Beverage Container Review

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Final Report by

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Executive Summary

In January 2013 Dr. Tom Owen, Director of the Office of Environment and Sustainability was charged with conducting a formal review of campus beverage container options in response to the Thompson Rivers University Students' Union (TRUSU) request for a ban on all plastic beverage containers. Due to a lack of precedent, a review was undertaken to determine the impacts of beverage containers offered on campus and the potential consequences of a plastic beverage container ban. A Terms of Reference (Appendix I) was developed to guide the review and ensure ample opportunity for campus input.

Public Input

It is interesting to note at the outset that what started as a TRUSU led campus based campaign has now broadened and received input from a range of industry and community groups. That broad participation is not only consistent with the principles and practices of environmental sustainability but it also suggests a foundation for the implementation of the results of the review. Three oral presentations and multiple written submissions were received by campus stakeholders in response to the review. Written and oral submissions have been posted online at www.tru.ca/sustain

Research

A literature review of both peer-reviewed academic and industry publications determined the current consensus regarding environmental impacts of beverage container systems. The literature review results were mixed. The studies all clearly indicated that container recycling, light-weighting and container reuse will significantly lessen the environmental impact of all materials. However, the studies did not conclusively determine the ideal beverage container when comparing aluminum, glass, or plastic. No single container system came out as the ideal option.

Recommendations

A broad-based effort to reduce disposable packaging on campus—with a focus on plastic bottles—is recommended. The beverage supplier should more closely follow the BC Recycling Regulation of which it is required to comply under BC's Environmental Management Act. A multi-stakeholder committee will be created with representatives from the beverage supplier, TRU Purchasing Department, Ancillary Services, TRU Student Union, Environmental Advisory Committee, and the Office of Environment & Sustainability to work towards implementation of the recommendations.

The Committee will work with TRU's beverage supplier to examine the opportunities available under each recommendation and outline an implementation timeline. The committee will review Coca-Cola's progress at mutually agreed-upon points throughout the implementation timeline.

Introduction

Thompson Rivers University (TRU) is committed to environmental sustainability in both its Strategic and Academic Plans. TRU's Strategic Plan states that, as the University of Choice for Environmental Sustainability,

> "Thompson Rivers University recognizes that it has a significant role to play in education, research, policy development and information exchange related to the health of the local and global environments in which we live and work. TRU seeks to be the University of Choice for students concerned about environmental sustainability and to be recognized for its leadership and stewardship in responding to environmental challenges." (TRU, 2007)

As defined by the landmark 1987 Brundtland Report, sustainability is the principle of "meeting the needs of the present generation without compromising the ability of future generations to meet their own needs." Sustainability requires that organizations and individuals consider the environmental, social, and economic impacts of their actions. True sustainability is achieved when environmental concerns become an integral part of the economic decision-making process and are paid the same close scrutiny as economic matters. Including environmental impacts as part of this process requires that decision makers take on a long-term perspective, illustrated through the ecological concept Seven Generation Sustainability. Originating with the Iroquois under their Great Law, Seven Generation Sustainability urges the current generation of humans to live sustainably and work for the benefit of the seventh generation, hundreds of years into the future.[1]

Fully implemented sustainability may require individuals and organizations to adopt other ways of conducting business or to work with others to come up with mutually beneficial solutions.

Ecological Footprint & CSAP

TRU has undertaken specific actions to improve our institutional environmental sustainability throughout the years. The Campus Sustainability Action Plan (CSAP) is a multi-stakeholder document that was created in tandem with a campus ecological footprint analysis. The CSAP reports the results of TRU's current environmental impacts and outlines actions to reduce those impacts. The CSAP is organized under three broad categories—Built, Natural, and Human environments. Specific goals, actions and tasks are described in more detail within those categories using a three-year timeline. The Office of Environment and Sustainability coordinates the implementation of the plan with the support of the Environmental Advisory Committee.

[1] The Constitution of the Iroquois Nations http://www.indigenouspeople.net/iroqcon.htm

TRU Beverage Container Issues – A History

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The following is a brief outline of recent beverage container-related campaigns at Thompson Rivers University.

January 2009 - UnBottle It Report

The UnBottle It Report was written by Dr. Jonathan Van Hamme, Associate Professor of Microbiology and presented to the Environmental Advisory Committee (EAC) on January 27th, 2009. The report outlined the negative environmental, social and economic impacts related to the use of bottled water. Dr. Van Hamme recommended TRU work towards eliminating the sale of bottled water on campus and provided a detailed implementation framework. At the time the report was presented to the EAC, there was a general consensus that TRU is legally bound by a contract with Coke to sell bottled water however "…other ways to reduce the use of bottled water in the report should be explored."[2] Specifically the EAC recommended more water filling stations be installed on campus, free reusable water bottles should be provided to students at orientation, and the transportation cost of bottled water should be calculated and reported as an impact-tracking item.

