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Evaluation of Durability of Nonwoven Polypropylene Grocery Bags Under Routine Use

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EVALUATION OF DURABILITY OF NONWOVEN POLYPROPYLENE GROCERY BAGS UNDER ROUTINE USE

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ABSTRACT

Recently, the thin plastic-film bags distributed at thousands of checkouts across the United States have been targeted by environmental advocacy groups as wasteful nuisance packaging, and many places have passed legislation to ban or restrict their distribution. The resulting demand for a more durable grocery bag able to withstand reuse has led to a rise in popularity for bags made from fabric, and the relative durability and low cost of nonwoven polypropylene fabric has made it a popular choice of material.

However, studies have shown that these bags come with their own set of issues: their reusability makes them a vector for cross-contamination, and many consumers do not reuse their bags enough to recoup the additional cost of materials and energy needed to create the thicker material. Many of the bag laws offer guidelines for determining if a given bag officially qualifies as "reusable," but at this time, virtually no data exists regarding the real-world durability of nonwoven polypropylene bags.

To test whether they could handle the real-world wear-and-tear, 40 nonwoven polypropylene bags were loaded with grocery items and carried by hand for 125 repetitions of 175 feet, with half of the samples undergoing machine-washing every 25 repetitions to determine if washing would affect the durability of the bag. Additionally, 80 bags were tested with the mechanically-assisted ATP-001 testing protocol suggested by the Los Angeles County Department of Public Works, to see if it could serve as an acceptable alternative to the physically-intensive walk test. Half of this sample was also washed, to see if this had an effect on lifespan.

All 20 of the unwashed, hand-carried bags withstood at least 50 reuses, and 12 out of 20 of them withstood the required 125 reuses necessary to meet the most strenuous definition of reusable bag required by various municipal laws. Washing did appear to result in a lower lifespan, with only 7 of the 20 bags able to withstand both 125 reuses and 5 machine-wash cycles. The ATP-001 tests, conducted with slightly different criteria for failure, resulted in similar rates of success, with 23 out of 40 unwashed bags and 14 out of 40 washed bags able to withstand testing.

DEDICATION

This work is dedicated to the curious minds and inquisitive spirits who refuse to settle for “the way it is” and feel driven to make their mark on the world.

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Finally, thanks to parents for supporting me throughout my higher education, and my wife Jennifer for knowing when to providing emotional support and the occasional kick in the pants needed for me to move forward.

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CHAPTER ONE

INTRODUCTION AND JUSTIFICATION

The environmental impact of single-use plastic goods, such as grocery bags, has become a significant issue around the globe. Recently, many municipalities in the United States have followed the lead of countries like Bangladesh and China in enacting legislation to discourage or prohibit the complimentary distribution of thin film plastic bags—commonly referred to as "disposable" or "single-use" bags—at points of purchase. These laws range from levying fees for each bag distributed, to total bans on bag distribution and fees or fines against grocery stores for noncompliance (Environment Australia, 2006). The stated purpose of these laws is often environmental, with a focus on reducing fossil-fuel consumption, landfilling, pollution due to improper disposal, or a combination thereof. Many laws also include guidelines to determine what constitutes a "reusable" bag versus a "single use" one, including material thickness and mechanical tests of durability.

This targeted reduction of single-use bags opens up a space in the market for an alternative method of carrying groceries. Coinciding with efforts to reduce or eliminate "disposable" bags is a rising market of heavier-duty bags intended for multiple reuses, which exceeded $1bil in imports in 2014. (International Trade Commission, 2015). One of the most common fabrics for manufacturing these durable bags is nonwoven polypropylene, likely owing to its cost effectiveness due to high yield-per-cost; i.e., at a given price point, NWPP provides more fabric than any other spunbonded polymer

(Dahiya, 2004). These bags can be recognized by their waffle-like texture and single-layer construction (i.e., no coating on the outside or “backing” on the inside), and commonly retail for $1.25 or less (Kimmel et al., 2014).

While these heavier-duty NWPP bags can withstand multiple reuses, life-cycle assessments (or LCAs) reveal that they also have a greater environmental cost in comparison to HDPE film bags (Muthu and Li, 2004; Kimmel et al., 2014). Reusable NWPP bags are made from a heavier thickness of plastic than standard bags, which means each reusable bag requires a greater amount of both material resources and energy usage in conversion, and occupies a greater footprint in a landfill upon disposal. Thus, if NWPP bags are to offer a measurable environmental benefit, they must be durable enough to withstand a number of reuses equivalent to their larger footprint. Yet despite the presence of test methods to define bag durability (such as the Ecologo ECS ATP-001, or the “walk tests” specified by the Los Angeles bag ban), there are little data to determine whether NWPP bags can truly fulfill the definition of “reusable bags” as set by county and local governments, and whether they can withstand enough reuses to truly represent a durable and sustainable alternative to HDPE film bags.

Additionally, reusability introduces the risk of cross-contamination between loads. Experts recommend washing bags between uses (Gerba et al., 2014), but machine washing represents significant strain on fabric, and may shorten the lifespan of the bag, hurting its net environmental impact.

Therefore, this study was proposed to test the durability of these bags by subjecting them to the walk test; to gauge the reliability of the Environmental Choice

ATP-001 procedure in predicting lifespan; and to determine if machine-washing affects the durability of these bags.

CHAPTER TWO

LITERATURE REVIEW

An understanding of the properties that make nonwoven polypropylene as a reusable alternative to single-use bags begins with an overview of the manufacturing process and how it relates to the properties of the material.

MANUFACTURING OF NON-WOVEN POLYPROPYLENE

As with most other commodity polymers, the life cycle of polypropylene begins with fossil fuels. This section will explain conversion from fossil fuels such as petroleum and natural gas, to polymerization, extrusion, and laydown.

Petroleum-based derivation

Petroleum is desirable as an organic material source because of its concentration of hydrocarbons, molecules which make up the backbone of engine fuels, lubricants, and raw material for the manufacture of plastics. By weight, over 90% of the raw crude is hydrocarbon chains of varying lengths and arrangements; the remainder includes water, salts, and trace amounts of organic solids and water-soluble metals. Before further refining, these impurities are removed to prevent damage to the equipment or contamination of the catalysts.

After removal of these contaminants, the desalted petroleum is heated in preparation for fractional distillation, which separates the various hydrocarbon chains by molecular weight. Since shorter-chain hydrocarbons, including propene (C_3H_8), have relatively low vaporization temperatures, they will rise to the top of the chamber and be drawn off for further separation into homogenous fractions for further processing.

Heavier, longer-chain polymers can also be converted into smaller molecules via “cracking.” Cracking typically involves intense heating of the molecules to force vaporization while starving the ambient air of oxygen to prevent combustion, and can include catalysts to improve yield. Similar to before, the resultant short-chain molecules are separated into homogenous fractions for further processing.

Natural Gas-based Derivation

Natural gases are the other primary source of hydrocarbons for use as fuel and polymer-making feedstock. For gas reservoirs coincident with petroleum deposits, the raw mixture is processed by repeatedly heating and cooling it to force any petroleum in the mixture to condense and separate from the gas. The remaining gas is then pressurized and passed through a series of chambers to separate out condensate, particulate matter, water, and non-hydrocarbon gases, all of which could contaminate or damage pipelines and machinery if allowed to enter the system.

Once the stream of gas is purified, it is taken in at a refinery and, similar to petroleum, undergoes fractional distillation to separate the mixed-length hydrocarbon chains into homogenous fractions for further treatment. The lighter weight distillates may contain propene ready for processing, while fractions with heavier, longer hydrocarbon chains can be “cracked” into shorter molecules.

From Monomer to Polymer Resin

Once the propene monomer has been isolated, it is ready to be polymerized. The monomer is usually exposed to a catalyst—either a Ziegler-Natta catalyst containing titanium (IV) chloride and aluminum alkyls, or a metallocine-based catalyst—to induce a breaking of the double bond and allow the molecules to develop into extended polymer chains ("Polypropylene"). In order to terminate polymerization, the mixture is exposed to water, dissolving the catalyst and causing the polymer to precipitate as tiny pellets of polypropylene resin ("Polymers: An Overview"), which represents the feedstock for the next step.

Extrusion and Spunbonding

Similar to plastic films, the polypropylene resin is first melted, and then extruded; in this case, the die is an arrangement of tiny metal holes, called "spinnerets," with multiple spinnerets making up a single "block." As the melted resin exits the spinnerets and becomes exposed to the air, it begins to solidify into numerous thin, threadlike strands. In order to induce lengthwise orientation in the polymer chains, the still-cooling filament is stretched downward either pneumatically (as through a venturi tube) or mechanically (as by a windup roll). Immediately before laydown, bundles of these individual strands are entangled to ensure a random, intertwined arrangement of fibers on the web. The conveyors are designed to be permeable, and may include a vacuum system underneath the mesh belt to encourage laydown (Dahiya, et al., 2004). Finally, the fibers are bonded together in one of three ways: needlepunch, chemical bonding, or thermal bonding. The fabric for NWPP bags is usually thermally-bonded, using heated calender rolls with an embossed pattern to provide the “waffle-weave” appearance, and collected into a finished roll at the end (Rupp, 2008).

Mechanical Characteristics of NWPP fabric

Microstructure Properties: The randomized laydown of material onto the web results in isotropy (i.e., consistent material properties regardless of the direction of the sample) due to a lack of strong “orientation.” This has been confirmed at microscopic levels; while strands may occasionally cluster together and partially fuse under the pressure and heat of manufacturing, they lack a specific alignment and show an “isotropic microstructure” (Ridruejo et al., 2010). Compared to their woven counterparts, nonwoven fabrics have a lower stiffness and strength, but higher energy absorption and deformation due to the lack of strong orientation, as curved fibers are able to straighten further than fibers already pulled straight during orientation.

Nonwoven polypropylene has also been found to demonstrate “notch-insensitive” behavior, even under strain; since the arrangement of fibers on the web is fairly random, linear disturbances like tears and slits are unable to create a fault line and their propagation is interrupted by crosswise strands. This is especially useful for stitching the panels together, since it prevents the stitch holes from weakening the entire fabric.

Deterioration mechanisms

Ridruejo, et al., found that damage began occurring at low strain levels when the initial bonds between the randomly-aligned fibers were pulled apart, resulting in a loss of fabric stiffness and reorientation of fibers. After reaching maximum load, the continued strain began to cause a "fracture zone." Around this fracture zone, the fabric began to thin out, leaving a hole where the fibers perpendicular to the load direction separated from each other while only load-direction fibers remained. Increasing the strain rate was found to increase strength and decrease ultimate strain and energy-absorption, but did not "substantially alter" the mechanisms of fracture.

Materials tests

In conducting their LCA, Muthu and Li analyzed the tensile strength, tear strength, and bursting pressure of the bags they tested, including three separate grammages of NWPP fabrics.

	Grammage		
	40 g/m^2	**75 g/m^2**	**100 g/m^2**
Tensile strength (max load)	~140 newtons	~220 newtons	~220 newtons
Tear Strength	~25 newtons	~30 newtons	~30 newtons
Mullen Burst Pressure	~30 PSI	~40 PSI	~75 PSI

Table 2.1: Results of Material Property Tests

Increasing the grammage of the fabric used in the bags seems to have a positive effect on its strength properties, although the effect does not seem to be predictable; the increase from 40 g/m^2 to 75 g/m^2 greatly increases the tensile strength (e.g., stretching apart at both ends) but causes little increase in resistance to bursting, while the increase from 75 g/m^2 to 100 g/m^2 nearly doubles burst strength but fails to noticeably improve tensile strength.

Health and Hygiene Issues

Survey of foodborne illness pathogens present in reusable bags

The reusability of NWPP bags also carries with it the risk of pathogenic transmission, as some raw foods can contain pathogens responsible for food poisoning and other sicknesses (“Food Safety Tips,” 2011). In order to better understand the potential for disease transmission by these bags, Dr. Ryan Sinclair of Loma Linda University, and David L. Williams and Dr. Charles Gerba of the University of Arizona collaborated to conduct a study on whether reusable shopping bags could harbor pathogens between uses. Reusable shopping bags were collected from approximately 30 shoppers at three separate locations: San Francisco, Los Angeles, and Las Vegas. Heterotrophic plate counts of bacteria were conducted on them, comparing the results to control samples of newly-purchased, unused NWPP bags and unused HDPE film bags distributed at the point of purchase.

In the unused bags, no bacterial growth was detected. However, a significant count (>30 colony-forming units, or CFUs) of bacteria was found in all but one of the reusable bags taken from consumers. Coliform bacteria, which are commonly used as indicators of pathogens and fecal contamination, were found on 51% of bags; *Esherichia* *coli*, a coliform with strains known to cause food poisoning, was found in seven bags (8% of samples).

Potential for Cross-contamination of Food Products by Reusable Shopping Bags

Since many bags are left in car trunks between uses, the study also tested the effect of storage in a car trunk for two hours on bacterial population. The first sample, stored in 47°C, experienced a tenfold growth in CFUs, while the second, stored at 53°C, showed slight decrease. While these results do not conclusively indicate that the trunk conditions encourage bacterial growth, they do indicate that the fabric does not have intrinsic antibiotic properties, and are at risk for enabling pathogens to survive on them.

Consumer Habits Regarding Cleaning Reusable Bags

Despite the risks of disease transmission and cross-contamination, a significant number of shoppers do not take proper food-safety precautions with their bags. Of the subjects surveyed in the University of Arizona study, only 25% of respondents said they used separate bags for meat and vegetables, and only 3% reported "regularly" washing their bag (Gerba, 2012). A 2014, study conducted by Edelmann-Berland (in conjunction with a Clemson University life-cycle assessment) found that a majority of respondents (54%) claim to clean their bags at least once a month. While these data represent a large increase of washing over the Gerba, et al. survey, many bags are still not routinely washed, and nearly one third of respondents said they have never washed their reusable bags (28 percent) or only cleaned them once a year (4 percent).

Bag Sanitation

As an extension of the microbiology tests, Gerba, et al., also tested the effectiveness of various methods of washing to reduce bacterial counts in reusable NWPP grocery bags. Clean, unused bags were purchased at a grocery store and 5mL of *S. Typhimurium* in meat juices were dripped on the sides and bottom of the bags. After air-drying for thirty minutes, each bag was swabbed and the samples were inspected to get a baseline count of colony-forming units (CFU) for heterotrophic plate-count bacteria and Salmonella.

The bags were separated into four treatment groups: one was machine-washed with only regular detergent, one was machine-washed with a detergent containing bleach, one was hand-washed in regular detergent, and one was hand-washed in a detergent containing bleach. The machine-washed bags were tumble-dried; the hand-washed bags were air-dried overnight. Upon swabbing after drying, the bacterial counts in all four bags was determined to be below detectable levels, suggesting at least a 99.9% reduction in bacteria for all chosen methods of washing.

Life Cycle Assessments

The EPA defines a life-cycle assessment as “a cradle-to-grave approach for assessing industrial systems that evaluates all stages of a product's life” which “…provides a comprehensive view of the environmental aspects of the product or process” (EPA.gov, 2006). This can be useful in developing a more complete picture of the environmental impact of products, verifying claims made regarding sustainability and ecological benefit, and offering a way to compare competing alternatives.

Chico State University

In 2011, Joshua Greene of California State University-Chico conducted a study expanding on three grocery bag LCAs previously conducted by consulting firms: an American study by Boustead Consulting and Associates which "found that single-use plastic bags require less energy, fossil fuel, and water than an equivalent amount of paper bags[, and] generate less solid waste, acid rain, and green house gases than paper bags," an Australian study from Hyder Consulting Pty Ltd of Victoria which "found that reusable polypropylene bags had the lower environmental impacts than reusable cotton bags, single-use plastic bags, and single-use paper bags," and a Scottish study from the Scottish Executive of Edinburgh, which "found that reusable plastic bags, that are used 20 times or more, have less environmental impacts than all other types of lightweight carrier bags, including, paper, plastic, or degradable plastic." In addition to summarizing and comparing the findings from the previous LCAs, the Chico State LCA also investigated how the use of recycled plastic feedstock during manufacturing and the laundering of reusable bags affected the net environmental impact.

The Chico State study cites the University of Arizona study on cross-contamination of reusable bags by Gerba. et al., as grounds for including washing in the LCA, concluding that while "[t]he human health impacts are not typically found in LCA studies," they "are warranted [in this one] due to the need to consider health with environmental aspects of consumer choices." The LCA calculations assume each laundered bag is responsible for 2 gallons of water usage per wash, from estimating a load as 20 bags and water usage by the machine as 20 gallons to wash and 20 gallons to rinse. Therefore, a bag washed once a week will account for 104 gallons of water usage. Greene does mention that "the wash cycle may also cause the bags to deteriorate, especially around the stitching that holds the bags together," but does not include premature bag retirement in its calculations.

China/Hong Kong

In 2014, Yi Li of Hong Kong Polytechnic University and Subramathan Muthu of Global Sustainability Services conducted a life-cycle assessment of a wide variety of grocery bags, as part of their development of their "eco-functional assessment," of a sustainability metric which takes into account the "assessment of [a product's] functional life" (Muthu and Li, 2014). This appears to mean defining a product's impact not only as the amount of material and energy a product creates, but the amount of further waste averted over the lifespan of the product; a single-use product thus has a high impact because "an immediate new product has to replace the current product after its life ends (Muthu and Li, 2014)."

They acknowledge that the reusable bags have an environmental cost as well: "[i]f reusable bags are thrown [away] after the first use, their life cycle impacts will be very higher[sic] than the single use ones," but "they try to alleviate the impacts to a certain level by means of being reused many more times till disposed."

