Plastic Recycling Awareness among Students at UC Berkeley

Rachel Abramson

Abstract Plastics are the fastest growing portion of municipal solid waste. Out of the 22.4 million tons of plastic produced in 1999, only about 5.6% were reused. Plastic packaging purchases by the individual consumer have increased four times faster than plastic recycling by the consumer. Using recycled plastic to manufacture new plastic products can reduce the energy needed for production by about 80%. In order to increase plastic recycling, current environmental attitudes and recycling awareness must be considered as obstacles. This study analyzed the differences in awareness of plastic recycling between students living in residence halls and students in cooperative housing at UC Berkeley, with the hypothesis that students who live in cooperative housing have a higher awareness than students living in residence halls. Awareness was further subdivided into five categories: plastic recycling in Berkeley, plastic recycling codes, energy savings, water use, and recent public policy. This study found that students living in cooperative housing had a higher overall awareness. However, the two populations had a similarly low level of awareness for each of the five subcategories. This highlights the need for a better educational campaign in regards to plastic recycling.

Introduction

Plastics have improved the health, safety, and efficiency of everyday life. With their unique qualities of lightweight and strength, plastics are used in packaging, automotive applications, medical systems and more (Subramanian 2000). The versatility and low cost of plastics have contributed to plastic's displacement of other materials, such as glass and paper, causing an increase in plastic production at a rate of about 5% per year since 1973 (IWMB 2003). Plastic provides both structural and insulating qualities and reduces the amount of material needed to support a product while still maintaining the functions of packaging (IWMB 2003). As a result, plastic sales have reached more than 50 million tons in 2000, up from 30 million tons in 1990 (IWMB 2003). U.S plastic resin sales–which are used in packaging (26%), building and construction (22%), consumer and institutional (14%), exports (10%), and transportation (5%)(IWMB 2003)–have increased from 6 billion pounds in 1960 to 108 billion pounds in 2000 (Plastic Debris 2005).

However, the many different uses of plastic make it difficult to handle as waste (IWMB 2003). A typical postconsumer product contains up to 20 different types of plastic materials in addition to non-plastic material (EPA 2002). This complicates the first step of a complete recycling scheme- identification, separation, and classification (Santos *et al* 2005) –as it is difficult and time consuming to separate plastic based on density, shape, and color (Poulakis and Papaspyrides1997) when a single product contains multiple types of plastic.

This difficulty in recycling is more critical since plastic is the fastest growing portion of municipal solid waste (IWMB 2003). Nearly 50% of the plastics created in 1999 were dumped in landfills (IWMB 2003). Out of the 22.4 million tons of plastic produced, only about 5.6% were recovered (EPA 2001, EPA 2002). Because of plastics' light unit weight to volume ratio, they take up approximately twice the percentage of volume when compared by weight (IWMB 2003). It is not known exactly how long plastic wastes will take up this extra space in landfills (IWMB 1992) due to their slow decomposition. For example, Type 6 plastic disintegration is estimated to take from hundreds to thousands of years to decompose (IWMB 1992). In sum, the manufacturing of plastic continues at a significantly faster pace than recycling (IWMB 2003). Considering plastic packaging alone, sales to consumers are increasing four times faster than recycling by the consumer (IWMB 2003). The rate of plastic recycling has stagnated at a low level (IWMB 2003).

Since more than 95% of the total energy needed to make one kilogram of plastic is used in extraction and refining (IWMB 2003), plastic recycling significantly reduces fossil fuel consumption (Shent *et al* 1999) by avoiding these stages. This is particularly beneficial given that these stages use energy from burning fossil fuels, which releases pollutants such as sulfur, dioxide, nitrogen oxide, and carbon monoxide into the air (EPA 1998). Manufacturing plastic products from recovered materials to produce a new product can reduce the amount of energy needed by about 80% (EPA 1998), resulting in savings of 50-75 mBtu of energy per ton of material recycled compared with the production of virgin materials (EPA 2002). The energy saved from recycling four kinds of plastic is equivalent to 150-200 gallons of gasoline per ton of plastic recycled (IWMB 2003). Plastic recycling conserves energy while also making a significant reduction in the total volume of municipal solid waste (Shent *et al* 1999). Compared to the use of virgin plastic, manufacturing plastic from recovered materials results in a net reduction in 10 major categories of air pollutants: aldehydes, ammonia, carbon dioxide, carbon monoxide, hydrocarbons, methane, nitrogen oxides, other organics, particulates, and sulfur oxides; and 8 major categories of water quality indicators and pollutants: biochemical oxygen demand, chemical oxygen demand, dissolved solids, iron, metal ions, oil, sulfuric acid, and suspended solids (EPA 1998).