September 2009 - Water Bottle Alternatives

In keeping with the EAC recommendations of January 2009, the Office of Environment and Sustainability partnered with other university departments to hand out over 3000 water bottles at the 2009 fall student orientation. Water bottles were also offered at the 2012 fall student orientation. TRUSU has repeatedly offered free reusable water bottles to its membership as part of its Ban the Bottle campaigns throughout the academic year. Ancillary Services sells, on average, 750 reusable water bottles each year through the TRU Bookstore. In addition, specialized water bottle refill stations were installed in all major Kamloops campus buildings throughout 2009 and 2010. With over 40 locations on campus where students, staff and faculty are able to refill reusable water bottles for free, there is no shortage of accessible municipal water at TRU.

June 2012 - Captain Charles Moore

On June 15th, 2012 Captain Charles Moore was presented with an honorary doctorate from TRU at convocation in recognition of his lifelong commitment and contribution to society, specifically for his research on the impacts of plastics on marine environments. Dr. Moore is founder of the Algalita Marine Research Foundation and captains the foundation research vessel, the Alguita, documenting the great expanses of plastic waste in the world's oceans. Dr. Moore has spoken multiple times on campus regarding the harmful effects of plastics. TRU removed all plastic water bottles from the June 2012 Convocation ceremonies in recognition of Dr. Moore's work.

[2] EAC Minutes, January 2009. Available at: http://www.tru.ca/__shared/assets/JAn27200925782.pdf

Fall 2012 - TRUSU Campaign

In the past TRUSU has encouraged the use of municipal tap water over bottled water, stating that "the commercial bottling of water...treats water as a commodity, rather than a basic human need and right."[3] In the fall of 2012 the Student Union expanded their campaign to eliminate the sale of plastic bottles completely, a much broader mandate than simply bottled water. This campaign impacts all beverages currently sold in plastic bottles. To be clear, TRUSU does not wish to ban certain beverages – the ultimate goal of the campaign is to offer packaging alternatives that do not include plastic while keeping the variety of beverages available on campus the same. To date TRUSU has received 2,700 signatures in support of this campaign as well as garnered the support of more than half of TRU's academic departments and some administrative departments.

January 2013 - Review Initiated

In January 2013 Dr. Tom Owen was charged with conducting a formal review of campus beverage container options in response to TRUSU's request for a ban. Due to a lack of precedent and research available on the issue, this beverage review was undertaken to determine the impacts of beverage containers offered on campus and the potential consequences of a plastic ban. A Terms of Reference (Appendix 1) was developed to guide the review and ensure ample opportunities for campus input.

Precedents

Based on our research an outright ban on plastic beverage containers is unprecedented. The focus of other university and municipal campaigns has been only on bottled water, not plastic bottles. A list of campuses that have made some sort of commitment to phase out or limit the sale of bottled water according to the Polaris Institute is provided below.

Campuses with bottled water action[4]	
01. The University of Winnipeg	13. Université de Sherbrooke
02. Memorial University	14. University of Toronto Scarborough
03. Brandon University	14. University of Toronto Mississauga
04. Ryerson University	15. Vancouver Island University
05. Fleming College, Frost Campus	16. St Mary's University College
05. Fleming College, Sutherland Campus	17. Collège Ahuntsic
06. University of Ottawa	18. Collège Shawinigan
07. Trent University	19. Cegep de Sherbrooke
08. Bishop's University	20. CEGEP De Victoriaville
09. College universitaire De Saint Boniface	21.Vanier College
10. Queen's University	22. Carleton University
11. University of King's College	23. Cegep De St-Félicien
12. Concordia University	24. York University

[3] TRUSU, Students for Sustainability http://trusu.ca/section/182
[4] Polaris Institute "Inside the Bottle" campaign http://www.insidethebottle.org/Campuses.html

Review Approach & Methods

This review employs evidence-based decision making, a system that entails making managerial decisions informed by the best available scientific evidence (Clancy and Cronin, 2005). This consists of not only consulting peer-reviewed academic articles but also looking to other factual evidence such as government reports, industry data and concrete results from campuses that have previously examined beverage container systems. This approach ensures the research uses both qualified and relevant material to inform the decision making process. It requires an unbiased approach and utilizes a combination of traditional research and factual evidence.

First priority is placed on utilizing peer-reviewed research published in recognized academic journals. Due to the nature of the data involved, government sources were also consulted as well as industry journals and other consultant peer-reviewed research. Wherever possible, peer-reviewed academic research was preferred above all other sources.

Best Practices

Peer-reviewed academic journal articles were consulted to determine best practices for beverage container system comparison. Life Cycle Assessment (LCA) is currently the most widely accepted method for product comparisons. The methodology employed in LCA fosters a holistic approach and takes into account a variety of impacts (S. G. Lee and X. Xu, 2005). Also called Life Cycle Analysis/Inventory or Cradle to Grave Analysis, LCA involves the evaluation of multiple aspects of a product system through all stages of its life cycle including:

1) raw material acquisition,
2) extraction,
3) production,
4) transportation,
5) manufacturing,
6) packaging,
7) distribution, and
8) end of life treatment or disposal.