Manufacturing processes

Nonwoven and film bags share similar origins in manufacturing. Ethylene and propene monomers are both byproducts of petroleum and natural gas refining, and both monomers are polymerized into resin to create feedstock for the products. After the resin is produced, the paths diverge. Single-use PE bags are made from blown film that is fed into a machine which heat-seals the bottom and cuts an opening at the top; nonwoven bags are made from pieces of polymer-based fabric which can be stitched together with thread, or melted together with heat and pressure.

Assessment of Functional Aspects

In order to better qualify the assumptions of strength, durability, and reusability, the researchers compared 8 material categories were put through a series of tests to evaluate and quantify physical and mechanical characteristics. Many of the tests of strength properties (e.g., tear strength, tensile strength, and burst resistance), and composition properties (e.g., weight, grammage, formaldehyde content).

In addition, Muthu and Li also developed a machine they termed the “eco-functional assessor” to administer the following three tests, for which no testing standards were found:

- Weight-holding capacity: the maximum load a bag could sustain while suspended by both handles for a set length of time while maintaining its integrity

- Reusability: the maximum load a bag could sustain while being "subject[ed] to a to and fro motion" for a set amount of repetitions,
- Impact strength: the maximum force an unloaded bag could "catch" when a load of a given weight was dropped from a fixed height onto a bag not supported by the ground for a set number of repetitions.

The experimenters chose to test weight-holding capacity for 5 minutes, reusability for 100 repetitions, and impact strength for 5 drops.

Weight Holding:

	40 g/m^2	**75 g/m^2**	**100 g/m^2**
Thermo-bonded	14kg	25kg*	25kg*
Sewn	20kg	25kg*	25kg*
*Maximum capacity for volume of bag			

Table 2.2: Results of weight-holding test

Reusability

	40 g/m^2	**75 g/m^2**	**100 g/m^2**
Thermo-bonded	15kg	20kg	20kg
Sewn	15kg	20kg	20kg

Table 2.3: Maximum weight withstood for 100 cycles on Eco-Functional Tester

Impact Strength

	40 g/m^2	**75 g/m^2**	**100 g/m^2**
Thermo-bonded	2.7 cycles @ 2kg	5 cycles @ 3kg	5 cycles @ 3kg
Sewn	2.7 cycles @ 2kg	5 cycles @ 3kg	5 cycles @ 3kg

Table 2.4: Impact strength of various grammages and methods of NWPP bags

Clemson University LCA

In 2013, Clemson University, conducted a life-cycle assessment of the four most common bags used for consumer transport of grocery products, publishing their results in the 2014 study "Life Cycle Assessment of Grocery Bags in Common Use in the United States," a study by Dr. Robert Kimmel, Dr. Kay Cooksey, and Allison Littman (REFERENCE).

In order to provide a more complete picture of the environmental impacts of grocery bags, the Clemson LCA conducted an analysis of four of the most common grocery bags available for use (thin-film HDPE, Kraft paper, thicker-gauge LDPE film, and nonwoven polypropylene fabric bags) across 12 environmental impact categories. The LCA also factored in the impact of washing the reusable grocery bags as per the recommendations of Gerba, et al., and incorporated calculations from a survey conducted by Edelman-Berland designed to estimate consumer behavior regarding consumer reuse and washing of grocery bags.

The Clemson LCA conducted many of its comparisons through the concept of equivalency; i.e., the number of times a bag must be reused in order to offset its environmental costs when compared another type of bag. HDPE film bags containing 30% recycled content were found to have the lowest impacts in 9 out of 12 categories and the lowest average impact overall, while NWPP bags were found to have the highest impacts across all categories. Using the mean impact of HDPE film bags with 30% recycled content as a benchmark, it was determined that a NWPP bag had to be reused either 21.5 times (if a bag's life-cycle is said to end once groceries are unloaded) or 33.9 times (if secondary usage as, e.g., a pet waste bag or trash liner is considered part of the life cycle) to achieve an equivalent average environmental impact.

Edelman-Berland survey: The analytics specialists at Edelman-Berland developed and administered an online survey between February 28 and March 7, 2014 regarding grocery bag usage habits. A sample of 1002 people who had received or purchased reusable bags in the past year was drawn from across the US (Hilex Reusable Bag Study).

Since direct observation would have led to observer interference, the survey used questions regarding consumers' shopping behaviors to calculate an estimate of their bagging habits. While nearly three-quarters of respondents claim that they remember their bags "every time" (31%) or "most of the time" (42%), the average respondent claims to have remembered to bring a reusable bag only 6.4 times in the past 10 trips—meaning they forgot reusable bags 36% of the time. The survey also found that a large majority of respondents (86%) view "reusable bags are more environmentally friendly than other bags," suggesting that NWPP bags enjoy a "green" reputation among most consumers.

Given the reported usage numbers, it was calculated that the average NWPP grocery bag sees 15 grocery-related reuses on average during its lifespan. However, as noted in the Clemson LCA, a NWPP requires at least 22 reuses to offset the environmental impact of a HDPE film bag containing 30% recycled content. This shortfall suggests that, despite its “green” reputation, current usage habits fail to make the average NWPP bag a better option for the environment.

Plastic Bag Legislation

In many places around the world, governments have taken legislative action to encourage or compel consumers to change their single-use grocery bag consumption habits. This is often accomplished one of two ways: by levying a fee on shoppers who receive plastic bags at the point of payment, or by prohibiting retailers from furnishing lightweight plastic bags, with fines for noncompliance. Certain classes of bags are usually granted exception from these laws, such as those used to contain “loose” products like produce or snacks sold in bulk, or to contain foods prepared on-site like sliced deli meats or bakery goods, or ones available with the raw meat to prevent cross-contaminating other groceries.

Laws affecting the distribution of thin-film “single use” bags typically do so through bans (which may penalize noncompliant stores with fines), or per-bag surcharges (which place the burden of cost on the customer, encouraging them to seek other methods of transporting groceries).

However, some states have passed statewide legislation to place the power to legislate the issue solely in the hands of the state. These state laws supersede any local legislation, and as a result, the municipal and county bans or fees in these states are effectively nullified; any new measures to legislate plastic bags will either have to occur at the state level, or require state law to be overturned before they can enact local legislation.

State-by-state summary of lightweight plastic bag legislation

As of the publication of this paper, no national legislation of “single-use” bags exists; all laws regarding their distribution are at a state level or lower. Also included in this section are laws which do not directly impact distribution of bags, but implement programs designed to change consumer behavior via education or recycling. In order to avoid cluttering this section with parenthetical citations, a list of links to the text of each law is available in Appendix A.

States with no current laws:

The following states do not have measures or countermeasures at any level of government regarding distribution of thin-film “single use” bags at grocery stores: Alabama, Arkansas, Delaware, Florida, Georgia, Idaho, Indiana, Kansas, Kentucky, Louisiana, Missouri, Michigan, Minnesota, Montana, Mississippi, Nebraska, New Hampshire, Oklahoma, North Dakota, Pennsylvania, South Carolina, South Dakota, Tennessee, Utah, Vermont Virginia, West Virginia, or Wyoming.

Alaska: Three municipalities, Bethel, Homer, and Hooper Bay, have banned plastic bags.

Arizona: In April 2015, the state legislature passed an amendment to give the state sole power over various environmental compliance measures, including bag legislation. As a result, four municipal measures in Bisbee, Phoenix, Tempe, and Tucson were converted to voluntary programs to encourage reusable bag usage ("Arizona - Bag Legislation"). The state measure is currently being challenged as unconstitutional (Wasser).

California: The first plastic bag legislation in the U.S. was a bag ban in the City and County of San Francisco in April 2007 (SFEnvironment, 2016). Since then, 10 counties and 31 additional municipalities have passed bag bans; these bans encompass five of California's ten largest cities: Los Angeles, San Jose, San Francisco, Long Beach, and Oakland.

The state legislature passed a bill in 2014 to create a statewide ban on plastic bags, but this legislation has been suspended and is awaiting further action before it goes into effect ("California – bag legislation").

Colorado: Six municipalities, Aspen, Breckenridge, Cabondale, Roaring Fork Valley, Telluride, and Vail, have instituted bans. Two cities, Boulder City and Durango, have instituted fees.

Connecticut: The town of Westport passed a ban on plastic bags in 2008.

D.C.: In 2009, as part of the Anacostia River Clean Up and Protection Act, Washington DC instituted a 5 cent per bag fee. A portion of the fee goes to the fund to clean up the Anacostia River.

Hawai'i

The state of Hawai'i achieved a *de facto* statewide ban after each major island passed their own individual bans. Currently, the Hawai'ian legislature is working on forming a statewide ban to condense these individual laws into a single statewide code.

Illinois: Two municipalities, Chicago and Evanston, have banned disposable plastic bags.

Iowa: Marshall County passed a bag ban in 2008.

Maine: Three municipalities, Falmouth, Portland, and South Portland, introduced a 5-cent fee per each non-reusable bag given at checkout. One municipality, York, banned lightweight bags altogether.

Maryland: One town, Chesterton, banned lightweight bags. Montgomery County, has instituted a 5 cent per-bag fee.

Massachusetts: 17 municipalities, many of them suburbs of Boston, have banned single-use plastic bags.

New Jersey: One municipality, the Borough of Longport, has instituted a 10 cent per-bag fee.

New Mexico: Two municipalities, Santa Fe and Silver City, have banned plastic bags.

New York: In addition to bans in 11 municipalities, the state of New York amended the Environmental Conservation code requiring retail locations to offer bag collection areas and sell reusable bags on site.

North Carolina: A 2008 state law banned distribution of plastic film bags in the Outer Banks region. The first draft of the law initially encompassed the entire state, but the scope was later narrowed to the Outer Banks specifically.

Oregon: Four municipalities, Portland, Eugene, Coravlis, and Ashland have banned plastic disposable bags. These first three municipalities represent the first, third, and tenth most populous cities in Oregon, respectively.

Rhode Island: One municipality, the town of Barrington, has passed a plastic bag ban.

Texas: 8 municipalities (Austin, Brownsville, Fort Stockton, Kermit, Laguna Vista, Laredo, Port Aransas, Sunset Valley). Austin is 4th largest, Laredo is 10th largest.

Virginia: In January 2015, the state senate approved an amendment to Article 7.1 of Chapter 38 of Title 58.1, adding measure to implement a 5-cent fee on plastic bags distributed by retailers in the Chesapeake Bay Watershed area; 4 cents of each fee goes to the Virginia Water Quality Improvement Fund.

Washington: 12 municipalities, including Seattle (the largest city) and Tacoma (third largest city), and one county, Thurston, have banned bags.

Wisconsin: One municipality, Madison, requires retail stores to provide on-site bag recycling. Another municipality, the city of Eau Claire, has passed a law to undertake a study on bag legislation, but has not yet enacted any bans or fees.

Test Methods for Bag Durability

The earliest legislation in the United States targeting single-use grocery bags began in San Francisco, in 2012 with an expansion of a 2007 waste-reduction ordinance. The ordinance provides qualities to determine whether a bag may be considered "reusable," including a required minimum amount of reuses and methods for simulating reuse.

EcoLogo Environmental Choice Program, Acceptance Test Procedure ATP-001: The Environmental Choice Program was developed by the Canadian Department of the Environment to approve claims of environmental benefit of products ("Environmental Choice Program"). In 1995, they developed the Environmental Standard ATP-001 test to provide a highly specific, easily-replicated methodology of testing the durability of a bag. The bags are set on a concrete block and loaded with 10kg of various materials to simulate an assortment of groceries, then set on a swing arm which raises it up and lowers it back to the concrete at a fixed speed. The bag is inspected after 300 raise-and-lower cycles and placed back on the hook, until it has failed (defined as more than 10% elongation, or damage) or completed its requisite number of cycles.

Walk-Test: The "Walk Test" was specified and described by the San Francisco law ("San Francisco 311"), though it does not cite any pre-existing standards. This test is less detailed and specific than the Environmental Choice Program test; however, it can easily be reproduced without a need for specialized equipment. The bags are loaded with 22 lbs. of unspecified product which simulates groceries, carried 175 feet, and set down; this is repeated 125 times or until the bag develops a hole or cannot maintain its load and be carried by both straps.

CHAPTER THREE

MATERIALS AND METHODS

The primary purpose of the experiment was to evaluate the durability of nonwoven polypropylene bags by walk-testing them to simulate “real-world” usage and their ability to meet the requirements initially laid out by Los Angeles and adopted by many subsequent lawmakers. The 125-repetition mark is higher than almost all of the subcategories of global warming potential in the Clemson LCA, with the sole exception of water depletion estimates in secondary-usage-inclusive estimates (146.4 trips). The results would also offer a basis for comparison on whether NWPP bags can recoup their environmental cost. The secondary objectives were to see if machine-washing affects the lifespan of NWPP bags, and to determine if the Ecologo Environmental Choice ATP-001 represents a reasonably accurate equivalent to walk-testing.

Study Design: The study was comprised of two separate tests: the walk test and the Environmental Choice Program Acceptance Test Procedure 001 (or ATP-001). For each test, half the sample would serve as a control population, to be tested “as-is.” The other half of each sample would undergo machine-washing in a procedure detailed later in this chapter. Bags were tested and inspected after each testing until they either failed inspection or survived five testing cycles.

Sample Details

All 200 bags were purchased in a single-order batch from wholesale bag supplier Holden Bags. The product name of the bags used for this test was “Little Storm.” Two samples (80 bags for the Ecologo Environmental Choice Series ATP-001 test, and 40 for the walk test) were selected from the batch of 200. According to the manufacturer’s website, the grammage of the “Little Storm” line of bags is 100 g/m^2, the handle length is 22 inches, and the dimensions are 13”x12”x8”, making for a volume of 1248 in^3, or 20451 cm^3 (Holdenbags.com, 2016).

Bag construction: The nonwoven polypropylene bags used in this experiment were made up of eight pieces of fabric, which are connected to one another by seams sewn with cotton thread:

- One long sheet which serves as both the “side” and “bottom” of a bag; hereafter referred as the “spine” panel.
- Two “face” panels made up of square sheets of fabric. One “face” panel contains a “loop” which allows the bag to be hung up without straining the handles.
- Two “seam covers,” which are long, thin strips stitched along the border of the “face” and “spine” panels to provide protection and reinforcement of the seams
- Two long strips folded longitudinally upon themselves and stitched along the “face” panels to form the handles; each assembled “face” contains a single handle piece.

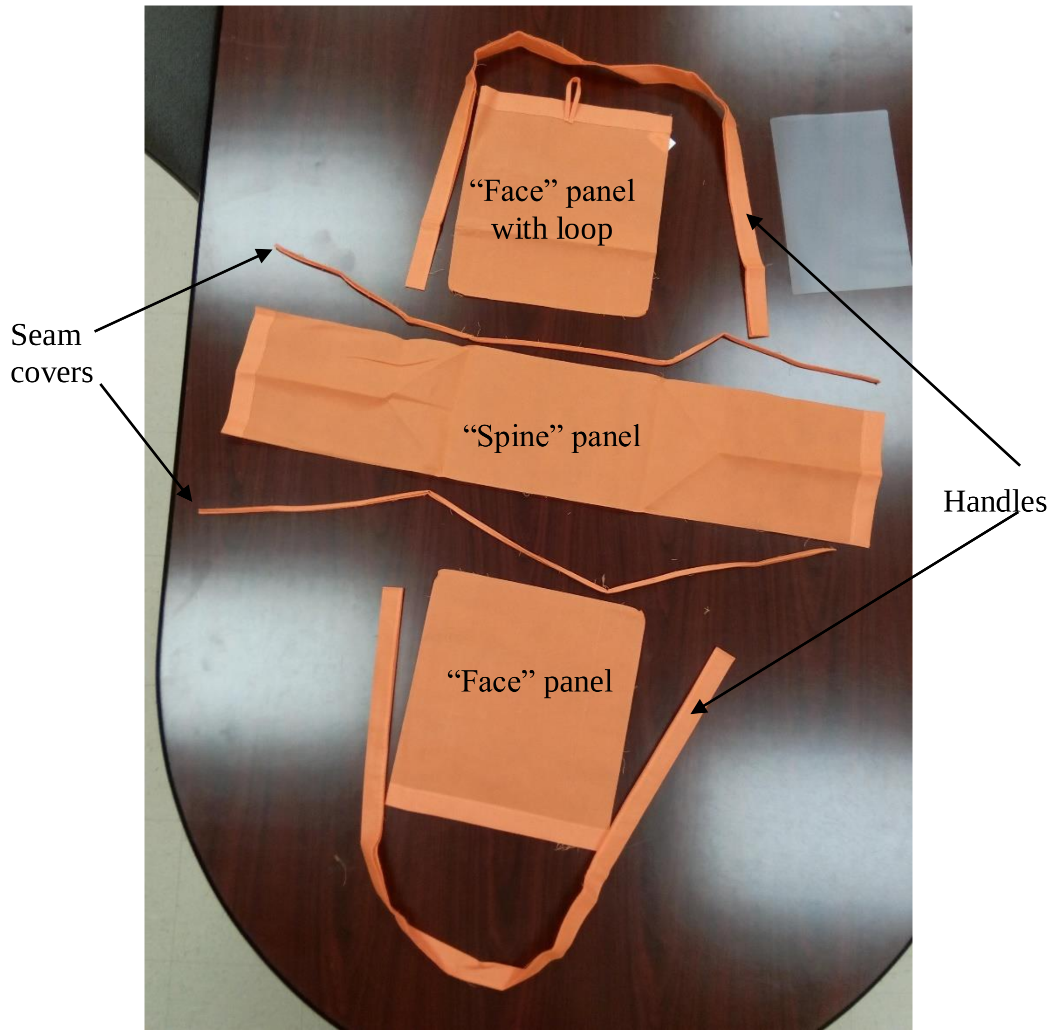

Figure 3.1: NWPP bag, deconstructed and labeled

Contents of Tested Bags

Per the instructions in the ATP-001, each of the bags placed on the testing machine hooks were loaded with the following items:

- 21 half-pint paint cans (ATP-001 standard, item 4.4),
- 22 wood blocks with dimensions 5cm x 5cm x 10cm (ATP-001 standard, item 4.5),

- An amount of ball bearings necessary to give the bag a net weight of 10 kgs (ATP-001 standard, item 4.6: "granular material such as…lead shot").