However, research has shown that plastic recycling uses large amounts of water, exceeding the reduced emissions of pollutants in water, to remove impurities from the plastic (Santos *et al* 2005). These impurities are then washed into the effluent, requiring the recycling facility to treat the effluent before discharge (Santos *et al* 2005). Yet the levels of solids, high pH, oil and grease in the effluent can easily be decreased by simple physical-chemical treatments such as preliminary tanks which remove solids heavy enough to sink to the bottom of the tanks (Santos *et al* 2005).

There are significant expenses in plastic recycling programs, but the weight of the evidence suggests that plastic recycling has important economic benefits. In the past there was little market demand for recycled plastic since virgin plastic, plastic containing no recycled material, was priced so low (Subramanian 2000). Also, plastic recycling is expensive since standard collection and processing costs are more than twice as high as scrap values (IWMB 2003). Since plastic must be largely homogeneous to recycle, manufactures and recyclers face large sorting costs (Lea 1996). But as new technologies make reprocessing plastic easier and cheaper, it is becoming more cost effective for industries to use recycled plastics (IWMB 1992). Operation costs for processing recycled plastics are now estimated at 10-20 cents per pound, making them competitive with the costs for manufacturing virgin plastics (EPA 2002). These lower costs for recycled plastic can increase the market demand for recycled plastic (Ambrose *et al* 2002). Also, the increasing price of oil makes plastic recycling more cost competitive. Virgin plastic production consumes 4% of American oil use (Graham 2006), which is equivalent to more than 300 million barrels of crude oil in 2007 (EIA U.S. total…2008). With current oil prices of $108.98 per barrel (EIA world crude…2008), the United States spends almost $33 billion producing virgin plastic. Plastic recycling would reduce this cost. In addition to substantial cost savings, two studies from California found that recycling creates 4.7 jobs per 1000 tons while disposal only creates 2.5 jobs per 1000 tons (IWMB 2003).

To increase consumers' plastic recycling, environmental attitudes and awareness must be considered (Davis *et al* 2006). To analyze attitudes and awareness, a theoretical framework for understanding a person's recycling behavior was required (Davis *et* al 2006). The Theory of Planned Behaviour is a theoretical framework for systematically analyzing the issues that influence behavioral choices (Davis *et al* 2006). It has been extensively used to analyze behaviors such as driving violations (Parker *et al* 1992), shoplifting (Tonglet 2002), and dishonest actions (Beck and Ajzen 1991). The Theory of Planned Behaviour has also been used to study behavioral choices such as recycling plastic (Davis *et al* 2006). It states that people's attitudes and awareness are large determinants of their behavior (Davis 2006). To test individuals' awareness of plastic recycling, one must first assume that people have a rational basis for their behavior concerning plastic recycling (Davis *et al* 2006). The immediate determinant of an individual's behavior in regards to plastic recycling is the individual's intention to recycle or not (Davis *et al* 2006). The intentions of the individual are influenced by their favorable or unfavorable attitude towards recycling, their view of social pressure to recycle, and their view concerning their ability to recycle (Davis *et al* 2006). Other factors such as personality and demographic characteristics influence the individual's recycling behavior, but the influence is indirect and controlled through the components of the Theory of Planned Behaviour since they manifest in the individual's attitude towards recycling (Davis *et al* 2006). The main inhibitors of an individual's willingness to recycle are apathy, self-centeredness, vulnerability, apprehension, and belief that technology will fix everything (Owens and Halfacre-

Hitchcock 2006). While the Theory of Planned Behaviour states that convenience influences a person's recycling behavior, this study theorizes that the societal pressure a person feels to clean up their environment is larger than any personal cost such as timeliness and inconvenience. Using the Theory of Planned Behaviour (Davis *et al* 2006) and the assumption that the cost to society in failing to clean up their environment is greater than the cost in taking the time to clean it up (EPA 1973), this study assumes that people would recycle if made aware of recycling options.

This study analyzes the awareness of plastic recycling between students living in residence halls and students in cooperative housing at UC Berkeley. Universities and colleges are important in educating and influencing individuals on issues concerning sustainability such as plastic recycling (Owens and Halfacre-Hitchcock 2006). Policies are often implemented at colleges to promote environmental practices like recycling (Owens and Halfacre-Hitchcock 2006). In the United States, colleges and universities annually spend over $250 billion combined promoting sustainability (Owens and Halfacre-Hitchcock 2006).