(European Environment Agency, 1997)

LCA represents a well-established set of techniques designed to guide sustainable development. To improve quality and consistency amongst assessments, the International Standard Organization developed standard documents ISO 14040 and 14044 to outline the process for undertaking life cycle assessments (ISO, 2006). LCA is the ideal methodology to use for a beverage container analysis; in fact the most prominent use of LCA since the early 1990's has been in the field of packaging (C. C Huang, 2004). Though governments in Europe routinely commission LCA's, these analyses can seldom provide unequivocal answers as to which product is environmentally preferable (European Environment Agency, 1997). Like any comparison method, there are limitations to life cycle assessment.

Limitations of Life Cycle Assessment

While LCA is currently the best available methodology to compare products, it is still at times avoided by governments and companies due to its inherent complexity, the high cost of analysis and long timeframes associated with studies (European Environment Agency, 1997). In a guide to life cycle assessments, the European Environment Agency stresses that LCA's "…should not be used to claim that a particular product is environmentally friendly." It is only possible to say that within the specified set of criteria outlined in each individual LCA, one product performs better than another. Although ISO documents provide a solid framework, LCA's still have significant variation amongst them due to differences in research approaches, available data and a variety of other reasons. It is a complicated procedure that will become even more complicated when comparing LCA's of similar product systems (i.e. beverage containers) functioning in different countries (Christiansen, 1992). Variations in approaches, data sources, geographical context, and government regulation can pose problems when using the results of LCA studies from one country to guide decision making in another. There is unfortunately a lack of Canadian beverage container system life cycle assessments; as a result, studies from the United States, Europe, and Asia have been used in this review. Despite this general themes and conclusions can still be drawn from the assessments.

Scope

Glass bottles, plastic containers, and aluminum cans are the primary packaging containers analyzed in this review. At TRU's campuses some beverages are also sold as fountain drinks, in aseptic/gable-top cartons, and Styrofoam containers. These materials were generally excluded from the analysis for three main reasons:

1) Data on these materials were not fully available;
2) They represent a very small percentage of beverage packaging on campus, and
3) Inclusion of these materials would necessitate a much more extensive and costly analysis.

The omitted material types were also not identified as items of concern through the public consultation process.

A general background of the reviewed materials is provided on the next few pages.

Aluminum Cans

Aluminum is a very lightweight metal derived from bauxite ore. Bauxite ore is mined by open pit methods, sent to a refinery for conversion to alumina and finally to a smelter to extract the metal. The metal is then sent to fabrication plants where it is rolled, extruded, or cast into sheets. Magnesium and manganese are often added to aluminum to improve its strength.

Characteristics

Aluminum is a material of choice for food containers. Unlike most metals, aluminum is highly resistant to corrosion and is an excellent barrier to moisture, air, odor, light, and microorganisms – making it an ideal food packaging material. Aluminum cans are also a more cost-effective shape than the bottle in terms of volume; cans fill with liquid much faster than bottles, speeding up the production process. During transportation aluminum cans are easily stacked on top of each other with no risk of breakage, making transport straightforward and efficient.

Aluminum cans cannot be securely reclosed once opened, unlike glass or plastic bottles. This makes cans less convenient than bottles. The cylindrical shape of the container is also somewhat restrictive, unlike moldable glass and plastic. Aluminum bottles with re-sealable lids are manufactured and available in Canada, however these are not currently offered for the beverages sold at TRU.

Recycling & End of Life

Aluminum is easily reclaimed and processed into new products, making recycling an attractive option (Stilwell et al, 1991; Plunkert, 2000). It is one of the most expensive and sought-after scrap metals. Used aluminum beverage cans are the lowest-cost source of raw materials for aluminum production, therefore recycling is an economically desirable endeavor and less capital-intensive than virgin aluminum production. It is possible for aluminum cans to be made entirely from used cans, although the industry standard is around 40% virgin materials and 60% recycled (PE Americas, 2010).

Aluminum is fairly safe for the environment once disposed or left as litter. An aluminum can resists oxidation and degrades very slowly if exposed to the elements.

Aluminum cans recycled through the BC recycling system are turned back into sheet stock for new cans (Encorp, 2011). Aluminum cans, on average, account for 29% of the beverage container sales at TRU (comparing glass, aluminum, and plastic). The typical recycled content included in the average can purchased at TRU is estimated to be around 68% recycled materials (PE Americas 2010). The Encorp 2011 recycling rate for aluminum cans in BC was 83.9%, meaning about 84% of all aluminum cans sold in British Columbia were recovered for recycling.

Typical Recycled Content	68%
2011 Encorp Recycling Rate	83.9%
TRU Market Share	29%

Glass Bottles

Glass is one of the oldest known packaging materials. The production of glass containers involves heating a mixture of silica (sand), sodium carbonate, and limestone/calcium carbonate and alumina to high temperatures until the materials melt into a thick liquid mass that is then poured into molds.

Characteristics

Glass is an ideal food packaging material. It is odorless, chemically inert with virtually all food products and impermeable to gases. It maintains product freshness for a long period of time without impairing taste or flavor. Glass is rigid, provides good insulation, and can be produced in numerous shapes. The transparency of glass allows consumers to see the product, yet variations in glass colour can protect light-sensitive contents.