Figure 3.2: A NWPP bag loaded with wooden blocks, half-pint paint cans, and ball bearings (not visible).

Figures 3.3 and 3.4: Wooden blocks (left) and half-pint paint cans (right).

Figure 3.5: Ball bearings at the bottom of a NWPP bag, used as “granular material.”

Walk-Test Bag Load

In order to provide a realistic simulation of a grocery load, each bag was loaded with the following items purchased from a local supermarket, resulting in a net load of 22 pounds, 4 ounces.:

- One-gallon jug of water (8 lbs)
- One large bag of rice (10 lbs)
- Four cans of beans (product weight: 15oz., package weight 2oz.)

Figure 3.6: Initial load for walk-test bags

Unfortunately, many of the gallon jugs succumbed to leakage over the course of experiment, and a substitution was made by adding another bag of rice and removing two cans of beans, resulting in a new net weight of 22 pounds, 2 ounces. The 2-ounce difference was not believed to have a significant impact on the results.

Figure 3.7: Alternate load, substituting a second bag of rice for a gallon jug and removing two cans

Testing Equipment

ATP-001 Testing Machinery ("Up-Down Tester")

The machinery for conducting the ATP-001 was constructed on-site by a department engineer to satisfy the requirements listed in section 4 of the standard. A complete manifest of the parts used in building the ATP-001 Testing Machinery is included in Appendix C. In summary, the tester required a system for controlling the input of pressurized air, two pneumatic cylinders working in parallel to raise and lower a flat metal bar, two hooks onto which bags could be set, as well as any tubing necessary for transporting air, and any fasteners required to connect the parts of the device.

However, the terms used to describe the dimensions of the hooks were found to be inconsistent with industry terminology; thus, two spring-closed carabiners were wrapped with two-sided tape and used as hooks.

Sequence of Operation for ATP-001 Testing Machinery

1. The testing laboratory is supplied by a commercial air compression system with built-in air dryer and oil separator. All air supplied to the pneumatic system in the lab is regulated down to 90 PSI.

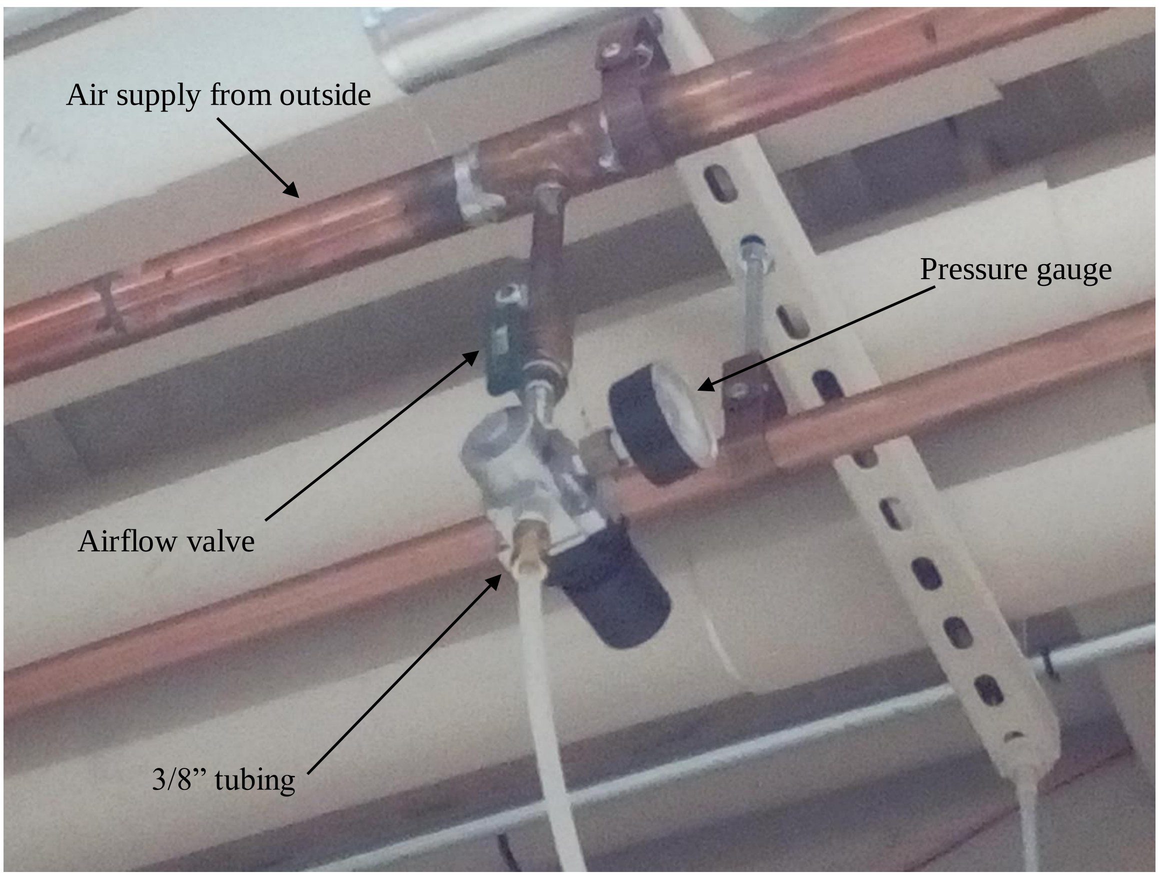

Figure 3.8: Air-supply valve with 3/8” tubing

2. A length of 3/8” tubing runs from an air supply valve to a hand-actuated directional valve. When toggled, the valve allows air to flow in to move the pneumatic cylinders (3) up or down. The valve contains four exhaust mufflers (4) which regulate speed by controlling rate at which the pneumatic air is vented.

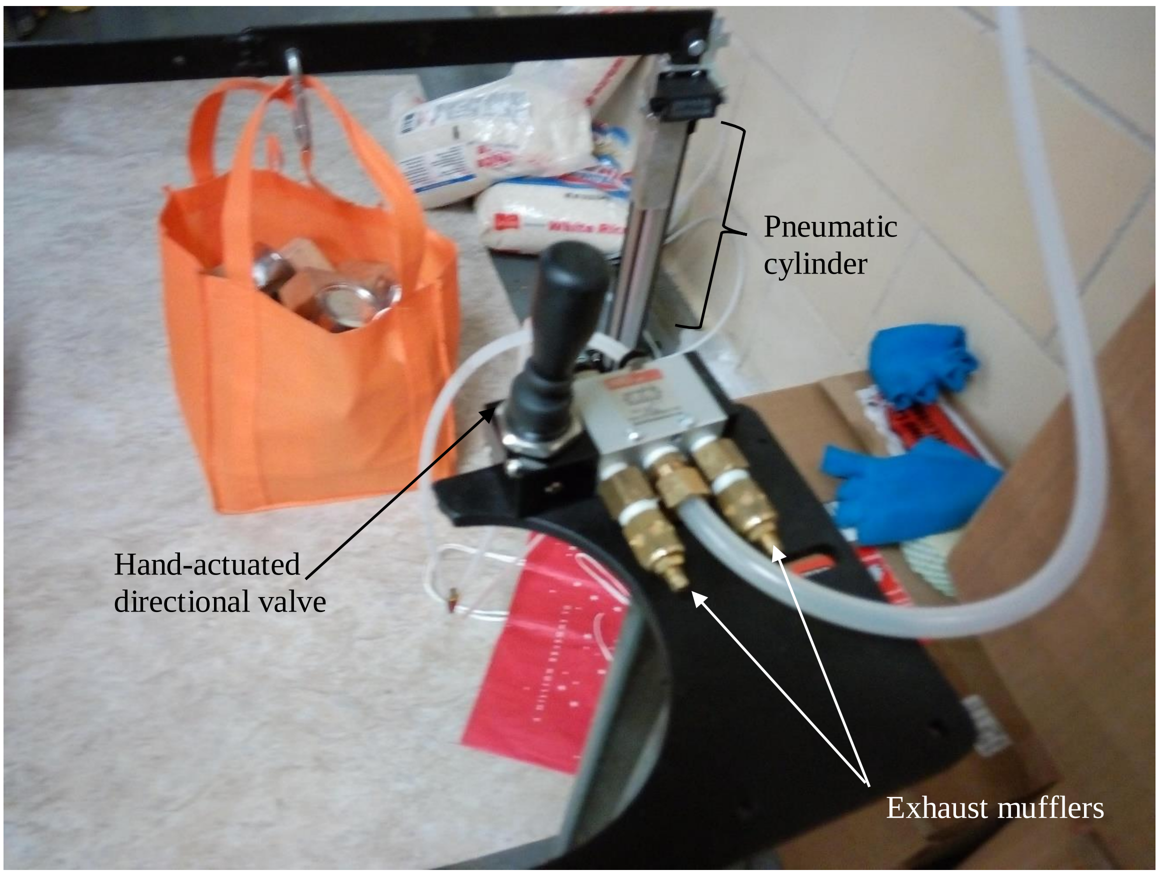

Figure 3.9: Hand-actuated switch, two mufflers, and part of the lifting apparatus

3. Two pieces of ¼” tubing, both split at separate T-junctions, run from the hand-actuated valve to the double-action pneumatic cylinders (3). Both sets of tubing

are the same length, to ensure both paths are receiving the same volume of air at the same rate.

4. Two pneumatic cylinders, bolted to the floor for stability, extended or retracted their actuators in parallel with one another, depending on the position of the hand switch.
5. Attached to the end of the actuators is a ¼" thick iron crossbar, with two holes drilled equal distances from the actuators to keep the load balanced between actuators.
6. Inserted through the holes are two carabiners, upon which the loaded bags were hung for testing.

Figure 3.10: Apparatus with pneumatic cylinders retracted at rest (second cylinder obscured by valve platform)

Figure 3.11: Apparatus with pneumatic cylinders extended

Testing Procedures

Bags were subject to a four- or five-part testing cycle: washing, loading, testing, unloading, and inspection. If a bag withstood five full testing cycles, spontaneously failed during use, or was found to meet failure criteria during inspection, it was retired. All results were noted on a spreadsheet available in Appendix F.

Washing: For the bags selected for washing, this represented the start of a testing cycle. First, the PE liners at the bottoms of the bags were removed. The bags were then loaded into a washing machine and tumble-dried, then inspected for damage. If a bag failed during post-laundry inspection, failure was noted as occurring during the washing stage.

Loading: The bags were placed on the ground, and the loads chosen for each test were placed in the bag.

Testing: The bags were subjected to testing. The specific procedures used for testing are listed later in this section.

Unloading/Inspection: After a testing cycle was completed, the bags were unloaded so that they could be handled without putting any strain on them. Following the unloading, the bags were inspected, with special attention given to the seam covers and the reinforcement stitching on the handles at the point closest to the bag opening. Points of damage were measured using a set of digital calipers, and an indication of the location was made on the bag using permanent marker; it is not believed that the marker ink affected any of the mechanical properties of the NWPP fabric.

Retirement: Bags were retired from further use if they sustained enough damage to meet or exceed the failure criteria, or if they survived five testing cycles. The reason for retirement was noted on a spreadsheet (Appendix D).

Machine Wash Settings:

Machinery used: Whirlpool combination Washer/Dryer, model no. WET3300SQ2

Wash Settings: "Warm" water (~90˚F), "Medium" load size "Regular" cycle length.

Detergent: Arm and Hammer "Clean Scentsations" with "Twilight Sky" fragrance. No further additives (e.g., bleach, OxyClean, fabric softener) were used.

Dryer settings: “High” heat setting (63C/145F), “Energy Preferred Automatic Setting” timer.

Bag Loading Procedures

ATP-001: As specified in Item 5.5.2 of the ATP-001 Procedures, wooden blocks and metal cans were tossed into the bag and allowed to come to rest at random. Once all blocks and cans were loaded, ball bearings were added until the bag weighed 10 kg.

Walk test: Heavy items were loaded on the outer edge, while lighter objects were stacked in the middle of the bag.

Inspection and Retirement

The bags were evaluated by the failure criteria specified in Item 5.2 from the ATP-001 procedures (the full text of which is available in Appendix A). However, item 5.2.1c was reinterpreted: since the bags used in the test are nonwoven and cannot experience weave disruption, a 25mm non-elastic deformation would be considered a failure instead. The walk test employed the same except for the following modification: the threshold for separation between fabric (i.e., unravelling of a seam) was increased to 25mm (~1 inch), as 5mm was felt to be too stringent for the real-life usage represented by the walk-test, as a single dropped stitch could mean failure.

Critical failure: If a bag was spontaneously unable to carry a load while being lifted by both handles, this was termed a critical failure. The repetition number at which the failure occurred and the apparent cause of critical failure (e.g., if the handle snapped, or if a large tear developed on the bottom panel and caused contents to fall out) were noted on the spreadsheet.

Inspection Failure: If a washed bag was found to meet one of the failure conditions after post-wash inspection, or if a bag was able to contain a load for its given testing cycle, but failed upon post-testing inspection, it was deemed an inspection failure. The testing cycle during which the failure occurred was noted on the spreadsheet.

Mechanisms of Failure

Seam separation: If the stitching on the protective strips over the seam between the "spine" and the "face panels" came undone and allowed a gap between the two panels, this was termed "seam separation." This most commonly occurred at three locations on the bag:

- *Corner:* At the ends of the reinforcement strips, roughly coincident with the corners of the opening,
- *Bottom*: Where the "spine" comes in contact with the ground during routine use, or the bordering edges of the "face" which abut the "spine."

Fig. 3.12: Seam separation on a corner.

Figure 3.13: Seam separation on the bottom seam

Handle Strain: As the bag is lifted by the handles, the stitching which connects the handles to the upper rim of the bag would often start to stretch and pull away from the body of the bag. During inspection, the handle would be downward with just under the amount of force necessary to place strain on the thread, and the distance of separation would be measured with digital calipers. This distance was deemed “handle strain.”

Figures 3.14 (left) and 3.15 (right): Handle strain

Hole or Tear: Separation between two points of fabric which are located on the same panel. The edges of a *tear* may touch each other at rest, but will pull apart under strain. The edges of a *hole* will not touch even when the panel is relaxed.

Figure 3.16: A tear. Note how the edges still line up, but are no longer connected.

Figure 3.17: A hole. Note how the fabric does not fully "close."

Walk Testing

After finding a long room with a clear straight-line walkway, a point was marked near one end of the room. A distance of 87.5 feet was measured out with the assistance of a ruler, and another tape mark was made. Therefore, a cycle from one mark to the other and back would make for a total of 175 feet.

Walking Cycle: A single walk cycle consists of:

- Lifting the bag(s) up vertically using the handles,
- Walking from the starting point to the halfway point marked on the floor

- Placing the bag(s) on the floor at the halfway point and turning
- Lifting the bag(s) up vertically again
- Walking back to the point of origin, and
- Setting the bag down again.

The walk cycle was considered complete after the bag is set down a second time, and participants were instructed to make a tally mark to keep track of the number of cycles they had completed.

Inspection: After 25 walk-test cycles, the groceries were removed from the bag, and the bag was inspected visually for indications of failure. Special attention was paid to the seam covers, and to where the handles were sewn onto the bag, as these sections appeared to be under the most strain. If a bag failed, the location and size of the failure was noted on a spreadsheet and the bag was immediately retired.

CHAPTER FOUR

RESULTS AND DISCUSSION

Results

In this section, the durability of unwashed (control) and washed bags for each type of test (Walk and ATP-001) will be covered. Modes of failure for each type of test, and the failure rates of unwashed and washed bags are examined. Additionally, a comparison between test types and discussions regarding applicability to real-world usage is discussed.