The city of Berkeley, an active proponent of recycling plastic, has passed legislation prohibiting plastics with little recyclable value; such as expanded polystyrene containers (Verespej 2007, associated press) which produce ozone depleting gasses during manufacturing and is primarily used in single-use products (IWMB 1992). Berkeley recycles type 1 and type 2 plastics, which consist of items such as milk and beverage containers (Alameda County Waste Management Authority 2007). These plastics represent the most practical components of the plastic recycling process due to their ease of separability, market availability to the individual consumer, and their large concentration in municipal solid waste (Barlaz *et al* 1993). In 1992, over 84% of the 938.5 million pounds of plastic recycled was type 1 and type 2 plastic (EPA 2003). Previous research concerning plastic recycling focused on recycling processing and policies instead of consumer awareness. But public awareness must be determined in order for any recycling program to be successful in terms of consumer participation. With increasing participation and the ongoing technological innovations, plastic recycling can become even more efficient.

There are different recycling programs for students at UC Berkeley. The Campus Recycling and Refuse Services (CRRS) manage Residence Halls' recycling services. Services for recycling plastic consist of recycling chutes or rooms inside the building (CRRS Recycling in… 2007).

The Campus Recycling and Refuse Services employs a Recycling & Refuse Manager, a Recycling Operations Supervisor, Truck Drivers, and Equipment Operators (CRRS about us 2007). None of these workers live in the Residence Halls and they have no direct contact with the students. In contrast, Cooperative housing has a waste reduction manager living in each house who is responsible for recycling education (University's Student's Cooperative Association Recycling in… 2007). Cooperative housing often promotes education and community service projects concerning sustainability and environmental issues such as restoring Strawberry Creek (USCA Recycling in…2007). Since The Theory of Planned Behaviour states that the pressure a person feels to recycle is a large determinant of their recycling activity (Davis *et al* 2006), it is logical that plastic recycling awareness is higher in Cooperative Housing because students interact directly with their waste reduction manager.

The objective of this study is to see if there is a significant difference of overall plastic recycling awareness between students living in cooperative housing and residence halls at U.C. Berkeley. For this study, the overall awareness is divided into five categories: plastics that are recyclable in Berkeley, plastic recycling codes, energy savings from plastic recycling, water use and plastic recycling, and recent public policy regarding plastic recycling. My hypothesis is that students living in cooperative housing will not only have a higher overall awareness regarding plastic recycling, but they will also have a higher awareness in each of the five subcategories than students living in residence halls. The findings of this project are important because they will determine whether individuals do not recycle plastic because they are unaware of available services, or because the make a choice not to recycle.

Methods

This study consisted of conducting 100 surveys in two different populations: residence halls and cooperative housing. For the population representing residence halls, I administered 50 surveys at Unit One. Unit One consists of Cheney Hall, Deutsch hall, Putnam Hall, Freeborn Hall, Christian Hall, and Slottman Hall (Unit 1). There are approximately 1380 students in Unit One (Unit 1). Since all Residence Halls share similar characteristics, I chose Unit One to represent the Residence Hall population. Because it is a block from campus, Unit 1 would have many students coming and going from campus (Unit 1). For the group representing cooperative housing I administered 25 surveys at Cloyne Court and 25 surveys at Casa Zimbabwe. These are the two largest cooperative houses, 124 students in Casa Zimbabwe (USCA Casa Zimbabwe) and 148 students in Cloyne Court (USCA Cloyne), and therefore would have a wider range of students than a smaller cooperative house.

The surveys were done on weekdays from 5-6 p.m. and weekends from 7-8 p.m. I assumed that students would be either returning home from class or leaving Unit One for dinner at these times. The weekdays and weekends did not contain any holidays.

In order to gain access to students, I conducted my surveys in the lounges and common space of the Residence Hall and cooperative housing. These spaces share similar characteristics, as they are places where students voluntarily gather.

The surveys consisted of five categories: awareness of plastics that are recyclable in Berkeley, awareness of plastic recycling codes, awareness of energy savings from plastic recycling, awareness of water and plastic recycling, and awareness of public policy concerning plastic recycling (Appendix I). Right answers were assigned one point, and wrong answers or no answers were given no points.

My null hypothesis was that there is not a significant difference between the population of students living in residence halls and the population of students living in cooperative housing. The alternative hypothesis was that there is a significant difference.

To test for overall awareness, I used a two sample, two-tailed T test. I calculated the averages for all of the surveys from each population, and used that information to perform the T test. The result of the T test told me whether I could reject the null hypothesis or not. To test for awareness regarding the five subcategories, chi-square analysis was used since it is the best statistical analysis when comparing two samples with categorical outcomes.

