs such as food, housing, transport, health services etc. The demand for energyworldwide has increased tremendously in recent years in parallel to rapid economic growth particularly in developing countries. Most of this energy demand is met by fossil fuels where combustion of this fuel releases greenhouse gases such as carbon dioxide, sulphur dioxide, nitrogen oxide, carbon monoxide and a few organic compounds. These greenhouse gases are detrimental both human and environment. With regards to energy, the world is facing twin threats: inadequate and secure supplies of energy at affordable price; and environmental damage due to overconsumption of non-renewable energy (IEA, 2006).

Worldwide residential sector consumes about 16-50% of total energy (Saiduret *al.*, 2007) and this residential share is expected to rise in the future (Abrahame & Steg, 2009). It is cited by Mills & Schleich (2010) that in the EU, major household appliances account for 35% of the total residential end-use energy (Bertoldi & Atanasiu, 2007). In the UK, energy use in the domestic sector was reported to have increased by 18% during the period 1990-2004, to account for just over 30% of the country's final energy consumption (Faierset *al.*, 2007). Consumption of appliances and lighting in the UK represent the biggest residential energy use growth area, increasing at a rate of about 2% per year since the 1970s (Postnote, 2005).

Similar increasing trend is noted in developing countries such as Malaysia where ownership of appliances have been steadily increasing. A survey on adoption of household technology products byAiniet *al.* (2008) showed that there was a penetration rate of 100% for refrigerator and television and 89% for washing machines in the country. A calculation on energy consumption of 23 household electrical and electronic appliances in Malaysia showed that three highest consumption of electric were refrigerator/freezer, air conditioner, and washing machine which accounted for 2277, 3970 and 1952 GWh per year respectively in 2009 (Saiduret *al.*, 2007).

With rising concern for water and energy crisis, various eco-friendly policies and programs are being implemented worldwide such as the appliance energy

consumption labeling scheme in order to increase the diffusion of energy-efficient appliances. However the rate of adoption of such appliances is not making a significant impact on the reduction of carbon emissions needed to meet the current targets through the Kyoto Protocol (Frierset *al.*, 2007). There are various reasons why consumers are not adopting efficient appliances such as: electricity as an intangible and complex product (Trufferet *al.*, 2001), unclear relative economic benefits of appliances (Mills & Schleich, 2010), higher capital cost (Saiduret *al.*, 20017), and individuals' cognitive abilities, values and attitudes (Frierset *al.*, 2007).

In order to preserve our natural resources and to reduce the negative impacts to the environment, consumers need to include environmentally friendly features as one of the important criteria in making purchase decision. Two important key features that relate to washing machine are water and energy consumption. Adoption of high energy and water efficiency washing machines is not only environmentally friendly but was found to be profitable relative to the price premium for most households (Davis, 2008). In this vein a laboratory experiment was conducted to gauge the water and energy consumption level of various types of washing machines that are available in the market. Therefore, one of the main objectives of the study is to evaluate the energy and water usage of twin tub, top and front loading type of washing machines at different loading levels.

Methodology

Types of washing machines

Basically there are three types of washing machines available in the market namely front loading, top loading and twin tubs exhibiting different mechanism, features and performance. Front loading washing machine, sometimes called drum type, is popular in Europe, Russia, Australia and South America. Top load washing machine is prevalent mainly in the USA and Asian countries. Twin tub washing machine is dominant in China, South East Asia and some parts of Middle East countries. For the present experiment, a total of ten washing machines representing three types namely top loading (4 units), front loading (4 units) and twin tub (2 units) were selected. They were a mixture of Japanese, Korean, European and local Malaysian brands. The price of each machine varies from a few hundred Ringgit Malaysia for the twin tub to above one thousand Ringgit Malaysia (>USD350) for the top and front loading washing machines. Table 1 shows the type and capacity of the washing machines used. The test was conducted using tap water at a normal room temperature of about 26°C. Wash clothes used were mono colored cotton materials consisting of bed sheets (big and

small size), pillow cover, shirts, undershirts, underpants and towel and cotton handkerchiefs adapted from Australian/New Zealand Standard. Different kinds of wash clothes were combined to obtain the desired wash load capacity.