Walk Test:

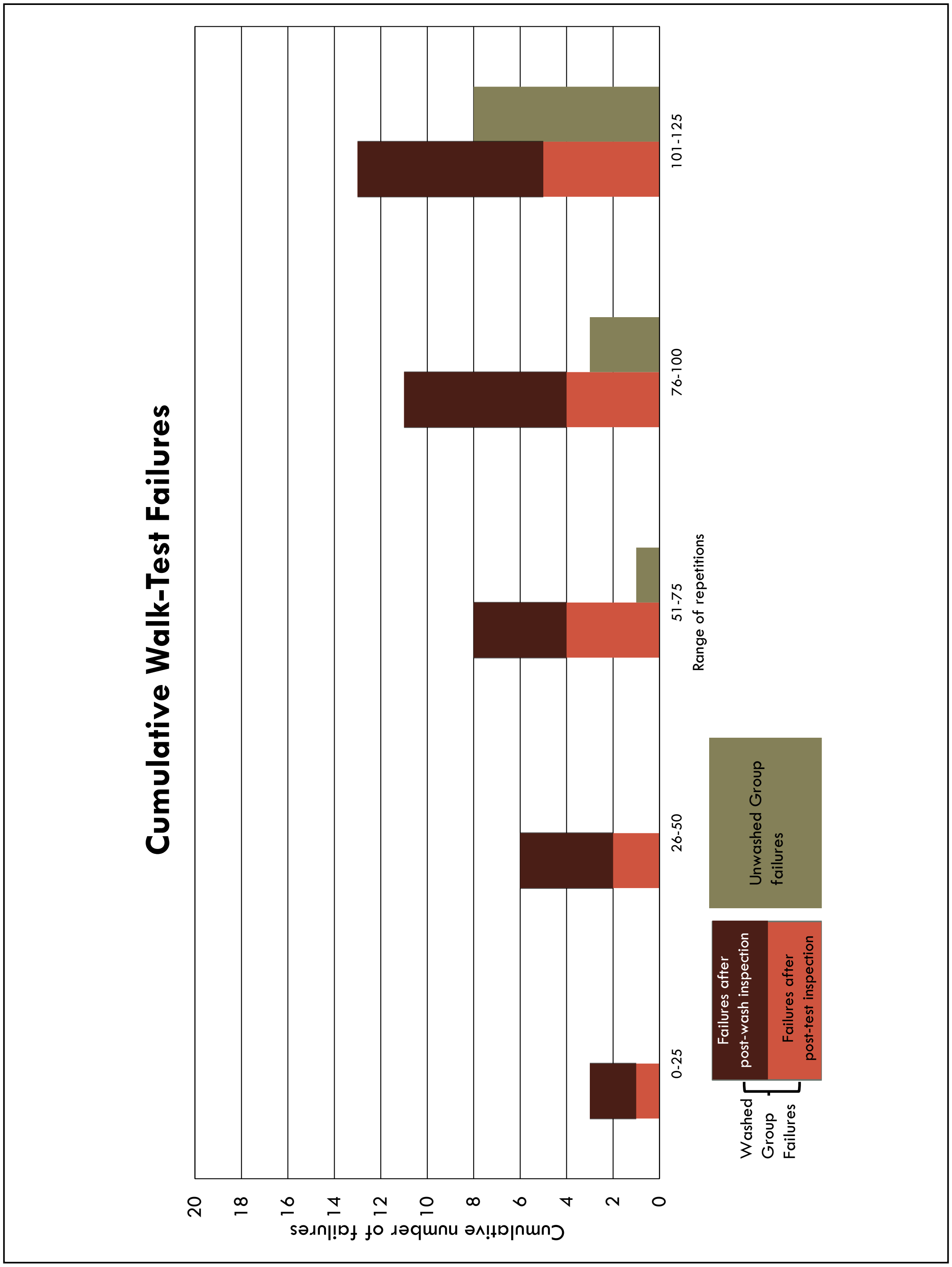

Figure 4.1: Cumulative failures during walk-test.

Durability: No unwashed) bags were observed to fail among during the first 50 repetitions (i.e., the first two walk cycles). One failed during the third cycle, 2 failed during the fourth cycle, and 5 failed during the fifth cycle, for a total of 8 failures. 12 of the 20 bags, or 60% of the samples, were able to withstand the required amount of testing to be considered "durable" or "reusable" bags.

Washing: Two bags failed after the first machine-washing before they had been subjected to a single walk-test. Each testing cycle saw at least one failure. Less than half the population remained after 100 repetitions and 4 washings. Ultimately, only 7 out of 20 treated bags, or 35% of the samples, withstood five washings and the 125 reuses required. The majority of treatment-group failures, 61.5% (8 out of 13), were discovered on post-wash inspection.

Ecologo ATP-001 Results:

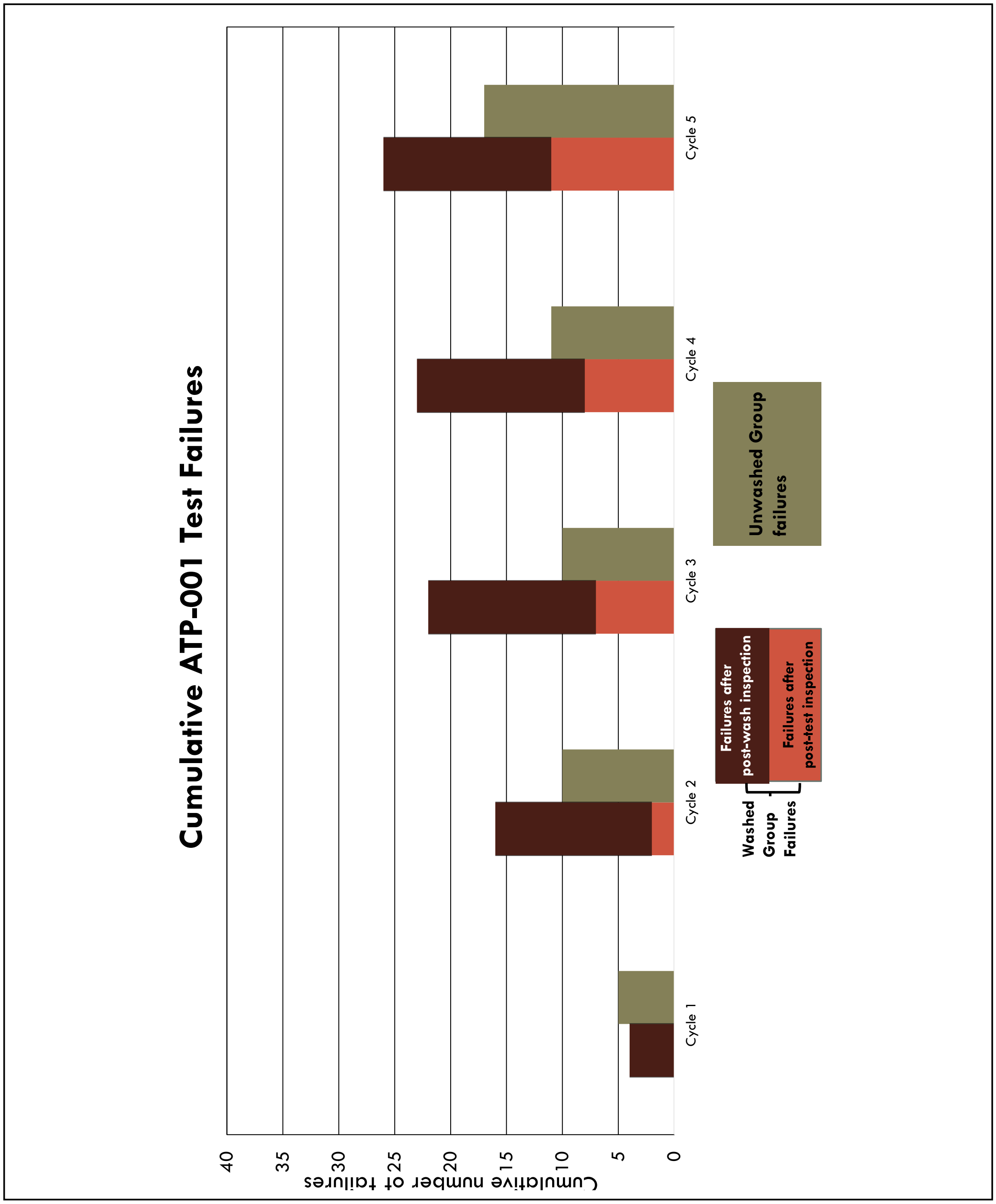

Chart 4.2: Cumulative failures during ATP-001 test

Durability of Unwashed Bags during ATP-001 testing:

For the ATP-001 test, forty untreated (i.e., non-washed) bags were tested until 1500 repetitions, or failure, whichever occurred first. Five bags were observed to fail during the first testing cycle, and another five failed during the second. There were no failures during the third cycle, only one during the fourth cycle, and 6 during the fifth cycle, for a total of 17 failures. A total of 23 of the 40 bags, or 57.5% of the samples, were able to withstand the required amount of testing recommended by authorities such as the LA County Department of Public Works ("About the Bag").

Washing: All four of the failures in the first cycle, and 10 of the 12 failures during the second cycle were discovered after washing. However, after the initial failures during the first two cycles, no further post-wash failures were found in cycles 3 and 4, and only one further post-wash failure occurred in cycle 5. Overall, only 35% of bags (14 out of 40) survived both five washes and 1500 up-down cycles, and the majority of washed group failures, 57.7% (15 out of 26), were discovered upon post-wash inspection.

Modes of Failure

Causes of Failure	Walk Test (40 total bags)		ATP-001 (80 total bags)	
	Washed (13 failures)	Unwashed (8 failures)	Washed (26 failures)	Unwashed (17 failures)
Handle broke during test	2			
Stitching unravelled…	…to a length ≥25mm…		…to a length ≥5mm…	
…at corner seams	5	1	23	10
…along bottom seam	1	4		
…on a handle	2	2		
…between handle and bag ("handle strain")			1	3
Hole or slit >5mm…				
…on side		1	1	3
…on bottom	2	1		

Table 4.1: Modes of failure during testing

For both tests, unraveled stitching made up the majority of failures across all categories. Unraveled corners made up a majority of failures in ATP testing, and the largest plurality of failures in walk-tests. Overall, unraveled stitching on some portion of the bag represented 15 of the walk-test failures, while holes or slits through the surface of the bag made up only 4 failures. Both broken handles snapped at the top of the reinforcement stitching.

Comparison of Tests

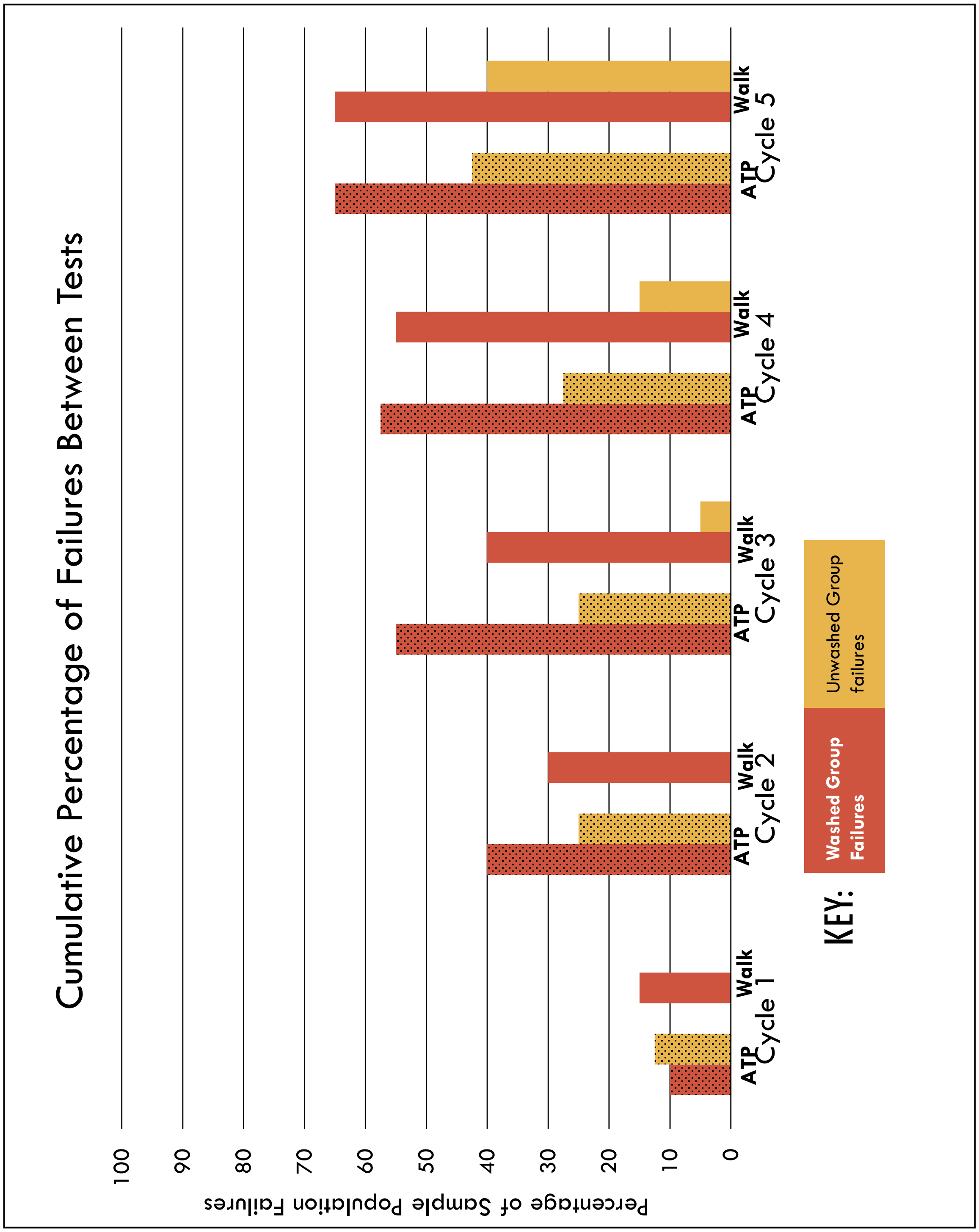

Figure 4.3: Comparison of failure rates between both tests

Initially, the percentages of failures between control (unwashed) bags are very dissimilar; in fact, the number of unwashed bags in the ATP test exceeds that of the washed bags in the same test, and the rate nearly matches that of the washed walk-test bag failure. Additionally, failures in the ATP-testing group appear to occur in starts and stops; the percentage of failures nearly doubled between cycle 1 and cycle 2, but no failures occurred between cycles 2 and 3. In contrast, walk-test failures occurred at a fairly constant rate among the treated group.

Additionally, as seen in Table 4, the modes of failures between tests were often different, and occurred at different rates; for instance no ATP-tested bag failed due to a snapped handle or a hole on the bottom of the bag, and no walk-test bag failed due to "handle strain." However, there were a couple of notable similarities in failures modes: in both tests, unravelling corners was the most common mode of failure, accounting for a plurality of walk-test failures (6 of 21, or 28.6%) and a majority of ATP-test failures (33 of 43, or 76.7%).

Implications for LCAs

As noted by Muthu and Li, and further studied by Kimmel et al., NWPP bags represent a greater initial burden on resources than single-use bags; whether the NWPP bag represents an "environmentally friendlier" alternative to single-use thin-film bags relies on the ability of the bag to endure a sufficient number of reuses to make up its initial impact.

Assuming that the walk-test provides a reasonable simulation of the real-world abuse a bag undergoes while carrying groceries, and given that none of the unwashed bags failed before 50 reuses, it seems reasonable to assume that a given NWPP, barring manufacturing defects or damage in excess of routine wear, can last for at least 50 trips. Furthermore, as a large number of NWPP bags are rarely or never washed (Edelmann-Berland, 2014), these bags should be able to survive more than the average 14.6 reuses.

Are NWPP bags being used to their full potential?

The Edelman-Berland survey calculated that the mean consumer reuse rate of bags was 14.6 times. Even though 100% of bags tested withstood 50 trips, only 20% of respondents use their bags for more than 44 trips. Over 50% of unwashed NWPP bags withstood 125 reuses, but under 10% of surveyed users were found to have reused their bags to that extent (LCA, pg 12). These results suggest that consumers are not using these bags to their full potential, and may be discarding them when they still have potential usage left in them.

Are NWPP bags durable enough to recoup their environmental impact?

All of the unwashed bags survived more than the number of reuses required to achieve mean equivalency with thin-film bags, as well as a sufficient number of reuses needed to surpass equivalency in 10 out of 12 factors, the exceptions being terrestrial ecotoxicity and water depletion. Furthermore, 85% of the unwashed bags in the test withstood the number of reuses needed to achieve all equivalencies (excluding water depletion when secondary-uses of HDPE film bags were factored in). Table 5, below, offers survival rates at various benchmarks of environmental impact.

Benchmark	# of reuses req'd	No. of unwashed bags which met criteria (%)
Lowest reuse criteria (freshwater eutrophication/ freshwater ecotoxicity/marine ecotoxicity)	13	20 (100%)
Current estimated avg. reuses	15	20 (100%)
Mean "break-even" point, excl. secondary reuses	22	20 (100%)
Mean "Break-even" point, incl. secondary reuses	34	20 (100%)
Highest reuse criteria (Terrestrial toxicity)	90	17 (85%)
Legal minimum requirement to be considered "reusable"	125	12 (60%)

Table 4.2: NWPP bag reuse benchmarks for various equivalencies.

Can NWPP bags withstand machine washing?: Whenever a load of NWPP bags were washed, the failure rate on post-wash inspection was always below 50%; however, 4 of the 5 wash cycles for walk-test bags saw at least one failure. This suggests that machine-washing bags may be something of a gamble in terms of durability; while machine washing does not necessarily guarantee failure, it appears to raise the odds of inducing it.

Can Washed NWPP Bags Achieve Equivalency?

The introduction of machine-washing complicates the discussion of durability and environmental impact. If a single NWPP bag is added to a load of laundry that would be washed as usual, it would require no additional water than what would ordinarily be used (pg 118). However, as part of the laundry load, it still represents a portion of water usage.

Essentially, unless a NWPP could be cleaned with less than 0.1 gallons (or 1.6 cups) of water, routine machine-washing effectively creates an irrecoverable "water debt" that no amount of reuse can recoup.

Even if the water depletion caused by washing is ignored, the tendency of washed bags to begin failing sooner than their unwashed counterparts means some of the bags are not reaching mean equivalency. Ultimately, 70-85% of washed bags withstood two machine-wash cycles and a sufficient number of trips to reach mean manufacturing equivalency (i.e., excluding washing), and 55-65% withstood four machine-wash cycles and a sufficient number of trips to recoup all manufacturing equivalencies; however, due to the use of additional natural resources required to clean a bag and the risk of causing failure before reaching equivalency, machine washing can only have a negative influence on the net environmental impact of a bag. Additionally, while a similar level of disinfecting can be achieved through hand-washing with detergent alone (Gerba, et al., 2011), machine-washing offers "set it and forget it" convenience, and it may be difficult to persuade consumers to hand-wash their bags instead of throwing them in with the laundry.