Results

Overall Awareness Overall awareness of plastic recycling is significantly higher in cooperative housing than in residence halls ($t= 3.85$, 2-tail, $p= 0.0002$). See Figure 1.

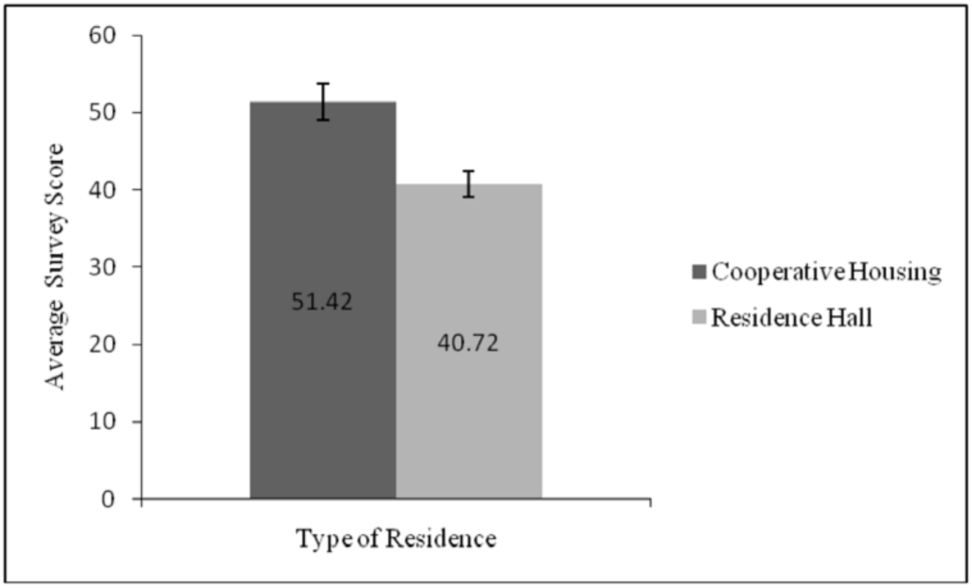

Figure 1 Average Survey Score for students in Cooperative Housing and Residence Hall

Plastics that are Recyclable in Berkeley There was no significant difference regarding awareness of what plastic is recyclable in Berkeley between students in residence halls and students in cooperative housing (Appendix I, Question 4, chi-square 0.77, p-value 0.3802). See Figure 2.

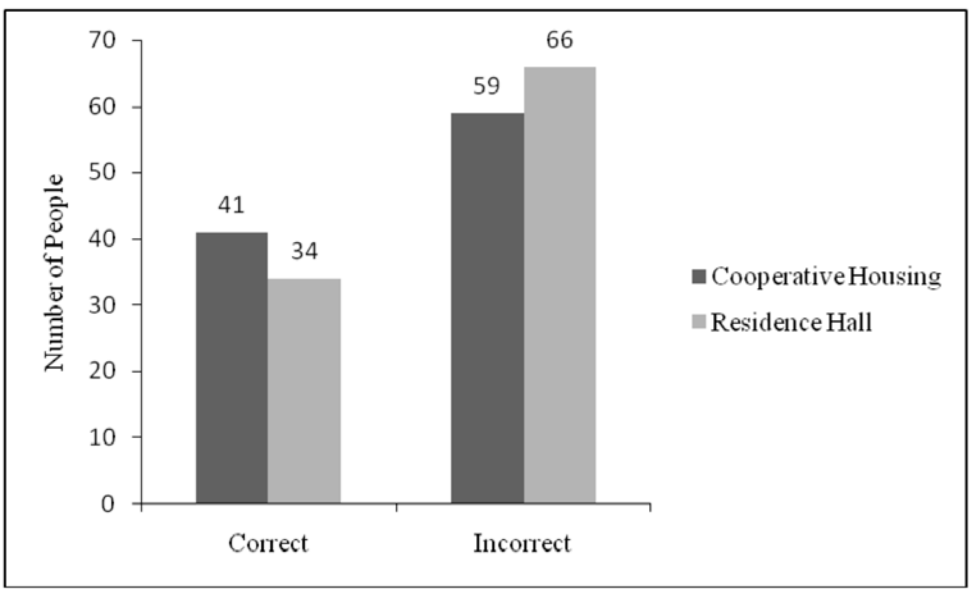

Figure 2 Awareness of plastics that are recyclable in Berkeley

Plastic Recycling Codes There was no significant difference regarding plastic recycling codes between students in residence halls and students in cooperative housing (Appendix I, Question 5, chi-square 0.52, p-value 0.4798). See Figure 3.