The heavy weight of glass can significantly raise transportation costs and its carbon footprint. Glass is brittle and susceptible to breakage from internal pressure, impact, or thermal shock. This characteristic increases the secondary packaging requirement for glass bottles (i.e. crates, cushioning, etc.) during transportation and storage (Stilwell et al, 1991).

Recycling & End of Life

Glass is easily reclaimed and has a high recycling rate in British Columbia. Recycled glass, or cullet, is used in glass manufacturing and can account for as much as 90% of all raw materials, although the industry standard is typically around 30-40% (Owens-Illinois, 2012). The raw materials to create glass are sometimes so cheap and plentiful that it is more economically advantageous to produce new glass rather than create recycled glass through the costly processes of cleaning, sorting, crushing, and re-manufacturing glass to useable specifications (MacBride, 2012). However because cullet melts at a lower temperature than raw materials, the energy savings in reheating are usually ample enough to make recycled glass economically attractive (Moser, 1995, Stilwell et al, 1991).

After-use disposal of glass is easy on the environment. After enough time it can break back down into its raw materials and remains inert.

In British Columbia, Encorp has found end-markets for glass in Airdrie, Alberta and Seattle, Washington (Encorp, 2011). According to Encorp, glass recycled in BC is re-made into wine bottles, fiberglass insulation, and sandblasting materials. Re-usable glass bottles are frequently cited as one of the most environmentally friendly beverage container options, however they are unfortunately heavier, costlier to ship and rarely used for non-alcoholic beverages in Canada.

Glass bottles account for only 5% of the beverage container sales at TRU. The typical recycled content included in a glass bottle purchased at TRU is expected to be around 37% recycled materials (Owens-Illinois, 2012). The Encorp 2011 recycling rate for glass bottles in BC was 80.9%, meaning that about 81% of all glass bottles sold in British Columbia were recovered for recycling.

Typical Recycled Content	37%
2011 Recycling Rate	80.9%
Market Share at TRU	5%

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Plastic Bottles

Plastics represent an enormous variety of chemical compositions with an endless number of final applications, making them perhaps the richest and most complex of all packaging materials. There are many different types and groups of plastic. This variation contributes to a general lack of understanding of the complexity of plastic materials, which can lead to confusion and inaccuracies. There are upwards of 20 different named types of plastic used in consumer and industrial products, while only 2 or 3 types are typically found in beverage containers sold at Thompson Rivers University.

The plastic used in beverage containers sold in British Columbia and at TRU consists primarily of polyethylene terephthalate (PET), which makes up the bottles, and polypropylene (PP), which makes up the lids and labels. Larger beverage bottles (2 litres or more) are typically made with high-density polyethylene (HDPE) combined with PP lids or labels. These plastics are created through condensation polymerization or polyaddition of monomer units. The raw materials for PP, HDPE, and PET are derived from crude oil and natural gas (Plastics Europe, 2011; Thompson et al, 2009).

Plastics are a very popular packaging material. They are relatively unbreakable, lightweight (up to 90% lighter than glass), durable, can be clear, coloured and made into any shape or size.

Recycling & End of Life

PP, HDPE and PET are thermoplastics which means they can be melted, remolded, and recycled. Though plastic packaging in general can be challenging to clean, sort and recycle, all three types in question here have a high potential to be mechanically recycled (Hopewell, 2009). Super-clean recycling processes for PET introduced in 1991 and refined over the past two decades have made PET bottle-to-bottle recycling viable, though it is not in widespread practice currently (Welle, 2011).

Because plastics have only been mass-produced for around 60 years, their longevity in the environment is not known with certainty (Andrady, 2003). The durability and increased usage of all types of plastics have created a major global waste problem, particularly in marine environments (Moore, 2009; Andrady 2003).

PET is recycled through the BC recycling system into strapping, containers, and fibre. While the current recycled content of plastic PET containers is not publically advertised, The Coca-Cola company (TRU's beverage supplier) has a publically-stated goal of using 25% recycled PET in its beverage containers by 2015.[5]

Plastic bottles on average account for 66% of the beverage container sales at TRU, the highest market share of all beverage containers. The typical recycled content included in the average plastic bottle purchased at TRU is not known but is expected to be much less than 25%. The Encorp 2011 recycling rate for <1 litre plastic bottles in BC was 73.2%, meaning 73.2% of all bottles sold in British Columbia were recovered for recycling.

Typical Recycled Content	Unknown (less than 25%)
2011 Recycling Rate	73.2%
Market Share at TRU	66%

[5] Coca-Cola Sustainability 2009, http://assets.coca-colacompany.com/a3/cc/09a520d94eb0a69f51ccd8d7b00a/SR08_SusPack_26_29.pdf

Campus Beverage Container Sales

	Aluminum Cans	PET Bottles	Glass Bottles
Soft Drinks	42,832	66,862	144
Juice/Fruit Beverages/Milk	8,340	30140	9370
Energy Drinks	21,798		
Sports Drinks		6,552	
Water		65,268	
Ready to Drink Tea/Coffee			2,904
Container Sales Total	72,970	168,822	12,418
% of Total Container Sales	29%	66%	5%

Ancillary Services & TRU Culinary Arts, 2011 Estimate

Information was solicited from Ancillary Services and TRU Culinary Arts regarding the amount and type of beverage containers sold on campus. The above information was provided by those departments and has not been independently verified.