Legal Definitions of Reusable Bags

While this experiment does offer insight into the durability of NWPP bags, whether they legally qualify as "reusable" by the common legal definitions is harder to say because of the subjective and interpretive nature of law. The language in the Los Angeles County law, which laid the groundwork for many subsequent bag laws, states that reusable bags are those which are "specifically designed and manufactured for multiple reuse[sic]," but no explanation of what constitutes "specific[…] design…for multiple reuse" is provided. Bags which undergo walk-testing must prove they have "the capability of carrying a minimum of 22 pounds, 125 times over a distance of at least 175 feet," but the law fails to provide any statistical parameters such as minimum sample size or acceptable rate of failure. To take this problem to its logical extreme, if a thousand bags were tested and only one survived, would that "prove" reusability despite a 0.1% survival rate? Or if only one bag failed, would that single failure disqualify a 99.9% survival rate because it "proved" that not every bag could not withstand the 125 repetitions? While these are both highly unlikely scenarios, they underscore the need for clearer acceptable parameters for testing and statistical analysis.

In absence of a more specific set of boundaries, three basic interpretations for determining whether these NWPP bags can legally be considered "reusable bags" are thus proposed:

- "Given a <u>maximum</u> sample size of 20 bags, all bags within the number of samples must withstand 125 reuses." By this metric, these NWPP bags fail to meet the definition of "reusable."
- "Given a <u>minimum</u> sample size of 20 bags, the average bag should survive 125 reuses." If "average" is interpreted as a success rate of at least 50%, the NWPP bags used in this test would qualify, since the final success rate was 60%. (It should be noted, however, that at a sample size of 20 bags, the difference between 60% success rate and one below 50% is only three bags.)

- “Given a <u>maximum</u> sample size of 20 bags, at least one bag can withstand 125 reuses.” By this definition, the NWPP bags certainly qualify as reusable, since 60% of unwashed bags withstood

The maximum sample sizes in interpretations 1 and 3 are to prevent testing *ad infinitum* until a single exception occurs and characterizing the behavior of 99% of bags on the results of 1%.

Washing

Some bag laws also include requirements that the bag is able to be washed; however, as with the previous section, the specifics of what makes a bag “washable” appear to be a matter of interpretation. Assuming the procedures used in the test are acceptable (e.g., bags were machine-washed before first use, and washed again after every 25 uses), and applying the interpretations used for unwashed bags:

- “Given a maximum sample size of 20 bags, all bags must withstand 5 washes and 125 reuses.” By this metric, these NWPP bags fail to meet the definition of “reusable.”
- “Given a minimum sample size of 20 bags, the average bag should survive 5 washes and 125 reuses.” If “average” is interpreted as a success rate of at least 50%, the NWPP bags used in this test would fail, since the final success rate was 35%. (It should be noted, however, that at a sample size of 20 bags, the difference between a 35% and a 50% success rate is only three bags.)

- “Given a maximum sample size of 20 bags, at least one bag can withstand 5 washes and 125 reuses.” By this definition, washed NWPP bags qualify as reusable, since 35% of washed bags survived five washes.

Recommendations to improve bag durability

Across all tests and treatments, unravelling seams were the number one cause for failure; thus, efforts in making these bags more durable should focus on improving seam strength and preventing unravelling. Solutions to this issue include increasing the number of seams per inch, or using a stronger stitch (“Stitches Per Inch (SPI) – What You Need to Know”, 2010); while these may result in more thread being used, their increased durability may help offset their cost. However, since the use of cotton thread contributes significantly to several of the environmental impact categories, these changes would also alter the impacts for the NWPP bags as a whole, meaning manufacturers would have to take the environmental costs as well as financial costs into account.

Limitations

Walk Test: For a test with binary (i.e., “pass/fail”) results, a large sample size is necessary to determine differences between populations. A sample size of 40, divided evenly between two treatments, provides only limited insight into whether machine washing reduces the lifespan of a NWPP bags in a statistically significant manner, and a much larger sample would have been desirable.

However, walk-testing is a physically intensive test, and the exertion required to conduct it severely limits the rate at which testing can be completed. Most participants felt they could not do more than two sets a day without risking strain or injury, and they still complained of sore hands, backs, arms, and legs after helping. Thus, to work through a large sample size would either require a large number of assistants, or a very long time: assuming a participant carries 2 bags for 2 sets (50 repetitions) per day, this makes for a best-case pace of 0.8 bags per person per day. This slow pace also prevented testing-until-failure. While tests until failure would have yielded more workable numerical data in smaller sample sizes, they would have also taken much longer; if a bag took 250 repetitions to fail, it would mean 5 days of testing a single sample—a particularly durable outlier could represent over a week of work.

Additionally, while the walk test does attempt to simulate a grocery bag lifespan by subjecting it to loading and carriage, there are numerous real-world factors which are difficult or impractical to control for. These include the load weight (since there is no guarantee every load will be 22lbs), the bulkiness of the groceries (since some packaged items may have sharp edges or be large enough to put strain on the panels), and the distance consumers carry their bags by the handles.

The failure criteria of each individual consumer are impossible to control for as well. Some consumers might disregard small tears or unraveled seams and continue to use the bag until critical failure (and some may even choose to repair their broken bags and continue reusing them). Others may consider surface dirt or stains to constitute failure and dispose of the bag, even if it shows little to no signs of damage.

ATP-001: In addition to the same variability the walk-test faces, the ATP-001 procedure contains many factors which hinder the extrapolation of its results into real-world conclusions:

- The ATP-001 test requires loading the bag with objects that bear no resemblance to a grocery load, like wooden blocks and granular material.
- Some of the testing requirements are vague: the machine must have a stroke of "minimum 20 cm," but no specific tolerance or maximum acceptable stroke length is given.
- For granular material, "sand, abrasive grit, or lead shot" were listed as examples of acceptable materials, but these all have very different properties of abrasion and are hardly interchangeable substitutes for one another in most applications.
- The terms used in the standard are not consistent with real-world practice; "mass resistance" does not appear to be a commonly-used term for any property of concrete, and terms like "soft faced" and "half-height" were not consistent with the terminology used by hook manufacturers.
- The "up-down" motion of the machine fails to replicate many of stresses that a bag undergoes during real-world usage, including but not limited to the pendulum-like swing of a carrier's arm, the torsion of handles if a bag bumps against a carrier's leg and spins, the handles rubbing against each other when a carrier shifts their grip, or the abrasion of a bag scuffing on the floor when it is set down. This is borne out by the difference in failure types: walk-test failures occurred in 6 different modes, with

no single mode holding a clear majority, while ATP-001 tests saw only 3 modes of failure, and unravelling corner seams were the clear majority, making up 76.7% of all ATP-001 failures.

Furthermore, the lack of a standardization agency, a certification body, publically available schematics or references, or even a manufacturer that dominates the market and establishes a *de facto* standard makes ensuring consistency between ATP-001 apparatuses virtually impossible. The Los Angeles County Department of Public Works provides a list of manufacturers that can assemble them on-demand, but none of them offered these testing apparatuses for retail sale. For the sake of expediency and cost, the apparatus constructed for this experiment was designed and manufactured on-site by a department engineer.

In this researcher's opinion, the EcoLogo ATP-001 test is of very limited use. Its only advantages over the walk-test are that it is not physically taxing (and therefore allows researchers to test more bags at a quicker rate), and that it could feasibly be automated; however, it fails to accurately reproduce the process of carrying a bag, and unless it becomes an industry standard, it is of very limited use in yielding workable data.

CHAPTER FIVE

CONCLUSIONS

All of the unlaundered bags subjected to walk-testing withstood 50 cycles, which fully encompasses 10 of the 12 reuse criteria. Additionally, over half--12 out of 20 bags--withstood the 125 reuses required by the LA bag laws. Unravelling stitching, especially on the upper corner seams of the bags, appeared to be the most common cause of failure.

While the ATP-001 test is not representative of the stresses a bag endures in walk-testing and the bags tested via the ATP-001 method have different rates of among the various modes of failure, there does appear to have a similar overall failure between bags walked 125 times and bags subjected to 1500 ATP repetitions.

CHAPTER SIX

FUTURE STUDIES

Currently, there is little data on the effect of machine washing on nonwoven polypropylene fabric, likely owing to its usage in goods that are either designed to be used once and disposed of (such as diapers, medical facemasks, or cleaning wipes) or in applications that cannot be laundered (such as geotextiles, carpet backing, or vehicle upholstery); a more complete understanding may help design bags able to better endure laundering.

Further testing in the same vein of this research, especially with more assistance, could help fill in many details on the true durability of these bags; if enough people were available walk bags in shifts, testing-until-failure of 30 bags could be done within the space of a couple months. To get a more complete picture of washability, bags could be put through repeated laundering to see how many cycles of machine washing they could withstand until failure.

Finally, while NWPP bags have been found to be durable enough to offset their environmental impact, they still reach the end of their lifecycle and end up as landfilled waste. Since they have been in the world of consumer goods for a number of years, a comprehensive study on rates of disposal would shed some light on whether their introduction has led to a reduction of bag waste.

APPENDICES

Appendix A

Links to the Full Texts of Bag Legislation

Alaska

Bethel: Bethel Municipal Code, Title 8, Chapter 8.12:
http://www.codepublishing.com/AK/Bethel/html/Bethel08/Bethel0812.html

Homer: Ordinace 12-36A (mayoral veto overridden):
http://www.cityofhomer-ak.gov/ordil.nance/ordinance-12-36a-prohibiting-sellers-providing-customers-disposable-plastic-shopping-bags

Hooper Bay: N/A; Hooper Bay does not appear to publish its codes online; news of the bag ban appears to be third-party reports:
Pamphlet from Anchorage Municipal Website:
https://www.muni.org/Departments/SWS/recycle/Documents/2.2%20Bags,%20bags,%20bags.pdf

Arizona
State countermeasure: SB1241, 2015 First Regular Session:
http://www.azleg.gov/legtext/52leg/1r/laws/0271.htm

California

American Canyon City: American Canyon Municipal Code, Title 5, Chapter 5.01;
http://qcode.us/codes/americancanyon/view.php?topic=5-5_01&showAll=1&frames=on

Arcata: Arcata Muinicpal Code, Title V, Chapter 3.5, Sections 5476-5479;
http://www.cityofarcata.org/documentcenter/view/1018

Belvedere: Belvedere Municipal Code, Title 8, Chapter 8.06;
http://www.cityofbelvedere.org/DocumentCenter/View/1964

Brisbane: Brisbane Municipal Code, Title 8, Chapter 8.17;
http://brisbaneca.org/sites/default/files/Plastic%20Bag%20Ordinance%20580_0.pdf

Burlingame: Burlingame Municipal Code, Title 8, Chapter 8.12
http://qcode.us/codes/burlingame/view.php?topic=8-8_12&showAll=1&frames=on

Calabasas: Calabasas Municipal Code, Title 8, Chapter 8.17; *https://www2.municode.com/library/ca/city_of_calabasas/codes/code_of_ordinances?nodeId=TIT8HESA_CH8.17REUSPLCABAREPABAPRUSREBA_8.17.010DE*

Calistoga: Calistoga Municipal Code, Title 19, Chapter 19.12; http://www.codepublishing.com/CA/Calistoga/html/Calistoga19/Calistoga1912.html

Capitola: Capitola Municipal Code, Title 8, Chapter 8.07; http://www.codepublishing.com/CA/Capitola/html/capitola08/Capitola0807.html

Carmel-by-the-Sea: Carmel-by-the-Sea Municipal Code, Title 8, Chapter 8.74; http://www.codepublishing.com/CA/CarmelbytheSea/html/carmel08/Carmel0874.html

Carpentaria: Carpenteria Code of Ordinances, Title 8, Chapter 8.51; https://www2.municode.com/library/ca/carpinteria/codes/code_of_ordinances?nodeId=TIT8HESA_CH8.51SIEBARE

Cathedral City: Cathedral City Municipal Code, Title 5, Chapter 5.84; http://qcode.us/codes/cathedralcity/view.php?topic=5-5_84-5_84_010

Chico: Chico Code of Ordinances, Title 8, Chapter 8.36; http://library.amlegal.com/nxt/gateway.dll/California/chico_ca/title8healthandsanitation1/chapter836single-usecarryoutbags

City of Beverly Hills: Beverly Hills Municipal Code, Title 5, Chapter 10; http://www.sterlingcodifiers.com/codebook/getBookData.php?chapter_id=86111

City of Marina: Marina Municipal Code, Title 8, Chapter 8.60; http://www.codepublishing.com/CA/Marina/html/Marina08/Marina0860.html#8.60.010

City of Napa: Napa Municipal Code, Title 5, Chapter 5.65; http://qcode.us/codes/napa/view.php?topic=city_of_napa_municipal_code-5-5_65

Colma: Colma Municipal Code, Subchapter 4.12 http://www.colma.ca.gov/index.php/codes/municipal-code/4-business-activities-1/888-m-chapter-4-subchapter-12-reusable-bags-1/file

Corte Madera: Corte Madera Municipal Code, Title 6, Chapter 6.18; https://www2.municode.com/library/ca/corte_madera/codes/code_of_ordinances?nodeId=TIT6HESA_CH6.18RESIECABA

Culver City: Culver City Municipal Code, Title 11, Chapter 11.16; http://library.amlegal.com/nxt/gateway.dll/California/culver/title11businessregulations/chapter1116plasticcarryoutbagregulations?f=templates$fn=default.htm$3.0$vid=amlegal:culvercity_ca$anc=JD_CHAPTER11.16

Daly City: Daly City Municipal Code, Title 8, Chapter 8.68;
https://www2.municode.com/library/ca/daly_city/codes/code_of_ordinances?nodeId=TIT8HESA_CH8.68REBA

Dana Point City: Title 6, Chapter 6.47;
http://danapoint.org/home/showdocument?id=11667

Danville: Danville Municipal Code, Chapter VII, Section 7-7;
http://library.amlegal.com/nxt/gateway.dll/California/danville_ca/volumeigeneralregulations/chapterviihealthandwelfare?f=templates$fn=altmain-nf.htm$q=[field%20folio-destination-name:%277-7%27]$x=Advanced#JD_7-7

Davis City: Davis City Municipal Code, Article 32.05;
http://qcode.us/codes/davis/?view=desktop&topic=32-32_05-32_05_010

Desert Hot Springs: Desert Hot Springs Municipal Code, Title 8, Chapter 8.44;
http://www.qcode.us/codes/deserthotsprings/view.php?topic=8-8_44

El Cerrito: El Cerrito Municipal Code, Title 8, Chapter 8.22;
https://www2.municode.com/library/ca/el_cerrito/codes/code_of_ordinances?nodeId=TIT8HESA_CH8.22SIEBARE

Encinitas: Encinitas Municipal Code, Title 11, Chapter 11.26;
http://www.qcode.us/codes/encinitas/view.php?topic=11-11_26-11_26_010

Fairfax: Fairfax Town Code, Title 8, Chapter 8.18;
http://library.amlegal.com/nxt/gateway.dll/California/fairfax_ca/title8healthandsafety/chapter818plasticbagreduction?f=templates$fn=default.htm$3.0$vid=amlegal:fairfax_ca$anc=JD_Chapter8.18

Fort Bragg: Fort Bragg Municipal Code, Title 6, Chapter 6.26;
http://www.codepublishing.com/CA/FortBragg/html/FortBragg06/FortBragg0626.html

Glendale: Glendale Muinicpal Code, Title 5, Chapter 5.74;
http://qcode.us/codes/glendale/view.php?topic=5-5_74

Gonzales: Gonzales Municipal Code, Title 5, Chapter 5.54;
http://www.codepublishing.com/CA/Gonzales/html/Gonzales05/Gonzales0554.html

Grass Valley: Grass Valley Municipal Code, Title 8, Chapter 8.17;
https://www2.municode.com/library/ca/grass_valley/codes/code_of_ordinances?nodeId=TIT8HESA_CH8.17PLCABA

Greenfield: Greenfield Municipal Code, Title 8, Chapter 8.52;
http://www.codepublishing.com/CA/Greenfield/html/Greenfield08/Greenfield0852.html

Half Moon Bay: Half Moon Bay Municipal, Title 7, Chapter 7.35; http://www.codepublishing.com/CA/HalfMoonBay/#!/halfmoonbay07/HalfMoonBay0735.html

Hercules: Hercules City Code, Title 5, Chapter 11; http://www.codepublishing.com/CA/Hercules/#!/hercules05/Hercules0511.html

Hermosa Beach City: Hermosa Beach City Municipal Code, Title 8, Chapter 8.68; http://www.codepublishing.com/CA/HermosaBeach/#!/HermosaBeach08/HermosaBeach0868.htm

Indio: Indio Code of Ordinances, Title IX, Chapter 103; http://library.amlegal.com/nxt/gateway.dll/California/indio/titleixgeneralregulations/chapter103reusablebags

King City: King City Municipal Code, Title 8, Chapter 8.39; http://qcode.us/codes/kingcity/view.php?topic=8-8_39

Lafayette: Lafayette Code of Ordinances, Title 5, Chapter 5.7; https://www2.municode.com/library/ca/lafayette/codes/code_of_ordinances?nodeId=TIT5HESA_CH5-7SIECABA

Laguna Beach: Laguna Beach Municipal Code, Title 7, Chapter 7.21; http://www.qcode.us/codes/lagunabeach/view.php?topic=7-7_21

Larkspur: Larkspur Municipal Code, Title 6, Chapter 6.18; http://www.codepublishing.com/CA/Larkspur/html/Larkspur06/Larkspur0618.html

Long Beach: Long Beach Municipal Code, Title 8, Chapter 8.62; https://www2.municode.com/library/ca/long_beach/codes/municipal_code?nodeId=TIT8HESA_CH8.62PLCABA

Los Altos: Code of Ordinances, Title 6, Chapter 6.40; https://www2.municode.com/library/ca/los_altos/codes/code_of_ordinances?nodeId=TIT6HESA_CH6.40REBA