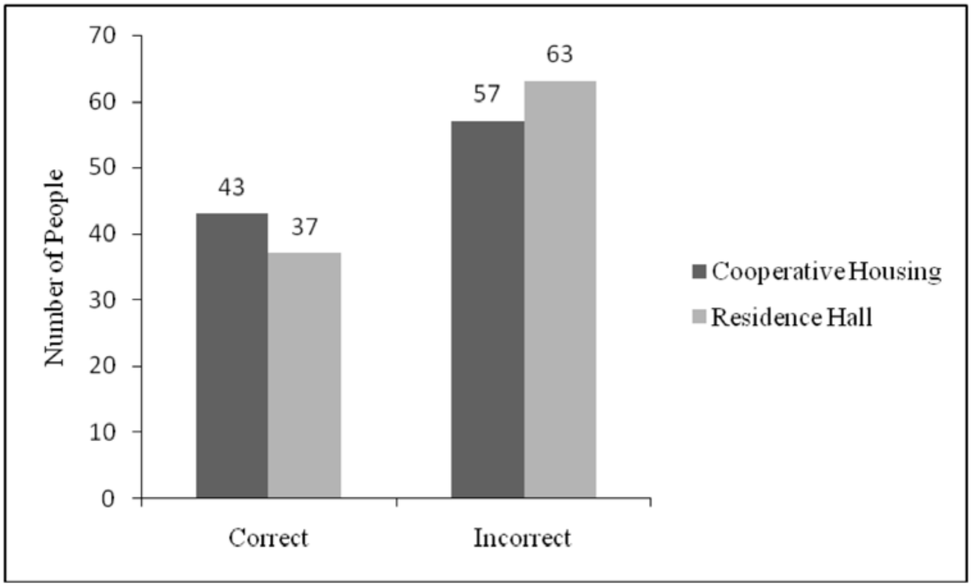

Figure 3 Awareness of plastic recycling codes

Energy Savings There was no significant difference in awareness regarding energy savings from plastic recycling (Appendix I, Question 6, chi-square 2.12, p-value 0.1454). See Figure 4.

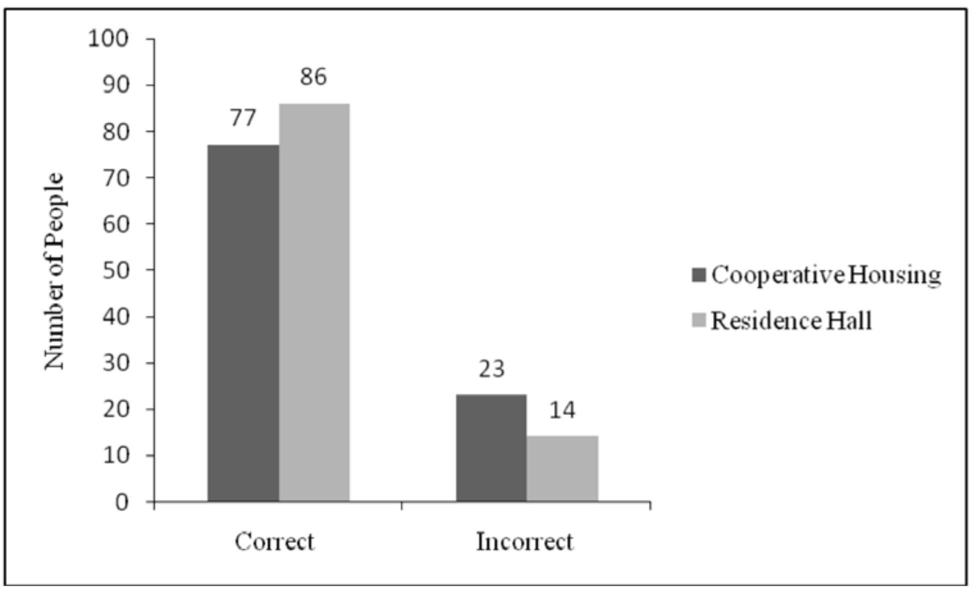

Figure 4 Awareness of energy savings

Water Use There was no significant difference in awareness of water use and plastic recycling (Appendix I, Question 7 and Question 8, chi-square 0.11 and 0.15, p-value 0.7401 and 0.6985). See Figure 5 and 6.