Table 1: Type and Capacity of Washing Machines

Type	No	Capacity (kg)
Front loading (FL)	FL1	6.5
	FL2	5.0
	FL3	5.0
	FL4	5.0
Top loading (TL)	TL1	8.0
	TL2	9.5
	TL3	6.9
	TL4	7.0
Twin tub (TT)	TT1	6.5
	TT2	5.0

Research procedures

Each of the machines was tested at three different load levels which are atfull load (as stated in the manual), 70% load and 50% load. The capacity of the washing machines varies from 5.0 kg to 6.5 kg for the front loading type, 9.5 kg to 6.9 kg for the front loading and 5.0 kg and 6.5 kg for the twin tub. A digital AND weighing scale was used to measure thedry mass of the wash clothes. Water pressure was determined using Wikai hydraulic water pressure meter. Water utilization was calculated using a Kent water consumption meter by subtracting the final (end of experiment) and initial (start of experiment) reading of the meter. Total energy used was obtained usingPhyfe electric power meter. The water flow rate was noted using a water flow meter. Other parameters such as loading easiness, vibration, and noise level and clothes interaction were also noted. The machines were connected directly to the mains and several limitations were noted namely: the water pressure varied between 10 ~ 35 psi;the water (directly from the mains) temperature fluctuated a few degrees above 26°C as it depends on the daily

temperature; and the voltage of the power supply fluctuated between 240 ~ 255 volts.

In order to minimize those errors namely variations in water temperature, water pressure and voltage supply, each experiment was conducted about the same time of the day (during weekdays) and within a period of three months (May and July, 2010). Each test was repeated twice and an average result was calculated. Similar wash programs were selected for each machine. The experiments were conducted in Product Testing Laboratory of the Department of Resource Management and Consumer Studies, University Putra Malaysia.

Results and discussion

Loading capacity

Table 1 shows the capacity of the washing machines used in the test. Top loading washing machines have a bigger load capacity of up to 9.5 kg while the front loading and the twin tub are generally smaller with a maximum loading of between 5 to 6.5 kg. Loading capacity may be a priority feature for a family with many members as more clothes can be cleaned in one wash. It was noted however that during the loading of the wash clothes, all the machines were unable to carry the maximum capacity as stated in the manual or specifications. The clothes have to be pushed in hard in order to fit into the drums and some spill over was observed. Thus it seems that the full load capacity which is indicated by the manufacturers' manual was found to be over rated for all the machines.

It was also found that even at 70% loading, the wash clothes seemed to move around the same tracing. This indicates that there was hardly any interaction between them and would eventually lead to poor wash performance. The condition was the worst for the twin tub machine as the clothes were already full to the brim at 50% loading capacity. Under full load condition, the noise generated was unbearably loud and all the machines vibrated violently and were displaced from their original positions. It is therefore important for the buyer to take into account of this limitation when deciding on the capacity of the washing machine before purchasing. From the results above, it is proposed that an additional allowance of about 30% has to be added to the estimated maximum loading expected. It was observed from the experiment that 50% of capacity/maximum load is the best wash load option in order to ensure good washing performance and a reduced amount of noise and vibration level.

Water consumption

Water consumption for the three types of washing machines was found to vary considerably. Table 2 shows water consumption test results for the washing machines at 100%, 70% and 50% load. As there was a variation in the capacity of the tested washing machine, average water consumption per kilogram of load was also calculated (liter/kg). In general, data indicated that the top loading washing machines and twin tub consumed almost two to three times more than the front loading type across all the loading. It was noted that FL 3 consumed a considerably low volume of water at 17.8 liter/kg at 50% load, which is almost half of the other front loading ones. This may raise some concern over its overall washing performance as insufficient water will affect the cleansing and rinsing abilities of the machine. For all the machines, the volume of water used per kg wash load increases as the percentage loading decreases.