Stakeholder Input

Public consultation was included in the form of public oral presentations for both the Kamloops and Williams Lake campuses and a written comment period extending from February 1, 2013 to March 22nd, 2013.

The following oral presentations were received and are available at www.tru.ca/sustain

TRU Students Union
TRU North Physical Resources and Environmental Committee
Canadian Beverage Association

The following written presentations were received.

BC Sustainable Energy Association and Kamloops 350
Council of Canadians Kamloops Chapter
Captain Charles Moore
TRU Environmental Advisory Committee
PepsiCo
Canadian Plastics Industry Association
General Grant's Kamloops
Merlin Plastics Supply
Nestle Water
Encorp Return-It
Canadian Beverage Association

Academic Literature Review

A literature review was conducted to determine the general consensus of beverage container life cycle assessments. Unfortunately to our knowledge there are no published academic LCA's that were conducted within Canada. Studies from the United States, Europe, and Asia were reviewed. The literature review results were mixed. Below is a summary of assessment conclusions.

A meta-analysis of twenty-two beverage container life cycle assessments conducted by researchers in Germany found that in general, the beverage container with most favorable results were cartons – aseptic and gable top paperboard-based cartons. This study recognized that for some indicators, the LCA results varied strongly. No clear trends were found when comparing PET, aluminum, and glass (von Falkenstein et al, 2010).

An Italian study comparing glass containers to PET containers found that both materials present some characteristics that are "…more or less environmentally favourable" (Vellini & Savioli, 2008). When producing 1 kg of material, glass performs better than PET in an environmental analysis. However the opposite becomes true when using a measurement specifically chosen for beverage containers—the unit volume of the container. The researchers found that PET containers are more environmentally preferable to the same-sized glass container, primarily due to the fact that "…lower quantities of PET are needed to produce a same-size container" than glass. The mass needed to manufacture each PET container is only 30 kg compared to 660 kg for glass. So although glass outperforms PET when comparing 1 kg of glass to 1 kg of PET, due to the fact that 1 kg of PET can make many more bottles than 1 kg of glass can, the environmental impact of PET is smaller. The study concludes that glass beverage containers can only be more environmentally benign than PET if the reuse factor for glass bottles is high (Vellini and Savioli, 2008).

A UK study comparing 0.75 L glass bottles, 0.33 L aluminum cans, 0.5 L and 2 L PET bottles determined that the 2 L PET bottles were the most favourable option for most environmental impacts, including the carbon footprint. This LCA found that the glass bottle is the least preferred option. Reusing the glass bottles just three times would make the carbon footprint equal to that of aluminum cans and the 0.5 L PET bottles. However if the recycling rate of PET bottles were 60%, then glass would need to be reused 20 times to be comparable. A graphical summary of the study results is provided below (Amienyo et al, 2012).