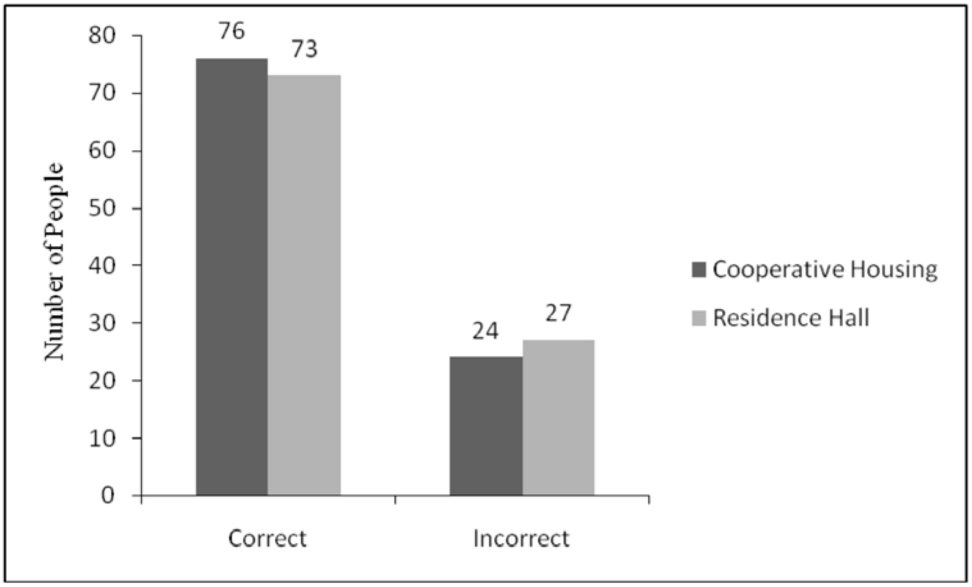

Figure 5 Awareness of water use and plastic recycling (Question 5)

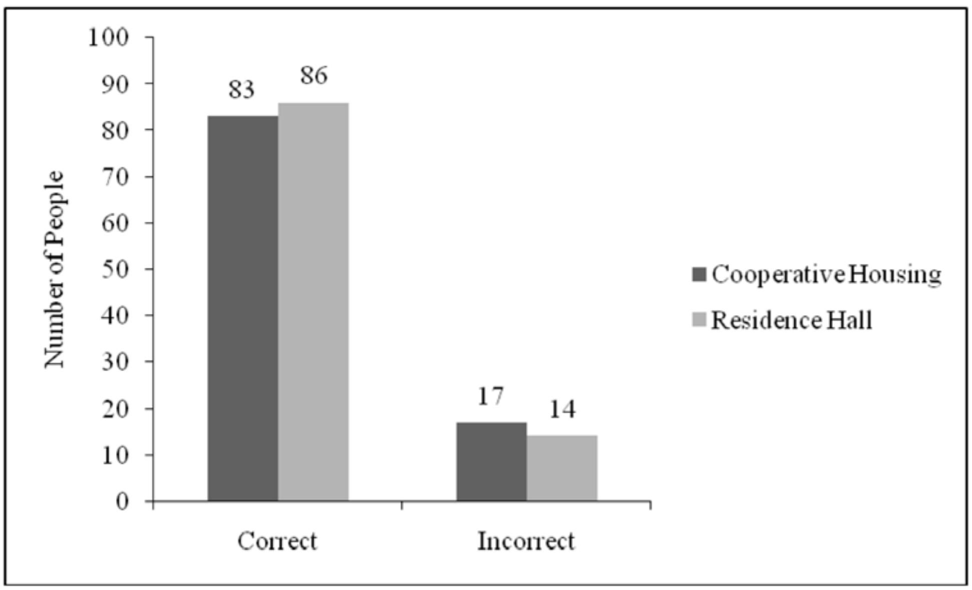

Figure 6 Awareness of water use and plastic recycling (Question 6)

Public Policy There was no significant difference in awareness of public policy concerning plastic recycling (Appendix I, Question 9, chi-square 3.01, p-value 0.0797). See Figure 7.