Table 2: Average Water Consumption for 100%, 70% and 50% Loading Capacity of Washing Machines

No	Capacity	100% Load		70% Load		50% Load	
		Liter	Liter/kg	Liter	Liter/kg	Liter	Liter/kg
FL1	6.5 kg	97.5	15.0	92.5	20.2	84.5	25.6
FL2	5.0 kg	89.5	17.9	91.0	26.0	92.5	37.0
FL3	5.0 kg	53.5	10.7	48.5	13.9	44.5	17.8
FL4	5.0 kg	109.5	21.9	95.5	27.1	91.5	36.6
TL1	8.0 kg	248.0	31.0	234.5	41.9	238.5	59.7
TL2	9.5 kg	213.5	22.5	204.0	30.4	214.0	44.6
TL3	6.9 kg	245.5	35.6	184.0	38.3	210.5	60.1
TL4	7.0 kg	276.0	39.4	236.5	48.3	288.5	82.4
TT1	6.5 kg	236.0	36.3	225.5	49.0	233.5	70.8
TT2	5.0 kg	218.0	43.6	219.5	62.8	233.5	93.4

This suggests that more water can be saved if washing is done at a higher load level but the consumers should also be aware that optimum maximum clothes interaction (hence washing performance) was observed to be at 50% load for both the top and front loading and of lesser amount for the twin tub. As such, a compromise has to be made between enhancing washing performance and overall water saving for a wash load. Comparing at 50% load, all the four front loading machines consumed the least volume of water per kg of load ranging from 17.8 liters/Kg to 25.6 liters/Kg as compared to

the top and twin tub machines. The water consumption of four top loading washing machines ranges considerably between 36.6liters/kg to 92.4 liters/kg while the twin tubs used an average 70.8 and 93.4 liters/kg each. The difference in the total amount of water consumption between the top and front/twin was found to be more than doubled.

Energy consumption

As for electrical consumption, the reverse was observed whereby the front loading machines consumed the most as compared to the other two types. Across all loading level, the front loading consumed as much as five times to that of top and twin tub washing machines (Table 3). At 50% load capacity, the front loading machines consumed power from a range of 186 Wh/kg to 231.5 Wh/kg while electricity consumption rate for top loading/twin tub varies only between 28.4 Wh/kg to 53.6Wh/kg. The total washing time for the front loading was about two hours while one hour for the top loading. The operation time for the twin tub is 45 minutes but additional time has to be added due to manual unloading for spinning cycle.

Table 3: Average Energy Consumption For 100%, 70% and 50% Loading Capacity of Washing Machines

No	Capacity	100% Load		70% Load		50% Load	
		Wh	Wh/kg	Wh	Wh/kg	Wh	Wh/kg
FL1	6.5 kg	534.3	82.2	578.3	125.8	614.0	186.0
FL2	5.0 kg	451.6	90.3	457.3	130.7	466.0	186.4
FL3	5.0 kg	553.8	110.8	591.5	169.0	578.7	231.5
FL4	5.0 kg	447.7	89.6	452.7	129.3	458.3	183.3
TL1	8.0 kg	152.0	19.0	154.2	27.6	151.4	37.8
TL2	9.5 kg	150.1	15.8	137.6	20.6	136.5	28.4
TL3	6.9 kg	148.1	21.5	133.3	27.8	139.5	39.8
TL4	7.0 kg	188.2	26.9	187.0	38.1	186.5	53.3
TT1	6.5 kg	165.2	25.5	157.8	34.3	155.5	47.1
TT2	5.0 kg	146.8	29.4	131.1	37.9	134.0	53.6

Conclusion

It is clearly evident from these tests results that front loading washing machines consumed a lot of more power but a smaller volume of water as compared to the top and twin tub machines. Similar point was noted by Honold (2000) regarding the differences in water and energy consumption between the top and front loading washing machines. On average the front loading uses about 20 liters/kg of wash while the top loading used twice as much. The twin tub has a relatively smaller capacity as compared to the other two types but consumes as much as three times of water to that of the front loading. For electricity consumption, the front loading types used as much as five times to that of top loading and the twin tub. The differences in power consumption are due to the bigger motor capacity and longer washing time of the front loading.

In conclusion, front loading washing machine has less water consumption and relatively slighter clothes damage, but it takes a long operation time, usually needs hot water wash and is more expensive to purchase. But, lower water consumption has side effect such as lower rinsing performance (Olsson *et al.*, 2008). However, top loading washing machine gives good wash performance, quiet and short operation time, but it requires bigger water consumption. In case of twin tub washing machine, the cost is cheap and structure is simple, but it is rather cumbersome as the wash process is not automatic. Therefore, it seems that each type of washing machine has both its advantages and disadvantages.