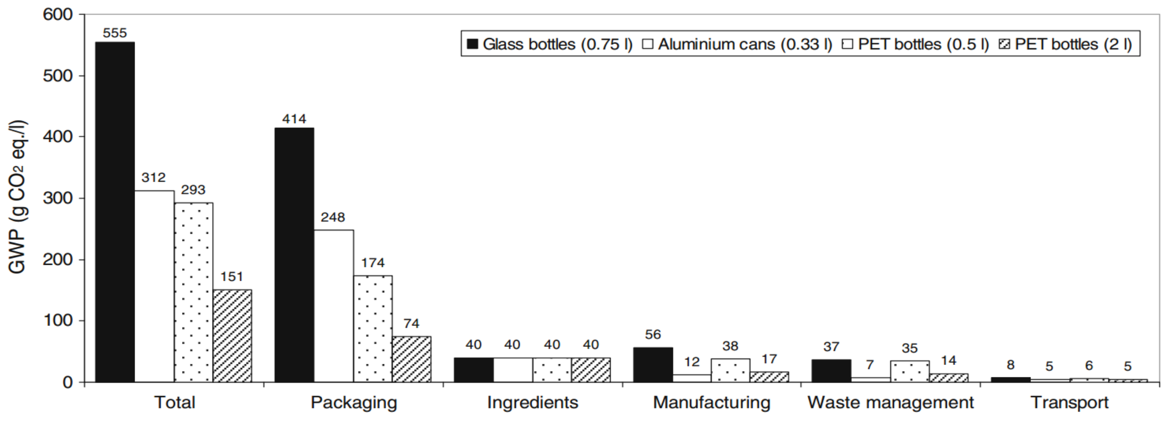


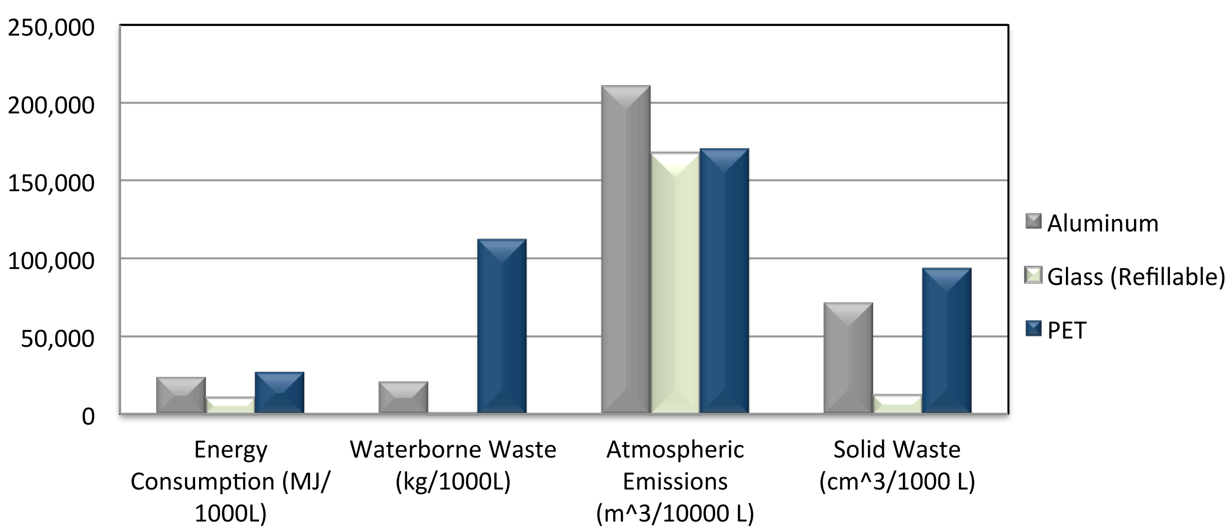
Fig. 1 Global warming potential (GWP) of the carbonated drink for different types of packaging showing the contribution of different lifecycle stages (Amienyo et al, 2012)

Another UK carbon footprint analysis of beverage packaging found that when comparing cartons, PET, HDPE, glass, aluminum, and steel materials, their results "…show that the carton packaging has the lowest carbon footprint…and glass bottle the highest" (Gujba & Azapagic, 2011). The carbon footprint is mainly influenced by the size and weight of the containers and recycling rates. HDPE and PET drink packaging were shown to have lower carbon footprints than aluminum, steel and glass. With higher recycling rates the carbon footprint of all materials is markedly improved. The study found that "a difference in weight of the containers significantly influences the carbon footprint results, hence the high result for glass." Furthermore, the larger volume the bottle, the lower the impact due to the lower amount of material required per functional unit. For example with water packaging, the best option is a 1.5 L PET bottle. The global warming potential of this bottle is 3.6 times lower than the best glass bottle option (Gujba and Azapagic, 2011).

A study from Taiwan conducted a multidimensional environmental evaluation of nine packaging materials—aluminum, cardboard, HDPE, PET, glass, PP, polystyrene (PS), steel, and liquid paperboard. A cluster analysis defined 3 groups according to impacts. Group 1 was the most environmentally preferable and also received high scores in an analytic-hierarchy process defined by the author. These materials were all plastics: PET, PS, HDPE, and PP. Group 2 scored lower on the analytic-hierarchy process and moderately in terms of environmental damage. These included cardboard boxes, liquid paperboards, and steel cans. The highest impact group included glass containers and aluminum cans. This is the least preferable group according to the researcher's criteria. Like most life cycle assessments this study cautioned that "not all attributes of a material are easily quantified" and more research is needed (Huang & Ma, 2003).

A Greek study published in July 2012 found differing results. These authors recognized that despite the current ISO methodologies for life cycle assessment, there remains poor or no agreement amongst them (Millet et al., 2007; Pizzol et al., 2011). This study offered slightly different life cycle inventory analyses using principal component analysis. The researchers found that refillable glass containers have the lowest overall impact. PET had a higher impact in most categories studied. Non-refillable glass containers were not included in this analysis, and so the results for glass are not of much use to this review since refillable glass bottles are not available for TRU. A summary of select factors is below.

Fig 2: Select ecological parameters of the examined packaging (Bersimis & Georgakellos, 2013)



Themes & Agreement

Clearly the results of the studies vary and general conclusions are difficult to draw. The above literature review did not find any conclusive evidence to prove aluminum, glass or PET as environmentally preferable or detrimental materials. The carbon footprints and assessments of each material depended heavily on the recycle/reuse rates of each material, geographical context of the study, container weights, sizes and recycled content (Millet et al., 2007; Bersimis & Georgakellos, 2013).

Despite the variation in study results, there was some general agreement found in the literature review. The studies all clearly indicated higher container recycling and reuse rates will significantly lessen the environmental impact of each material. Light weighting of materials was identified as another effective strategy to lower environmental impacts. Larger bottles carried more liquid with less packaging and were environmentally preferable. The most effective strategy of all, of course, is to eliminate much of the need for these containers in the first place.