Los Angeles: Los Angeles Municipal Code, Chapter XIX Article 2; http://library.amlegal.com/nxt/gateway.dll/California/lamc/municipalcode/chapterxixenvironmentalprotection

Los Gatos: Town Code, Chapter 11, Article IV; https://www2.municode.com/library/ca/los_gatos/codes/code_of_ordinances?nodeId=CO_CH11GAREWE_ARTIVSIECATBA

Malibu: Malibu Code- Title 9 Chapter 9.28;
http://qcode.us/codes/malibu/view.php?topic=9-9_28

Mammoth Lake:
https://www.municode.com/library/ca/mammoth_lakes_/codes/code_of_ordinances?nodeId=TIT8HESA_CH8.10DIREBA

Manhattan Beach: Code of Ordinances, Title 5, Chapter 5.88;
https://www2.municode.com/library/ca/manhattan_beach/codes/code_of_ordinances?nodeId=TIT5SAHE_CH5.88ENRE

Martinez City: Code of Ordinances, Title 8, Chapter 8.23;
https://www2.municode.com/library/ca/martinez/codes/code_of_ordinances?nodeId=CD_ORD_TIT8HESA_CH8.23CABA

Mill Valley: Mill Valley Municipal Code, Title 7, Chapter 7.40;
http://qcode.us/codes/millvalley/view.php?topic=7-7_40

Millbrae City: Millbrae Municipal Code, Title 6, Chapter 6.05;
http://www.codepublishing.com/CA/Millbrae/#!/millbrae06/Millbrae0605.html

Milpitas: Code of Ordinances, Title III, Chapter 5;
https://www2.municode.com/library/ca/milpitas/codes/code_of_ordinances?nodeId=TITIIIBUPR_CH5SIEBA_S4SIECATBA

Monrovia: Code of Ordinances, Title 8, Chapter 8.44;
http://library.amlegal.com/nxt/gateway.dll/California/monrovia/title8healthandsafety/chapter844plasticcarryoutbags

Monterey: Monterey City Code, Chapter 14, Article 4;
http://www.codepublishing.com/CA/Monterey/html/monterey14.html#4

Morgan Hill City: Code of Ordinances, Title 8, Chapter 8.52;
https://www2.municode.com/library/ca/morgan_hill/codes/code_of_ordinances?nodeId=TIT8HESA_CH8.52PLCABA

Mountain View: Chapter 16, Article IV, Section 16.82;
https://www.municode.com/library/ca/mountain_view/codes/code_of_ordinances?nodeId=PTIITHCO_CH16GARUWE_ARTIVREBA_S16.82SIECATBA

Nevada City:
http://static1.squarespace.com/static/54d3a62be4b068e9347ca880/t/5581f2c0e4b0dd959fcbaeff/1434579648262/Nevada.pdf

Novato: Code of Ordinances, Chapter VII, Section 7-7;
https://www2.municode.com/library/ca/novato/codes/code_of_ordinances?nodeId=CHVIIHE_7-7RESIUSCABA

Ojai City: Ojai Municipal Code, Title 5, Chapter 5.13;
http://www.qcode.us/codes/ojai/view.php?topic=5-13

Palm Desert: Palm Desert Municipal Code, Title 5, Chapter 5.12;
http://www.qcode.us/codes/palmdesert/view.php?topic=5-5_12

Palm Springs: Palm Springs Municipal Code, Title 6, Chapter 6.09;
http://www.qcode.us/codes/palmsprings/view.php?topic=6-6_09

Palo Alto: Palo Alto Municpal Code, Title 5, Chapter 5.35;
http://library.amlegal.com/nxt/gateway.dll/California/paloalto_ca/title5healthandsanitation*/chapter535retailandfoodserviceestablishm

Pasadena: Code of Ordinances, Title 8, Chapter 8.65
https://www2.municode.com/library/ca/pasadena/codes/code_of_ordinances?nodeId=TIT8HESA_CH8.65PLCABA

Pico Rivera: Pico Rivera Municipal Code, Title 5, Chapter 5.74;
http://qcode.us/codes/picorivera/view.php?topic=5-5_74

Pittsburg: Pittsburg Municipal Code, Title 8, Chapter 8.07;
http://www.codepublishing.com/CA/Pittsburg/html/Pittsburg08/Pittsburg0807.html

Pleasant Hill: Pleasant Hill Municipal Code, Title 9, Chapter 9.65;
http://www.codepublishing.com/CA/PleasantHill/html/PleasantHill09/PleasantHill0965.html

Richmond: Code of Ordinances, Title 9, Chapter 9.14;
https://www2.municode.com/library/ca/richmond/codes/code_of_ordinances?nodeId=ARTIXHE_CH9.14SIEBAOR

Ross: Ross Municipal Code, Title 5, Chapter 5.06;
http://www.townofross.org/sites/default/files/fileattachments/administration/page/236/5.06_carryout_bags.pdf

Saint Helena: Saint Helena Municipal Code, Title 8, Chapter 8.36;
http://www.codepublishing.com/CA/StHelena/#!/sthelena08/StHelena0836.html

Salinas: Code of Ordinances, Chapter 16, Article XII;
https://www2.municode.com/library/ca/salinas/codes/code_of_ordinances?nodeId=PTIITHCO_CH16HESA_ARTXIIUSSIECABAREPABAREBAREES

San Anselmo: Code of Ordinances, Title 5, Chapter 5.9; https://www2.municode.com/library/ca/san_anselmo/codes/code_of_ordinances?nodeId=TIT5SAHE_CH9RESIUSCABA

San Jose: Code of Ordinances, Title 9, Chapter 9.10, Part 13; https://www2.municode.com/library/ca/san_jose/codes/code_of_ordinances?nodeId=TIT9HESA_CH9.10SOWAMA_PT13SIECATBA

San Pablo: San Pablo Municpal Code, Title 5, Chapter 5.12; http://www.codepublishing.com/CA/SanPablo/html/SanPablo05/SanPablo0512.html

Santa Barbara: Santa Barbara Municipal Code, Title 9, Chapter 9.150; http://www.santabarbaraca.gov/services/recycling/single_use_bags/official_ordinance.asp

Santa Monica: Santa Monica Municipal Code, Title 5, Chapter 5.45; http://www.smgov.net/uploadedFiles/Departments/OSE/Business/Bag_Ordinance_2348_signed_020811.pdf

Sausalito: Sausalito Municipal Code, Title 11, Chapter 11.30; http://www.codepublishing.com/CA/Sausalito/mobile/?pg=Sausalito11/Sausalito1130.html

Seaside: Seaside Municipal Code, Title 8, Chapter 8.60; http://www.codepublishing.com/CA/Seaside/#!/Seaside08/Seaside0862.html

Solana Beach: Solana Beach Municipal Code, Title 5, Chapter 5.01; http://www.codepublishing.com/CA/SolanaBeach/#!/solanabeach05/SolanaBeach0501.html

Soledad: Soledad City Council Ordinance 686 (to modify Title 8, Chapter 8.24); http://ci.soledad.ca.us/documentcenter/view/1383

South Lake Tahoe: South Lake Tahoe, City Code, Article VI, Chapter 23; http://www.cityofslt.us/index.aspx?nid=651

South Pasadena: South Pasadena Municipal Code, Chapter 16, Article III; http://www.qcode.us/codes/southpasadena/view.php?topic=16-ii-iii

Sunnyvale: Sunnyvale Municipal Code, Title 5, Chapter 5.38; *http://qcode.us/codes/sunnyvale/view.php?topic=5-5_38*

Tiburon: Tiburon Municipal Code, Title III, Chapter 10A; http://www.townoftiburon.org/DocumentCenter/View/123

Truckee: Truckee Municipal Code, Title 6, Chapter 6.18; http://www.townoftruckee.com/home/showdocument?id=9723

Ukiah: City Code of Ukiah, Division 5, Chapter 9; http://www.codepublishing.com/CA/Ukiah/html/Ukiah05/Ukiah0509-0100.html

Walnut Creek: Walnut Creek Municipal Code, Title 5, Chapter 5.6; http://www.ci.walnut-creek.ca.us/home/showdocument?id=1086

Watsonville: Watsonville Municipal Code, Chapter 6-7; http://cityofwatsonville.org/download/Public%20Works/Single%20Use%20Bag%20OrdinanceChapter%206.pdf

West Hollywood: West Hollywood Municipal Code, Title 15, Chapter 15.72; http://www.weho.org/home/showdocument?id=11133

Yountville: Town Ordinance 16-447 (to modify Municipal Code Chapter 8.06); http://qcode.us/codes/yountville/revisions/16-447.pdf

Counties:

Alameda County: http://reusablebagsac.org/ordinancetext.html (Ordinance 2012-2)

Los Angeles County: Los Angeles County Code, Title 12, Chapter 12.85; https://www2.municode.com/library/ca/los_angeles_county/codes/code_of_ordinances?nodeId=TIT12ENPR_CH12.85CABA

Marin County: Marin County Code, Title 5, Chapter 5.46; https://www2.municode.com/library/ca/marin_county/codes/code_of_ordinances?nodeId=TIT5BURELI_CH5.46DIBAREOR

Mendocino County: Mendocino County Code, Title 9, Chapter 9.41; https://www2.municode.com/library/ca/mendocino_county/codes/code_of_ordinances?nodeId=MECOCO_TIT9HESA_CH9.41SIECABAREES

Monterey County: Monterey County Code, Title 10, Chapter 10.43; https://www2.municode.com/library/ca/monterey_county/codes/code_of_ordinances?nodeId=TIT10HESA_CH10.43USSIECABAREPABAREBAREES

San Francisco City and County: San Francisco Environment Code, Chapter 17; http://library.amlegal.com/nxt/gateway.dll/California/environment/chapter17plasticbagreductionordinance

San Luis Obispo County: Integrated Waste Management Authority Ordinance 2012-1; http://iwma.com/admin/ordinances/Ordinance_2012-1_Single_Use_Carryout_Bags.pdf

San Mateo County: San Mateo County Code, Title 4, Chapter 4.114; https://www2.municode.com/library/ca/san_mateo_county/codes/code_of_ordinances?nodeId=TIT4SAHE_CH4.114REBA

Santa Barbara County: Santa Barbara County Code, Chapter 16B; https://www2.municode.com/library/ca/santa_barbara_county/codes/code_of_ordinances?nodeId=CH16BSIEPLBABA

Santa Clara County: Santa Clary County Code, Title B, Division B11, Chapter XVII; https://www2.municode.com/library/ca/santa_clara_county/codes/code_of_ordinances?nodeId=TITBRE_DIVB11ENHE_CHXVIISIECABABA

Santa Cruz County: Santa Cruz County Code, Title 5, Chapter 5.48; http://www.codepublishing.com/CA/SantaCruzCounty/html/SantaCruzCounty05/SantaCruzCounty0548.html

Sonoma County: Sonoma County Waste Management Agency, Ordinance 2014-02: http://www.recyclenow.org/pdf/Ordinance_2014-02_Waste_Reduction_Program_for_Carryout_Bags.pdf

Colorado

Aspen: Aspen Municipal Code, Chapter 13.24; http://www.aspenpitkin.com/Portals/0/docs/City/clerk/coaspent13.pdf

Boulder City: Boulder City Municipal Code, Title 6, Chapter 15; https://www2.municode.com/library/co/boulder/codes/municipal_code?nodeId=TIT6HESASA_CH15DIBAFE

Breckenridge: Breckenridge Municipal Code, Title 5, Chapter 12; http://sterlingcodifiers.com/codebook/index.php?book_id=878&chapter_id=83407

Carbondale: Carbondale Town Code, Chapter 7, Article 7; https://www2.municode.com/library/co/carbondale/codes/municipal_code?nodeId=CD_ORD_CH7HESAAN_ART7DICABARE

Telluride: Telluride Town Code, Chapter 7, Article 7; http://www.telluride-co.gov/DocumentCenter/View/3112

Vail: Vail Town Code, Title 5, Chapter 13;
http://sterlingcodifiers.com/codebook/index.php?book_id=560&chapter_id=91111

Connecticut

Westport: Westport Code of Ordinances, Chapter 46, Article VI;
https://www2.municode.com/library/ct/westport/codes/code_of_ordinances?nodeId=PTIICOORTOWE_CH46SOWAMA_ARTVIRECHBA

DC

Washington, DC: Division I, Title 8, Subtitle A, Chapter 1, Subchapter 1-A;
http://doee.dc.gov/sites/default/files/dc/sites/ddoe/publication/attachments/Anacostia%20Clean%20Up%20and%20Protection%20Act%20of%202009_3.20.15.pdf

Hawai'i

Hawai'i County: Hawai'i County Code, Chapter 14, Article 20;
http://www.hawaiicounty.gov/lb-file-review/files/county-code/chapter14.pdf

Honolulu County: Honolulu County Code, Chapter 9, Article 9;
https://www.honolulu.gov/rep/site/ocs/roh/ROH_Chapter_9_.pdf

Kaua'i County: Kaua'i County Code 1987, Chapter 22, Article 19;
http://www.kauai.gov/Portals/0/PW_Recycling/PlasticBagReductionOrdinance885.pdf

Maui County: Maui County Code, Title 20, Chapter 20.18;
http://www.mauicounty.gov/DocumentCenter/Home/View/8369

Illinois

Chicago: Chicago Municipal Code, Title 11, Chapter 11-4, Article XXIII;

http://library.amlegal.com/nxt/gateway.dll/Illinois/chicago_il/title11utilitiesandenvironmentalprotecti/chapter11-4environmentalprotectionandcon

Evanston: Evanston City Code, Title 8, Chapter 8.25;
https://www2.municode.com/library/il/evanston/codes/code_of_ordinances?nodeId=TIT8HESA_CH25PLSHBA

Iowa
Marshall County: Marshall County Code of Ordinances, Ordinance 30;
http://www.co.marshall.ia.us/departments/bos/minutes/2008/2008-09-16_0946.pdf

Maine

Falmouth: Falmouth Code of Ordinances, Chapter II, Article 8, Section 12;
http://www.falmouthme.org/sites/falmouthme/files/news/2015-11-02_plastic_bag_ordinance_clean_-_final.pdf

Portland: City Code of Ordinances, Chapter 12, Article IX, §§12-230 – 12-237;
http://www.portlandmaine.gov/DocumentCenter/Home/View/1076

South Portland: City Code of Ordinances, Chapter 9, Article VI, §§9-745 – 9-752;
http://www.southportland.org/files/2714/4484/6543/CH_09_Garbage_and_Refuse_09-21-15.pdf

York: Single-Use Plastic Carry Out Bag Ordinance;
http://www.yorkmaine.org/LinkClick.aspx?fileticket=ZNpP568snO4%3d&tabid=181&mid=1632

Maryland

Chestertown: Town Code of Ordinances, Chapter 133;
http://library.amlegal.com/nxt/gateway.dll/Maryland/chestertown_md/partiigenerallegislation/chapter133plasticbagreduction

Montgomery County: Code of Mongomery County Regulations, Chapter 52, Article XIV;
http://library.amlegal.com/nxt/gateway.dll/Maryland/comcor/chapter52taxation-regulations?f=templates$fn=default.htm$3.0$vid=amlegal:montgomeryco_md_mc$anc=JD_52.101.01

Massachusetts

Barnstable: Barnstable Town Code, Chapter 195;
http://ecode360.com/30557108

Brookline: Town of Brookline General By-Laws, Part VIII, Article 8.33;
http://www.brooklinema.gov/DocumentCenter/View/353

Cambridge: Code of Ordinances, Title 8, Chapter 8.68; https://www2.municode.com/library/ma/cambridge/codes/code_of_ordinances?nodeId=TIT8HESA_CH8.68BRYOOWBA

Concord: Town Bylaws, Plastic Bag Reduction Bylaw, http://www.concordma.gov/Pages/ConcordMA_Recycle/plasticbag.reduction.bylaw.pdf

Framingham: Framingham Town Bylaws, Article VIII, Section 8; http://www.baglaws.com/assets/pdf/massachusetts_framingham.pdf

Great Barrington: Commonwealth Code, Chapter 135; http://ecode360.com/28687832

Hamilton: Town Bylaws, Chapter XXXV; http://www.hamiltonma.gov/Pages/HamiltonMA_News/021FFC8B-000F8513

Harwich: Harwich Town Code, Chapter 122, Article II; http://ecode360.com/30579267

Ipswich: General By-Laws of the Town of Ipswich, Chapter XXIII; http://www.baglaws.com/assets/pdf/massachusetts_ipswich.pdf

Manchester: General By-Laws of Manchester-by-the-Sea, Section 42; http://ma-manchesterbythesea.civicplus.com/DocumentCenter/View/545

Marblehead: Marblehead Town Code, Chapter 157, Article II; http://ecode360.com/29408985

Newburyport: Code of Ordinances, Chapter 6.5, Article III; https://www2.municode.com/library/ma/newburyport/codes/code_of_ordinances?nodeId=PTIICOOR_CH6.5EN_ARTIIIPLBA

Newton: Revised Ordinances of Newton, Chapter 12, Article IX; http://www.newtonma.gov/civicax/filebank/documents/64451

Northampton: City Code, Chapter 272, Article II, §272-18 thru 272-22; http://ecode360.com/29442308

Provincetown: Town of Provincetown General Bylaws, Section 13, Subsection 13-6; http://www.provincetown-ma.gov/DocumentCenter/Home/View/323

Truro: Truro General By-Laws, Chapter 3, Section 6; http://www.truro-ma.gov/licensing-department/news/town-of-truro-public-notice-new-section-to-the-truro-general-by-law-chapte

Wellesley: Wellesley Town By-Laws, Section 34.5C; http://www.baglaws.com/assets/pdf/massachusetts_wellesley.pdf