From the test results, it seems that the consumers are confronted with an option of either water efficient or energy efficient washing machines. In reality, there are other factors that have to be considered before making purchasing decision. Washing machine is a durable product where it is an item that has a long life expectancy (usually longer than five years) and the initial purchase price is costly. Once it is purchased, the consumer is stuck with it for a long time. A poor choice could lead to higher cost of operation and worse if the selection does not perform as expected. Advantages, disadvantages and constraints for each type of washing machine are highlighted in Table 4. They are some of the additional factors that consumers need to encompass when making purchase decision on washing machines. As each type of washing machine has some superior characteristics and performance over others but also possesses some weaknesses, the consumers therefore have to prioritized those attributes to suit one's needs. Among the key considerations in making purchase decisions of washing machine are the purchasing and maintaining cost (constraint by income, cost of electricity and water), loading capacity

(depends on the family size), and external factors such as housing space and local water pressure.

Table 4: Comparative Strengths and Weaknesses of Front Loading, Top Loading and Twin Tub Washing Machines

Features		Strengths	Weaknesses
Price and Design	Front loading	Fully automatic Many wash programs Easy access for loading, suitable for elderly and handicapped	The most expensive Average loading capacity
	Top loading	Fully automatic Many wash programs Bigger loading capacity	Moderate in price Loading and program buttons are at the top of the machines, unsuitable for elderly and handicapped
	Twin tub	The cheapest Smallest in size Very little options of wash programs	Smaller loading capacity Semi-automatic, manual control at washing and spinning cycle.
Water consumption	Front loading	The least water used	Require strong water pressure
	Top loading	Slightly better water consumption compared to twin tub	Require strong water pressure Used a lot of water, two times to that of front loading
	Twin tub	Water can be poured in manually, so can be utilized even the water mains is cut-off or low water pressure.	Highest water consumption, two to three times that of front loading. Water tap has to be turned on and off manually.
Electrical consumption	Front loading	Hot water wash option and hence improve washing performance	Consumed the most electricity, three to five times to that of front loading and twin tub. Operating time is the longest, about 2 hours.
	Top loading	The least power used Shortest operating time, about one hour	

Table 4 (Continued)

	Twin tub	Power used is slightly more than the top loading	Slightly longer operating time than top loading
Other performance parameters	Front loading	The least creases on the wash clothes	Heavy vibration especially at 100% and 50% loading. Full loading capacity is rather impossible, below 50% load is reasonable.
	Top loading	Vibration slightly less than front loading	Full loading capacity is rather impossible, but slightly better than front loading
	Twin tub	The least vibration	Full loading capacity is rather impossible. Spin cap is very hard to release particularly at high loading. Size of spin tub is too small to accommodate the entire wash load at once.

In the context of the present scenario where the world is facing both water and energy crises, it is pertinent that both these natural resources are utilized sustainably. With regards to energy saving features, energy labeling scheme has been introduced in many countries where relative energy-efficiency are rated against various washing machines. Hence, consumers can easily discern the level of energy efficiency between various brands and models. However, the choice regarding water efficient washing machine is more intricate as it is constrained by other factors such as water pressure, water quantity and water quality in a particular residential area which is beyond the control of the consumers. Furthermore, water efficient rating of washing machine is not yet available to the Malaysian consumers. Water-efficiency information or rating similar to that of Energy Star labeling would be able to create market incentives for manufacturers to design not just energy but water efficient washing machines.

The rate of technological advancement has been profound in all fields including domestic products. Consumers are confronted with an ever increasing number of choices with respect to product brands, models, design, prices and features. They are overwhelmed by the diversity and availability of choices that confront them. In these circumstances, the consumers are in dire need of assistance that can facilitate them in making informed choices. Consumer assistance should be provided by concerned parties such as the retailers, manufacturers, government and neutral bodies (such as consumer

organizations, education institutions) to enable purchase decisions be made wisely. Data on comparative testing of product features and performance as being presented here could provide some valuable information towards making insightful purchase decisions.

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