Figure 3: Literature Review Summary:

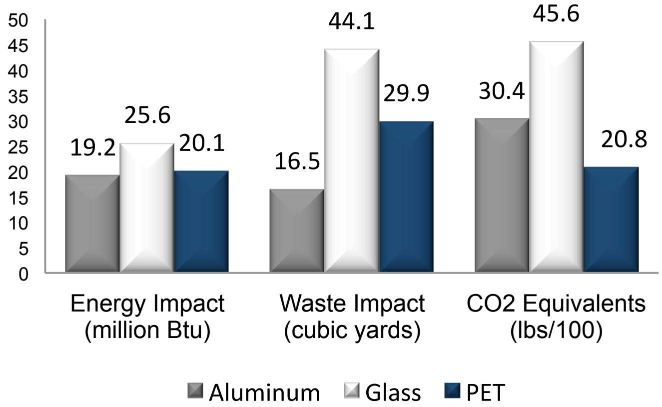
	Study 1	Study 2	Study 3	Study 4	Study 5
Materials Studied	PET HDPE PP PS Aluminum Steel Glass Cardboard	Carton Glass PET HDPE Aluminum Steel cans	Glass (0.75 L) Aluminum (0.33 L) PET (0.5 and 2 L)	Glass PET	PET Aluminum Refillable Glass
General Conclusions	In order of preference: PET PS HDPE PP Cardboard Steel cans Glass containers Aluminum cans	Carton has lowest carbon footprint followed by HDPE and PET. Glass has the highest carbon footprint.	2 L PET most efficient for carbon footprint. Glass is worst.	PET is preferred to glass. Glass can be more environmentally benign with 80% reuse rate.	Refillable glass best option PET worst option

Study 1: A Multidimensional environmental evaluation of packaging materials,
Study 2: Carbon footprint of beverage packaging in the United Kingdom
Study 3: Life Cycle Environmental Impacts of Carbonated Soft Drinks
Study 4: Energy and Environmental Analysis of Glass Container Production and Recycling
Study 5: A Probabilistic Framework For Evaluation Of Products' Environmental Performance Using Life Cycle Approach And Principal Component Analysis

Industry Literature Review

Franklin & Associates

Franklin & Associates conducted a full life cycle assessment for the PET Resin Association in August 2009. Initially the life cycle inventory compared a 12-ounce aluminum can, 8-ounce glass bottle, and a 20-ounce PET bottle. This analysis found that the PET bottle was the best choice. However, because the study seemed to place an unfair advantage on PET (comparing over 8,000 aluminum cans to 12,500 glass bottles to only 5,000 PET bottles) an addendum was added that provided an LCI analysis of the same container types all in 12-ounce sizes. The results of that addendum are graphically illustrated below.

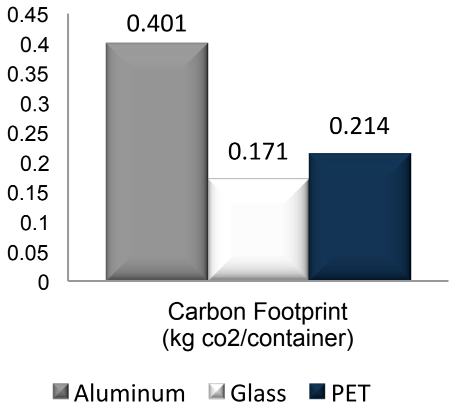


In the energy category, aluminum and PET had lower impacts with 19.2 and 20.1 Million Btu/10,000 containers respectively. The glass energy impact was between 22.4 and 25.6 million Btu. Franklin and Associates determined that with a less than 10% variation, the differences between a 12-ounce can, glass bottle, and PET bottle cannot be considered significantly different in terms of the total energy profile.

Volume of waste created was another category for comparison in this study. Glass was determined to produce the highest amount of total solid waste by weight and volume while aluminum produced the lowest total amount of solid waste. When comparing greenhouse gas emissions, PET produced the least amount of carbon dioxide equivalents. Greenhouse gas emissions for aluminum cans consisted of 3035 pounds of carbon dioxide equivalents per 10,000 containers. Glass ranged between 3678 and 4562 pounds and PET came out at 2084 pounds per 10,000 containers.

Owens-Illinois

Owens-Illinois, a global container glass company, conducted a life cycle assessment comparing a typical 355 ml container of glass, aluminum, and PET. This LCA found that glass has a carbon footprint of 0.171 kg co2/container; aluminum has an impact of 0.401 kg co2/container and PET with 0.214 kg co2/container in North America. For this study the preferred container ranking is glass, PET and then aluminum.



Coca-Cola & the Carbon Trust

Coca-Cola Great Britain (CCGB) and Coca-Cola Enterprises (CCE), in cooperation with the Carbon Trust calculated the carbon footprints of some of the company's most popular drinks. This industry carbon footprint assessment found the aluminum can to have the lowest environmental footprint for single-use containers, but also found the most *efficient* form of packaging to be the larger PET bottles.

To evaluate the full life cycle of the products, the assessment looked at the drink ingredients, manufacture, packaging, distribution, retailing, the use of the product by individual consumers, and the subsequent disposal. The assessment found that if a consumer were to recycle the Coke can, this would reduce the footprint by 70 g, bringing the total footprint down to 100 g, illustrating the significant benefits of recycling.