Wellfleet: By-Laws of the Town of Wellfleet, Article VII, Section 38; http://www.wellfleet-ma.gov/sites/wellfleetma/files/file/file/wellfleet_general_bylaws_as_amended_april_27_2015.pdf

Williamstown: Article 41; http://ecode360.com/documents/WI1660/source/LF861530.pdf

Other: The Vineyard Conservation Society of the state appears to have an ongoing initiative to ban bags throughout the island of Martha's Vineyard. Thus far, bylaws banning bags appear to have passed in Edgartown, Chilmark, Tisbury, and West Tisbury. The text of the law is available here: http://www.vineyardconservation.org/httpssitesgooglecomavineyardconservationorgvineyard-conservation-societyHome/plastic-bag-reduction-bylaw/bylaw-text-for-2016-town-meetings

The Tri-Town Health Department of Lee, Lenox and Stockbridge appear to have adopted the Thin-Film Bag Reduction Bylaw across their various municipalities. The text of the bylaw is available here: http://www.lee.ma.us/sites/leema/files/uploads/warrant_article_-_thin-film_bags_-_without_foodnotes_-_edited_april_24.pdf

New Jersey

Longport: Code of the Borough of Longport, Chapter 107; http://www.longportnj.gov/notices/O2015-14-Plastic-bag-reduction.pdf

New Mexico

Santa Fe: Santa Fe City Code, Chapter XXI, section 21-8; http://www.santafenm.gov/media/archive_center/2u___23_CD1.pdf

Silver City: Silver City Code of Ordinances, Chapter 40, Article II, Section 40-27; https://www2.municode.com/library/nm/silver_city/codes/code_of_ordinances?nodeId=PTIICOOR_CH40SOWA_ARTIILICO_S40-27RESIEPLCABAUS

New York

Statewide: New York Environmental Conservation Code, Article 27, Title 27; http://codes.findlaw.com/ny/environmental-conservation-law/#!tid=NDACD9F30CD1C11DDA61D96728C865745

East Hampton Town: East Hampton Town Code, Chapter 83;
http://ecode360.com/29783565

East Hampton Village: East Hampton Village Code, Chapter 231;
http://ecode360.com/15345681

Hastings-On-Hudson: Hastings-On-Hudson Village Code, Chapter 244, Article IV;
http://ecode360.com/30773552

Larchmont: Larchmont Village Code, Chapter 219;
http://ecode360.com/27180684

Mamaroneck: Mamaroneck Village Code, Chapter 281;
http://ecode360.com/26841918

New Paltz Village: New Paltz Village Code, Chapter 160;
http://ecode360.com/29522578

Patchogue Village: Patchogue Village Code, Chapter 315;
http://ecode360.com/30354948

Rye: Rye City Code, Chapter 154;
http://ecode360.com/15613969

South Hampton Town: South Hampton Town Code, Chapter 212;
http://ecode360.com/29600510

South Hampton Village: South Hampton Village Code, Chapter 82, Article VII;
http://ecode360.com/15145163

North Carolina

Statewide: North Carolina General Statutes, Chapter 130A, Article 309, Part 2G:
http://www.ncga.state.nc.us/Sessions/2009/Bills/Senate/HTML/S1018v0.html
(N.B.: while ratified at the state level, the area of effect only includes the Outer Banks)

Oregon:

Ashland: Ashland Municipal Code, Title 9, Chapter 9.21;
http://www.ashland.or.us/Page.asp?NavID=16548

Corvalis: Corvalis Code of Ordinances, Title 8, Chapter 8.24;
https://www2.municode.com/library/or/corvallis/codes/code_of_ordinances?nodeId=TIT8BU_CH8.14SIEPLCABA

Eugene: Eugene City Code, Chapter 6, Sections 6.850, 6.855, 6.860, 6.865; http://www.eugene-or.gov/2060/Plastic-Bags

Portland: Portland City Code and Charter, Title 17, Chapter 17.103; https://www.portlandoregon.gov/citycode/?c=56750

Rhode Island

Barrington: Barrington Town Code, Chapter 161, Article III; http://ecode360.com/26767055

Texas

Austin: Code of Ordinances, Title 15, Chapter 15-6, Article 7; https://www2.municode.com/library/tx/austin/codes/code_of_ordinances?nodeId=TIT15UTRE_CH15-6SOWASE_ART7CABA

Brownsville: Code of Ordinances, Chapter 46, Article II, Sections 46-47 thru 46-52; https://www2.municode.com/library/tx/brownsville/codes/code_of_ordinances?nodeId=PTIICOOR_CH46EN_ARTIILI_S46-47DEPEPLBARE

Fort Stockton: Code of Ordinances, Chapter 12, Article I, Sections 12-8 thru 12-11; https://www2.municode.com/library/tx/fort_stockton/codes/code_of_ordinances?nodeId=COOR_CH12GATR_ARTIINGE_S12-9PLBARE

Kermit: Code of Ordinances, Title IX, Chapter 98; http://library.amlegal.com/nxt/gateway.dll/Texas/kermit_tx/titleixgeneralregulations/chapter98plasticcarryoutbags

Laguna Vista: Laguna Vista does not appear to host a municipal code, nor a complete table of ordinances online. The only evidence appears to be scanned copies of Ordinance 2012-23:
http://www.baglaws.com/assets/pdf/texas_laguna_vista.pdf

Laredo: Code of Ordinances, Chapter 33, Article VIII; https://www2.municode.com/library/tx/laredo/codes/code_of_ordinances?nodeId=PTIICOOR_CH33ENPR_ARTVIIICHBARE

Port Aransas: Code of Ordinances, Chapter 10, Article II, Division 2; https://www2.municode.com/library/tx/port_aransas/codes/code_of_ordinances?nodeId=PTIIPOARCO_CH10HESA_ARTIILIWACO_DIV2RESIUSPLCHBA

South Padre Island: South Padre Island Code of Ordinances, Chapter 12, Section 12-30; http://www.myspi.org/egov/documents/1463762712_92748.pdf

Sunset Valley:

Virginia

Statewide: for Chesapeake Bay Watershed retailers:

In January 2015, the state senate approved an amendment to Article 7.1 of Chapter 38 of Title 58.1, adding measure to implement a 5-cent fee on plastic bags distributed by retailers in the Chesapeake Bay Watershed area; 4 cents of each fee goes to the Virginia Water Quality Improvement Fund.

Washington

12 municipalities, including Seattle (the largest city) and Tacoma (third largest city), and one county, Thurston, have banned bags.

Wisconsin

One municipality, Madison, requires retail stores to provide on-site bag recycling. Another municipality, the city of Eau Claire, has passed a law to undertake a study on bag legislation, but has not yet enacted any bans or fees.

Appendix B

Materials Used to Construct ATP-001 Tester

Part: Manual control 4-way air valve 1/4" NPT

- **Quantity:** 1
- **Supplier:** Zoro, Inc.
- **Part No.** G3467904
- **Price:** $61.95
- **Link:** https://www.zoro.com/aro-manual-air-control-valve-4-way-14in-npt-m212lm/i/G3467904/?q=G3467904

Part: Pressure gauge, 2" diameter

- **Quantity:** 1
- **Supplier:** Zoro, Inc.
- **Part No.** G0045552
- **Price:** $4.85
- **Link:** https://www.zoro.com/value-brand-pressure-gauge-test-2-in-4fmc6/i/G0045552/?q=G0045552)

Part: Exhaust port flow control, 1/4" NPT

- **Quantity:** 2
- **Supplier:** Zoro, Inc.
- **Part No.:** G3169941
- **Price:** $7.10 each
- **Link:** https://www.zoro.com/aro-exhaust-port-flow-control-14-in-npt-20313-2/i/G3169941/?q=G3169941

Part: 1½" double action pneumatic cylinder with 14" (35.56cm) stroke

- **Quantity:** 2
- **Supplier:** Automation Direct
- **Part No:** D24140DT-M; price: $131.00 each;
- **Price:** $131.00 each
- **Link:** http://www.automationdirect.com/adc/Shopping/Catalog/Pneumatic_Components/Pneumatic_Air_Cylinders/NFPA_Tie_Rod_Air_Cylinders_%28D-Series%29/D24140DT-M

Part: Flange plate for use with cylinder

- **Quantity:** 2
- **Supplier:** Automation Direct
- **Part No.:** DFM-1
- **Price:** $20.00 each
- **Link:** http://www.automationdirect.com/adc/Shopping/Catalog/Pneumatic_Components/Pneumatic_Air_Cylinders/NFPA_Tie_Rod_Air_Cylinders_%28D-Series%29/DFM-1)

Part: Rod clevis, 7/16" x 20 for cylinder rod end

- **Quantity:** 2
- **Supplier:** Automation Direct
- **Part No.:** DRC-2
- **Price:** $26.00 each
- **Link:** http://www.automationdirect.com/adc/Shopping/Catalog/Pneumatic_Components/Pneumatic_Air_Cylinders/NFPA_Tie_Rod_Air_Cylinders_%28D-Series%29/DRC-2

Part: DynaFlo® 1/4" Female NPT Aluminum Die-Cast Intermediate Regulator

- **Quantity:** 1
- **Supplier:** Fastenal Co.
- **Part No.** 0411018
- **Price:** $25.70
- **Link:** https://www.fastenal.com/products/details/0411018

Part: 1/4" Tube Nylon Push-to-Connect Union Tee

- **Quantity:** 5
- **Supplier:** Fastenal Co.
- **Part No.:** 0419610
- **Price:** $18.09/package of 5
- **Link:** https://www.fastenal.com/products/details/0419610?term=0419610

Part: 1/4" Tube x 1/4" Male NPT Nickel Plated Brass Push-to-Connect Connector

- **Quantity:** 5
- **Supplier:** Fastenal Co.

- **Part No.:** 0418681
- **Price:** $10.03/package of 5
- **Link:** https://www.fastenal.com/products/details/0418681

Part: Branch Tee, 0.170 In Tube Size, Brass

- **Quantity:** 2
- **Supplier:** Grainger
- **Part No.:** 2GUK8
- **Price:** $4.92 each
- **Link:** http://www.grainger.com/product/PARKER-Branch-Tee-2GUK8

Part: Part: 1/4" polyflow air tubing

- **Quantity:** 26ft
- **Supplier:** Ace Hardware
- **Part No.:** N/A
- **Price:** $0.25/ft
- **Link:** N/A

Part: 3/8" polyflow tubing for air supply line,

- **Quantity:** 6 feet
- **Supplier:** Ace Hardware
- **Part No.:** N/A
- **Price:** $0.75 per foot
- **Link:** N/A

Part: 5 inch square steel foot

- **Quantity:** 2
- **Supplier:** In-House
- **Part No.:** N/A
- **Price:** N/A
- **Link:** N/A

Part: 56" L x ¼" W x 1½" H, flat steel stock

- **Quantity:** 1
- **Supplier:** In-House
- **Part No.:** N/A
- **Price:** N/A

- **Link:** N/A

Part: 1/4" concrete bolt anchors,8 needed, supplied in-house.

- **Quantity:** 8
- **Supplier:** In-house
- **Part No.:** N/A
- **Price:** N/A
- **Link:** N/A

Part: 1/4" lag bolt

- **Quantity:** 8
- **Supplier:** In-house
- **Part No.:** N/A
- **Price:** N/A
- **Link:** N/A

APPENDIX C

Text of the ATP-001 Protocol

ENVIRONMENTAL CHOICE^{M} PROGRAM

Reusable Utility Bags
(CCD-100)

ACCEPTANCE TEST PROCEDURE

SUBJECT:	Reusable Shopping Bags
PROCEDURE NUMBER:	ATP001
ISSUE LEVEL:	003
EFFECTIVE DATE:	November 07, 1995

ENVIRONMENTAL CHOICE^{M} PROGRAM
REUSABLE UTILITY BAGS (CCD-100)
ACCEPTANCE TEST PROCEDURE

SUBJECT: Reusable Shopping Bags	ATP001

1.0 PURPOSE

1.1 The purpose of this Acceptance Test Procedure is to describe the method used by the Environmental Choice^{M} Program (ECP) or its representative, to verify that Reusable Shopping Bags (RSB) meet the requirements of the ECP criteria *Reusable Utility Bags* (CCD-100).

2.0 SCOPE

2.1 This document applies to RSBs made of natural or synthetic materials intended for consumer use.

3.0 RSB SPECIFICATIONS: GENERAL PROPERTIES

3.1 The RSB shall be new, clean, and free from blemishes, holes, tears, cuts, broken strands, or other imperfections that may impair serviceability. All cut edges shall be properly finished to prevent unravelling. All rivets or similar devices shall be free from sharp edges.

3.2 The RSB shall be open mouthed with the mouth facing up in the carrying position.

3.3 The RSB shall be equipped with two carrying handles, one on each side of the opening.

4.0 TEST EQUIPMENT AND MATERIALS

4.1 A cycling apparatus with a minimum stroke length of 20cm, capable of lifting and lowering a load of 10kg at the rate of 17"2cm/s.

4.2 A smooth soft faced hook of half-elliptical cross-section with a base dimension of 9cm, a half-height dimension of 2.3cm, and a width of 4cm. A soft face shall be a single layer of 3mm to 4mm foam tape applied to the handle surface.

4.3 A block of concrete (dimensions: 50cm long, 40cm wide, 20cm high) having a smooth, flat and horizontal impact surface, covered with smooth patterned non-cushioned vinyl floor tile (Solarium or equivalent). A smooth concrete floor of equivalent or greater mass resistance may be used in lieu of the concrete block.

4.4 Twenty-one (21) 1/2 pint paint cans with friction fit lids, filled with water to a total mass of 312g per can, including the lid. Can dimensions shall be a height of 8.0cm and a diameter of 7.5cm.

4.5 Twenty-two (22) hardwood blocks (dimensions: 5cm x 5cm x 10cm) with a smooth corner radius of not more than 2mm, and having a density not less than $0.62 g/cm^3$.

4.6 A quantity (15kg) of granular material such as sand, lead shot or abrasive grit with a apparent density of not less than $1.2 g/cm^3$.

4.7 Granular or powdered material such as sawdust or absorbent with an apparent density of not more than $0.30 g/cm^3$.

4.8 A container graduated in litres.

4.9 Lining (as required). Note that for certain RSBs, such as the "net" or "mesh" types, a lining in the shape of a bag will be required to contain the material. This lining should be sufficiently large and flexible to assume the shape of the RSB, when filled.

5.0 TEST CONDITIONS

5.1 TEST SAMPLES

5.1.1 A different RSB must be used for each test procedure.

5.2 ASSESSMENT CRITERIA

5.2.1 When a specific test states "Assess the RSB for damage", it shall be taken to mean:

Examine the RSB for tears; holes; broken stitches; seam failures; localized distortion; disfigurement of markings; and any other damage. Record the approximate size, location, and type of damage. The RSB fails the assessment if:

(a) any portion of the RSB becomes detached;

(b) any hole, separation, localized distortion, or other damage exceeds 5mm in its largest dimension; or

(c) weave distortion ("grinning" effect) in excess of 25mm in any direction when measured either from the seam to a point of undisturbed, or between two points of undisturbed fabric, as applicable.

5.3 CAPACITY TEST

5.3.1 Fill the RSB to its rim with granular or powdered material (4.7).

5.3.2 Using the graduated container (4.8) measure the volume of material in the RSB in cm^3. A capacity of less than 15,000"100cm^3 is cause for rejection.

5.3.3 Alternate Capacity Test: Fill a large graduated container with material and pour it into the RSB until full, recording the amount of material poured out as the capacity.

5.4 STATIC LOAD TEST

5.4.1 Immerse RSB in a container of tap water (at approximately ambient temperature) for 5 minutes. Remove RSB from container and allow excess water to drain for 2 minutes. Ensure that no water is trapped within the RSB.

5.4.2 Fill RSB with 15kg net of the granular mixture (4.6). If required, use a lining (4.9) in the RSB. Suspend the RSB in a free swinging manner by <u>one</u> handle from the test hook (4.2). After one minute measure and record the distance from the hook to the bottom of the RSB. Let the RSB stand for 30 minutes.

5.4.3 After 30 minutes, measure and record the distance again and calculate the RSB stretch as a percentage (%) of the first measurement (5.4.2). Stretch shall not exceed 10%.

5.4.4 Remove RSB, empty contents and assess the RSB for damage.

5.5 DYNAMIC TEST

5.5.1 Immerse the RSB in a container of tap water for 5 minutes. Remove the RSB from the container and allow excess water to drain for 2 minutes. Ensure that no water is trapped within the RSB.

5.5.2 Toss wood blocks (4.5) and cans (4.4) alternately one at a time into the RSB and allow them to come to rest in random order. Add granular material (4.6) to achieve a mass of 10kg net. If there is not enough space for all blocks and cans substitute additional cans for blocks.

5.5.3 Place the RSB on the concrete test surface (4.3) and attach the RSB handles to the cycling apparatus (4.1) using the hook (4.2).

5.5.4 With the RSB hanging freely from the hook by both handles, measure and record the distance from the hook to the lowest extremity of the RSB. Measure and record the width and thickness of the RSB.

5.5.5 Adjust the stroke length so that the RSB sits upright on the test block (lowest point of stroke length) with only a slight slack in the handles.

5.5.6 Raise and lower the RSB through 300 cycles or until damage (5.2.1) occurs, at a rate of about 15 cycles/min, raising the RSB 20 ± 2cm at an average speed of 17 ± 2cm/s and lowering it at an average speed of 40 ± 4cm/s.

5.5.7 Remove the RSB from the test hook, empty the contents and assess for damage.

5.5.8 Repeat steps in sections 5.5.2 through 5.5.7 for a total of 2,700 cycles, or until damage occurs. Dimensional measurements shall not exceed 10% of the initial measurements.