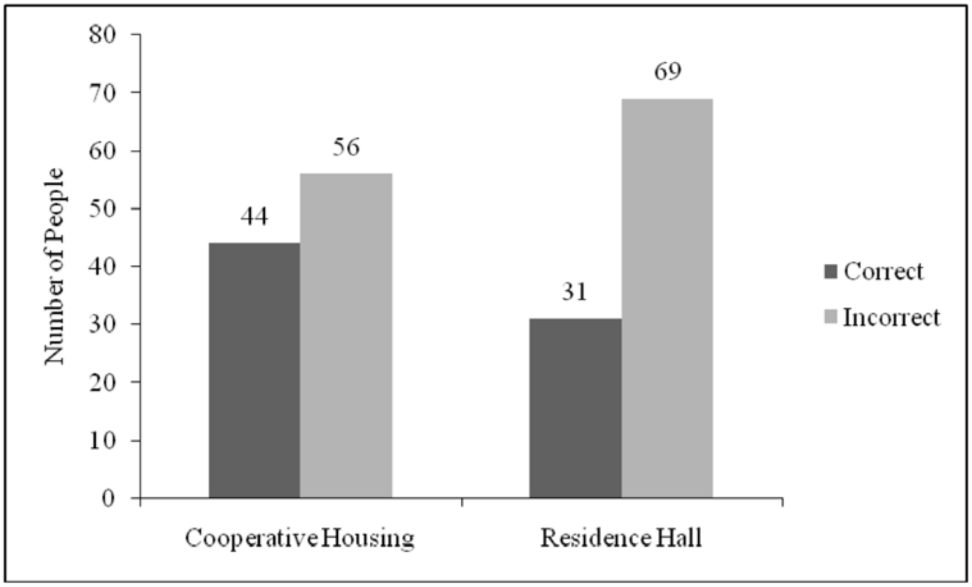

Figure 7 Awareness of recent litigation

Plastic Recycling Activity Appendix II provides the plastic recycling participation of the students in cooperative housing and the residence hall (Appendix II, chi-square 5.76, p-value 0.1239).

Score Distribution Comparison between the two Populations Appendix III provides a comparison of the percentage of students in each population for a given score.

Discussion

The results of the statistical analysis indicate that students living in cooperative housing have a significantly higher overall awareness of plastic recycling. But when this general knowledge is broken down into categories, the two populations have an insignificant difference in awareness.

While students in cooperative housing have a significantly higher awareness, Appendix III shows that their absolute level of awareness is low. Approximately 80% of the students in both populations scored less than 60% on the survey (See Appendix III).

I overestimated the influence of the social interactions students in cooperative housing have with the waste reduction manager. Many students in cooperative housing stated that even though they lived with a waste reduction manager, they never talked to the manager concerning recycling.

I used two part questions in regards to energy savings and water use. The first part was a simple yes or no question, and the second part required knowledge of precise information. In my statistical analysis, I only counted the yes or no answer. Due to the precise nature of the second part of the question, I expected that many of the correct responses would be from guessing rather than the student's awareness. This is why I did not use the information in my statistical analysis. The more detailed questions enabled me to gauge what the student's opinion was concerning plastic recycling. Question 6a asked the students how much energy is saved from making plastic with recycled materials. The majority of the responses from both populations were 40%, where the correct answer as 80%. Question 7a asked how much freshwater is needed to treat plastics before recycling. The majority of the responses from both populations were 10 liters of water per 500 mg recycled material; the correct answer was 2 liters of water per 500 mg recycled material. This implies that the current attitude towards plastic recycling is that it is not energy efficient and requires large amounts of freshwater. Since environmental attitudes are a large determinant of recycling behavior as well as awareness (Davis *et al* 2006), students' negative attitude towards plastic recycling could be preventing them from being efficient recyclers.

There are potential biases and problems with this study. There could be bias if students that are more environmentally aware are more likely to choose cooperative housing. This means that the data may reflect a self-selection bias rather than the effect of the recycling coordinator. Also, students may actively recycle, but not be informed on the issues of plastic recycling. Question 2 measured the difference in plastic recycling activity between students in cooperative housing and residence halls. In regards to how often they recycle plastic the majority of the responses from both populations were "usually". In light of the lack of awareness found regarding recyclable plastics, these students are probably inefficient recyclers. Even if they recycle, they may recycle any plastic that would increase the city's sorting costs.

UC Berkeley spends a significant amount of money promoting recycling. In 2001 it spent $10,500 to purchase 6,000 mugs for the Reusable Mug program (Recycling Summit 2003). The University also created a Student Recycling Education Coordinator (SREC) whose goal is to educate the students about the value of recycling and how and where they can recycle, which involved a $30,000 start up cost and an additional $10,000 annual expense (Recycling Summit 2003).

The findings of this study are important because they indicate that while the University spends significant amounts, current recycling education and programs are insufficient. The majority of students in the survey did not know what kinds of plastics were recyclable in

Berkeley, and what plastics corresponded to each plastic code. The University could save money if it promoted awareness more efficiently. This may mean that the University has to alter current programs and positions such as the Student Recycling Education Coordinator.