6.0 FORMS

Form Number	Title
ATP001-1	Test Result Sheet

SUBJECT: REUSABLE SHOPPING BAGS Test Results Sheet: ATP001-1	
File No:	Test Lab:
Guideline No: CCD-100	P.O. No:

Manufacturer	Type	Model	Test Technician	Pass/Fail	Date
			Name:		
			Signature:		

TEST REFERENCE (Section)	SPECIFICATION	TOLERANCE	RESULT	ERROR
3.0	**RSB SPECIFICATIONS: GENERAL PROPERTIES**			
3.1	No damage, finished to prevent ravelling, no sharp edges	N/A		
3.2	Open mouthed at top when in carrying position	N/A		
3.3	1 handle each side of opening	N/A		
5.3	**CAPACITY TEST**			
5.3.2 or 5.3.3	Record volume> 15,000cm^3		100cm^3	
5.4	**STATIC LOAD TEST**			
5.4.2	Record RSB length after 1 minute	N/A		
5.4.3	Record RSB length after 30 minutes	< 10% stretch		
	Damage	Section 5.2.1	* **(see below)**	
5.5	**DYNAMIC TEST**			
5.5.4	Initial height measurement (cm)	N/A		
	Initial width measurement (cm)	N/A		
	Initial thickness measurement (cm)	N/A		

* If applicable, sufficiently describe damage to RSB.

TEST REFERENCE (Section)	SPECIFICATION		TOLERANCE	RESULT	ERROR
5.5.4 and 5.5.7	300 cycles	Damage	Section 5.2.1	* **(see below)**	
		length (cm)	< 10% stretch		
	600 cycles	Damage	Section 5.2.1	* **(see below)**	
		length (cm)	< 10% stretch		
	900 cycles	Damage	Section 5.2.1	* **(see below)**	
		length (cm)	< 10% stretch		
	1200 cycles	Damage	Section 5.2.1	* **(see below)**	
		length (cm)	< 10% stretch		
	1500 cycles	Damage	Section 5.2.1	* **(see below)**	
		length (cm)	< 10% stretch		
	1800 cycles	Damage	Section 5.2.1	* **(see below)**	
		length (cm)	< 10% stretch		
	2100 cycles	Damage	Section 5.2.1	* **(see below)**	
		length (cm)	< 10% stretch		
	2400 cycles	Damage	Section 5.2.1	* **(see below)**	
		length (cm)	< 10% stretch		
	2700 cycles	Damage	Section 5.2.1	* **(see below)**	
		length (cm)	< 10% stretch		
5.5.8	Final width measurement (cm)		< 10% stretch		
	Final thickness measurement (cm)		< 10% stretch		

* If applicable, sufficiently describe damage to RSB.

APPENDIX E:

Text of the Los Angeles Bag Ban Law

ANALYSIS

This ordinance amends Title 12 – Environmental Protection of the Los Angeles County Code, by adding a Chapter regulating the use of plastic carryout bags and recyclable paper carryout bags and promoting the use of reusable bags within the County unincorporated area.

Pursuant to this new Chapter, plastic carryout bags, as defined, may no longer be distributed by affected stores and a 10-cent ($0.10) charge for recyclable paper carryout bags distributed by those stores will apply.

ANDREA SHERIDAN ORDIN
County Counsel

By
TRUC L. MOORE
Deputy County Counsel
Public Works Division

TLM:ia

09/23/10 (Requested)

11/16/10 (Revised)

HOA.741373.1

ORDINANCE NO. ___________

An ordinance amending Title 12 – Environmental Protection of the Los Angeles County Code, relating to regulating the use of plastic carryout bags and recyclable paper carryout bags and promoting the use of reusable bags within the County unincorporated area.

The Board of Supervisors of the County of Los Angeles ordains as follows:

SECTION 1. Chapter 12.85 is hereby added to read as follows:

12.85.010 Definitions.

The following definitions apply to this Chapter:

A. "Customer" means any person purchasing goods from a store.

B. "Operator" means the person in control of, or having the responsibility for, the operation of a store, which may include, but is not limited to, the owner of the store.

C. "Person" means any natural person, firm, corporation, partnership, or other organization or group however organized.

D. "Plastic carryout bag" means any bag made predominantly of plastic derived from either petroleum or a biologically-based source, such as corn or other plant sources, which is provided to a customer at the point of sale. "Plastic carryout bag" includes compostable and biodegradable bags but does not include reusable bags, produce bags, or product bags.

E. "Postconsumer recycled material" means a material that would otherwise be destined for solid waste disposal, having completed its intended end use and product life cycle. "Postconsumer recycled material" does not include materials and by-products generated from, and commonly reused within, an original manufacturing and fabrication process.

F. "Produce bag" or "product bag" means any bag without handles used exclusively to carry produce, meats, or other food items to the point of sale inside a store or to prevent such food items from coming into direct contact with other purchased items.

G. "Recyclable" means material that can be sorted, cleansed, and reconstituted using available recycling collection programs for the purpose of using the altered form in the manufacture of a new product. "Recycling" does not include burning, incinerating, converting, or otherwise thermally destroying solid waste.

H. "Recyclable paper carryout bag" means a paper bag that meets all of the following requirements: (1) contains no old growth fiber, (2) is one hundred percent (100%) recyclable overall and contains a minimum of forty percent (40%) post-consumer recycled material; (3) is capable of composting, consistent with the timeline and specifications of the American Society of Testing and Materials (ASTM) Standard D6400; (4) is accepted for recycling in curbside programs in the County; (5) has printed on the bag the name of the manufacturer, the location (country) where the bag was manufactured, and the percentage of postconsumer recycled material used; and (6) displays the word "Recyclable" in a highly visible manner on the outside of the bag.

I. "Reusable bag" means a bag with handles that is specifically designed and manufactured for multiple reuse and meets all of the following requirements: (1) has a minimum lifetime of 125 uses, which for purposes of this subsection, means the capability of carrying a minimum of 22 pounds 125 times over a distance of at least 175 feet; (2) has a minimum volume of 15 liters; (3) is machine washable or is made from a material that can be cleaned or disinfected; (4) does not contain lead, cadmium, or any other heavy metal in toxic amounts, as defined by applicable state and federal standards and regulations for packaging or reusable bags; (5) has printed on the bag, or on a tag that is permanently affixed to the bag, the name of the manufacturer, the location (country) where the bag was manufactured, a statement that the bag does not contain lead, cadmium, or any other heavy metal in toxic amounts, and the percentage of postconsumer recycled material used, if any; and (6) if made of plastic, is a minimum of at least 2.25 mils thick.

J. "Store" means any of the following retail establishments located within the unincorporated area of the County:

(1) A full-line, self-service retail store with gross annual sales of two million dollars ($2,000,000), or more, that sells a line of dry grocery, canned goods, or nonfood items and some perishable items;

(2) A store of at least 10,000 square feet of retail space that generates sales or use tax pursuant to the Bradley-Burns Uniform Local Sales and Use Tax Law (Part 1.5 (commencing with Section 7200) of Division 2 of the Revenue and Taxation Code) and that has a pharmacy licensed pursuant to Chapter 9 (commencing with Section 4000) of Division 2 of the Business and Professions Code; or

(3) A drug store, pharmacy, supermarket, grocery store, convenience food store, foodmart, or other entity engaged in the retail sale of a limited line of goods

that includes milk, bread, soda, and snack foods, including those stores with a Type 20 or 21 license issued by the Department of Alcoholic Beverage Control.

12.85.020 Plastic carryout bags prohibited.

A. No store shall provide to any customer a plastic carryout bag.

B. This prohibition applies to bags provided for the purpose of carrying away goods from the point of sale and does not apply to produce bags or product bags.

12.85.030 Permitted bags.

All stores shall provide or make available to a customer only recyclable paper carryout bags or reusable bags for the purpose of carrying away goods or other materials from the point of sale, subject to the terms of this Chapter. Nothing in this Chapter prohibits customers from using bags of any type that they bring to the store themselves or from carrying away goods that are not placed in a bag, in lieu of using bags provided by the store.

12.85.040 Regulation of recyclable paper carryout bags.

A. Any store that provides a recyclable paper carryout bag to a customer must charge the customer 10 cents ($0.10) for each bag provided, except as otherwise provided in this Chapter.

B. No store shall rebate or otherwise reimburse a customer any portion of the 10-cent ($0.10) charge required in Subsection A, except as otherwise provided in this Chapter.

C. All stores must indicate on the customer receipt the number of recyclable paper carryout bags provided and the total amount charged for the bags.

D. All monies collected by a store under this Chapter will be retained by the store and may be used only for any of the following purposes: (1) costs associated with complying with the requirements of this Chapter, (2) actual costs of providing recyclable paper carryout bags, or (3) costs associated with a store's educational materials or education campaign encouraging the use of reusable bags, if any.

E. All stores must report to the Director of Public Works, on a quarterly basis, the total number of recyclable paper carryout bags provided, the total amount of monies collected for providing recyclable paper carryout bags, and a summary of any efforts a store has undertaken to promote the use of reusable bags by customers in the prior quarter. Such reporting must be done on a form prescribed by the Director of Public Works, and must be signed by a responsible agent or officer of the store confirming that the information provided on the form is accurate and complete. For the periods from January 1 through March 31, April 1 through June 30, July 1 through September 30, and October 1 through December 31, all quarterly reporting must be submitted no later than 30 days after the end of each quarter.

F. If the reporting required in Subsection E is not timely submitted by a store, such store shall be subject to the fines set forth in Section 12.85.080.

12.85.050 Use of reusable bags.

A. All stores must provide reusable bags to customers, either for sale or at no charge.

B. Each store is strongly encouraged to educate its staff to promote reusable bags and to post signs encouraging customers to use reusable bags.

12.85.060 Exempt customers.

All stores must provide at the point of sale, free of charge, either reusable bags or recyclable paper carryout bags or both, at the store's option, to any customer participating either in the California Special Supplemental Food Program for Women, Infants, and Children pursuant to Article 2 (commencing with Section 123275) of Chapter 1 of Part 2 of Division 106 of the Health and Safety Code or in the Supplemental Food Program pursuant to Chapter 10 (commencing with Section 15500) of Part 3 of Division 9 of the Welfare and Institutions Code.

12.85.070 Operative date.

This Chapter shall become operative on July 1, 2011, for stores defined in Subsections J(1) and J(2) of Section 12.85.010. For stores defined in Subsection J(3) of Section 12.85.010, this Chapter shall become operative on January 1, 2012.

12.85.080 Enforcement and violation—penalty.

A. The Director of Public Works has primary responsibility for enforcement of this Chapter. The Director of Public Works is authorized to promulgate regulations and to take any and all other actions reasonable and necessary to enforce this Chapter, including, but not limited to, investigating violations, issuing fines and entering the premises of any store during business hours. The Director of the Department of Agricultural Commissioner/Weights and Measures and the Director of Public Health may assist with this enforcement responsibility by entering the premises of a store as part of their regular inspection functions and reporting any alleged violations to the Director of Public Works.

B. If the Director of Public Works determines that a violation of this Chapter has occurred, he/she will issue a written warning notice to the operator of a store that a violation has occurred and the potential penalties that will apply for future violations.

C. Any store that violates or fails to comply with any of the requirements of this Chapter after a written warning notice has been issued for that violation shall be guilty of an infraction.

D. If a store has subsequent violations of this Chapter that are similar in kind to the violation addressed in a written warning notice, the following penalties will be imposed and shall be payable by the operator of the store:

(1) A fine not exceeding one hundred dollars ($100.00) for the first violation after the written warning notice is given;

(2) A fine not exceeding two hundred dollars ($200.00) for the second violation after the written warning notice is given; or

(3) A fine not exceeding five hundred dollars ($500.00) for the third and any subsequent violations after the written warning notice is given.

E. A fine shall be imposed for each day a violation occurs or is allowed to continue.

F. All fines collected pursuant to this Chapter shall be deposited in the Solid Waste Management Fund of the Department of Public Works to assist the department with its costs of implementing and enforcing the requirements of this Chapter.

G. Any store operator who receives a written warning notice or fine may request an administrative review of the accuracy of the determination or the propriety of any fine issued, by filing a written notice of appeal with the Director of Public Works no later than 30 days after receipt of a written warning notice or fine, as applicable. The notice of appeal must include all facts supporting the appeal and any statements and evidence, including copies of all written documentation and a list of any witnesses, that the appellant wishes to be considered in connection with the appeal. The appeal will be heard by a hearing officer designated by the Director of Public Works. The hearing officer will conduct a hearing concerning the appeal within 45 days from the date that the notice of appeal is filed, or on a later date if agreed upon by the appellant and the County, and will give the appellant 10 days prior written notice of the date of the hearing. The hearing officer may sustain, rescind, or modify the written warning notice or fine, as applicable, by written decision. The hearing officer will have the power to waive any portion of the fine in a manner consistent with the decision. The decision of the hearing officer is final and effective on the date of service of the written decision, is not subject to further administrative review, and constitutes the final administrative decision.

12.85.090 Severability.

If any section, subsection, sentence, clause, or phrase of this ordinance is for any reason held to be invalid by a decision of any court of competent jurisdiction, that decision will not affect the validity of the remaining portions of the ordinance. The Board of Supervisors hereby declares that it would have passed this ordinance and each

APPENDIX E:

Chart of Individual Test Results

and every section, subsection, sentence, clause, or phrase not declared invalid or unconstitutional without regard to whether any portion of this ordinance would be subsequently declared invalid.

<u>12.85.10 No conflict with federal or state law.</u>

Nothing in this ordinance is intended to create any requirement, power or duty that is in conflict with any federal or state law.

[1285TMCC]

APPENDIX E:

Chart of Individual Test Results

Walk Test Raw Data		Key:	Survived all reps:	[green]			Failures:	Failure type Failure location Failure dimensions	
Bag	**1st Wash**	**Reps 1-25**	**2nd Wash**	**Reps 26-50**	**3rd Wash**	**Reps 51-75**	**4th Wash**	**Reps 76-100**	**5th Wash**	**Reps 101-125**

Bag	1st Wash	Reps 1-25	2nd Wash	Reps 26-50	3rd Wash	Reps 51-75	4th Wash	Reps 76-100	5th Wash	Reps 101-125
W41							Tear bottom 5mm			
W42			Unravel Corner 50mm							
W43									Unravel Corner 38mm	
W44										
W45							Tear 10mm			
W46						Unravel Handle 31mm				
W47										
W48	Unravel Corner 30mm									
W49						Unravel Handle 30mm				
W50						Breakage Handle Rep 62				
W51										
W52										

W53										
W54										Unravel Handle 37mm
W55			Unravel Corner 60mm					y		
W56										
W57	Unravel Corner 55mm									
W58										
W59		Breakage Handle Rep 23								
W60							Unravel Bottom 140mm			
U41								Unravel bottom 25mm		
U42										Unravel handle 25mm
U43										
U44										
U45										
U46										
U47								Unravel Handle 29mm		

U48								Unravel Bottom 30mm		
U49										
U50						Unravel Corner 25mm				
U51										
U52										Unravel Bottom 87mm
U53										Unravel Bottom 65mm
U54										
U55										
U56										
U57										Tears Front 7mm
U58										
U59										
U60										

Up-Down Test Raw Data			Key:	Survived all reps:			Failures:		Failure type Failure location Failure dimensions	
Bag	1st Wash	Reps 1-300	2nd Wash	Reps 301-600	3rd Wash	Reps 601-900	4th Wash	Reps 901-1200	5th Wash	Reps 1200-1500
W1										
W2					Unravel Corner 35mm					
W3			Unravel Corner 25mm							
W4					Unravel Corner 5.5mm					
W5			Unravel Corner 28mm							
W6									Unravel Corner 23mm	
W7			Unravel Corner 40mm							
W8										
W9										
W10										
W11										

W12											
W13											
W14									Unravel Corner 50mm		
W15					Unravel Corner 30mm						
W16					Unravel Corner 60mm						
W17					Unravel Corner 68mm						
W18			Unknown								
W19	Unravel Corner 40mm										
W20	Unknown										
W21						Unravel Corner 6mm					
W22	Unravel Corner 25mm										
W23	Unravel Corner 7mm										
W24	Unravel Corner 7mm										
W25	Unravel Corner 6mm										
W26	Unravel Corner 5mm										

W27			Unknown							
W28										
W29						Strain Handle 6mm				
W30							Holes Front 3 holes			
W31										
W32										Unravel 2 Corners 5.8/5.8mm
W33										
W34	Unravel Corner 7mm									
W35										
W36							Unravel Corner 5.3mm			
W37								Unravel Corner5.5mm		
W38										
W39	Unravel Corner 11mm									
W40							Unravels 2 corners 5/5.75mm			
U1								Slit/tear Front 18mm		

U2										
U3										
U4		Unravel Corner 12cm								
U5										
U6										
U7										Unravel Corner 10mm
U8										Strain Handle 5mm
U9										
U10		Slit/Tear Panel 11mm								
U11										
U12		Unravel Handle 9mm								
U13										
U14				Unravel Corner 6mm						
U15						Unravel Corner 15mm				
U16										

U17	Unravel Corner 21mm									
U18										
U19				Slit/tear Spine 9mm						
U20				Strain Handle 5mm						
U21										
U22										Unravel Corner 5mm
U23		Unravel 2 Corners 8/7mm								
U24										
U25										Unravel 2 Corners 6/5mm
U26										
U27										
U28		Unravel 2 Corners 6/5mm								
U29										
U30										

U31										
U32										
U33	Unravel 2 corners 6.5/5.5mm									
U34										
U35										
U36										
U37										
U38										
U39										
U40										Unravel Corner 5.5mm

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