Past studies regarding plastic recycling are mostly concerned with public policy and the technical efficiency of recycling (Santos *et al* 2005, Barlaz *et al* 1993, Lea 1996). Studies that have dealt with social behavior in terms of recycling have often been abstract and relied heavily on psychological theory (Davis *et al* 2006). And studies that have dealt with the ability of colleges and universities to influence environmental behavior refer to sustainability in general and are done on the national level (Owens, K. and A. Halfacre-Hitchcock. 2006). This study was original in that it analyzes whether there is a difference in recycling knowledge based on where a student lives in a university.

From the results of this study, I would recommend that students carry out recycling education programs. The low level of awareness of students living in Residence Halls may be because students are removed from recycling educators. Also, not only should these student educators live among the students, but also they must also actively and continuously teach recycling. The low level of awareness of students living in Cooperative Housing could be due to a lack of discussion with their waste reduction managers.

. To further assess the awareness of the public, the population analyzed by the study should be expanded to the entire community of Berkeley. Future studies should also focus on the effectiveness of recycling programs as well as the population's awareness. Technical and political measures in terms of recycling will not succeed without a higher level of awareness among the public.

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Appendix I

Plastic Recycling Survey

1. I currently live in
    a. Residence Hall
    b. Cooperative Housing
2. Do you recycle plastic?
    a. Always
    b. Usually
    c. Only when it's convenient
    d. Never
3. Does the city of Berkeley provide plastic recycling?
    a. Yes
    b. No
4. Plastic containers carry a number code on them. Circle the types of plastic Berkeley recycles

5. Which plastic number code represents the following image:

6. According to the Environmental Protection Agency, do manufacturing plastic products from recovered materials *significantly* reduce energy in terms of fossil fuel consumption for extraction and processing?
    a. Yes
    b. No

6a. Approximately how much energy is saved when making a plastic product from recycled materials?

a. 20%
b. 40%
c. 60%
d. 80%

7. Do the *majority* of plastics require the use of freshwater to remove harmful toxins before they can be recycled?

a. Yes
b. No

7a. For the plastics requiring freshwater treatment, approximately how much freshwater is needed relative to amount of recycled material?

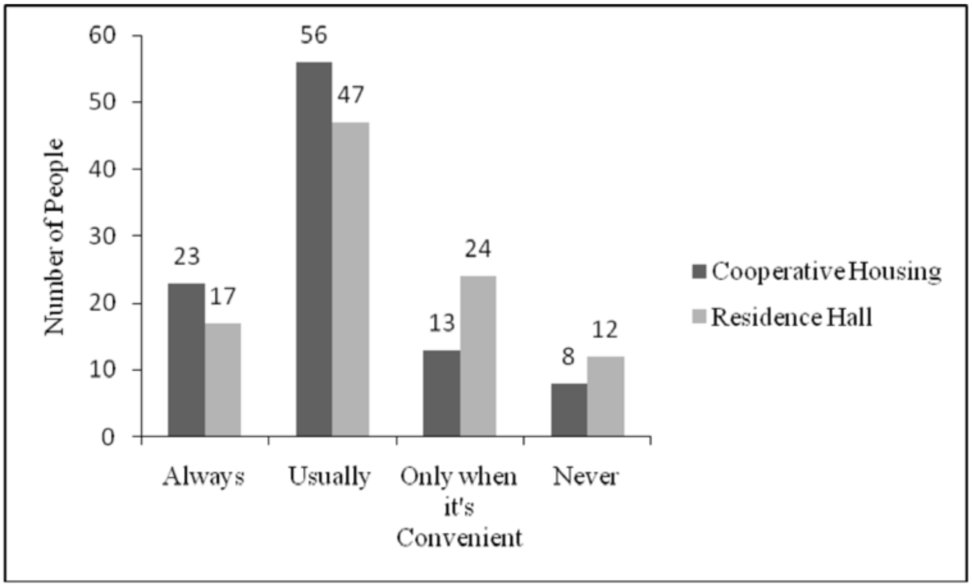
a. 2 liters of water per 500 grams of recycled material
b. 5 liters of water per 500 grams of recycled material
c. 10 liters of water per 500 grams of recycled material
d. 15 liters of water per 500 grams of recycled material

8. Does plastic recycling result in net reductions of air and water pollutants?

a. Yes
b. No

9. Which type of plastic is currently banned in the city of Berkeley?

Appendix II



Plastic Recycling Participation of the sample of both populations

Appendix III