According to Coke's assessment, the most environmentally efficient package is a 2 liter PET bottle – a 250ml serving of Diet Coke has a carbon footprint of just 50 grams of CO2e when served from a 2 liter bottle, compared to 240g from a 500ml pack (Coca-Cola, 2010). This is consistent with the findings of Gujba and Azapagic.

Carbon footprint (grams of CO2e)					
	Coca-Cola	Grams of CO2e/ml Coca-Cola	Diet Coke	Grams of CO2e/ml Diet & Coke Zero	Coke Zero
330 ml Aluminum Can	170g	.52	150g	.45	150g
330 ml Glass Bottle	360g	1.1	340g	.94	340g
500 ml Plastic Bottle	240g	.48	220g	.44	220g
2 L Plastic Bottle	500g	.25	400g	.2	400g

Note: The differences amongst the three drinks are due to different ingredient levels (less sugar in Diet Coke and Coke Zero).

Themes & Agreement

The industry review results are clearly mixed and depend heavily, yet unsurprisingly on which industry is conducting the assessment. Coke's analysis highlighted some themes that have been repeatedly prevalent throughout most of the LCA's studied: recycling decreases carbon footprint, light weighting material decreases environmental impacts, and reuse and use of larger containers to distribute beverages reduces the carbon footprint and resulting environmental impacts. These findings are consistent with the results of the academic literature review.

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Effects of plastic on the environment

Much of the argument in favour of banning plastic beverage containers stems from the negative effects of the ubiquity of all types of disposable plastic in our everyday lives, not simply PET beverage containers.[6] Within a short span of less than a lifetime, plastic has entered nearly all aspects of life in the civilized world (Andrady, 2003). The characteristics of plastic that make it so convenient—its light weight and durability—also make it an environmental hazard when handled inappropriately at end of life (Ryan et al., 2009).

The most substantial use of plastic is in disposable items that are discarded within a year of manufacture (Hopewell et al 2009). Increased usage of plastic has unsurprisingly been accompanied with a rapid increase in the amount of plastic litter in the marine environment with potentially devastating effects (Ryan, 2009; Thompson 2009). Floating debris can rapidly become colonized by marine organisms and facilitate the transport of non-native species. Plastic debris serves as a convenient transport mechanism for unwanted contaminants and can cause contaminants to become orders of magnitude more concentrated on the surface of the plastic debris than in surrounding seawater (Mato et al 2001). Over 260 species of wildlife have been known to then ingest or become entangled in this debris, causing a range of serious issues including impaired movement and feeding, reduced reproductive output, lacerations, ulcers and death (Laist 1997; Derraik 2002; Gregory 2009).

A recent commentary piece in the journal Nature argued for the need to classify certain plastics as hazardous waste. TRUSU used this article as part of their case for a ban. The article cited the fact that some plastics can be potentially toxic, absorb other pollutants, infiltrate food webs, and include additives that can accumulate in human blood (Rochman et al, 2013). The authors suggested classifying as hazardous the most problematic materials first – polyvinyl chloride (PVC), polystyrene (PS), polyurethane (PUR) and polycarbonate (PC), making up about 30% of US plastic production. It should be noted that PET and HDPE were not specifically named in this piece as hazardous or dangerous plastics. While the potentially hazardous impact of improper disposal of some plastics is clear and well researched, none of the plastics identified in this piece are used in the manufacture of beverage containers sold at TRU.

Based on the literature review, it is clear that improper disposal of plastics is having a broadly based negative impact on the environment in general and on the marine environment in particular. Despite this, the plastics used in beverage containers at TRU are not a particularly hazardous material based upon the known environmental impacts and recycling rates at this time.

The issue of which beverage container is the most environmentally friendly is far less clear from the studies reviewed. In fact the differences between the options in some studies were quite small. As outlined previously, that is not to say that plastics in general have the potential to have substantial negative environmental effects. In particular, the emphasis on the disposability of consumer products and planned obsolescence have created a significant waste problem.

The more agreeable solution would be to reduce the need for disposable materials rather than debating which disposable system is more preferable.

[6] See appendix III for a detailed description of common plastic types

Bottled Water

Bottled water has been the subject of significant controversy lately and has been banned or limited in sale at a number of Canadian Universities. The various actions against bottled water at universities and colleges across the country demonstrate that many students, staff and faculty see bottled water as detrimental to the environment, social justice, and human health. The top three student concerns regarding bottled water bans, according to research at the University of Winnipeg was loss of consumer choice, the perceived lower quality of the municipal source water, and concern that students will turn to unhealthier choices.

Dalhousie students conducted a survey that found that when people did purchase bottled water, their reasons were primarily due to convenience. At Dalhousie 61% of students surveyed did not purchase bottled water at all, while 32% purchased it between one and three times a week. Of the students who did purchase bottled water, 39% purchased it for convenience and 34% purchased because they did not know where the water fountains were. The student research found that the majority of students do not purchased bottled water on campus, and if they do, they do so infrequently.

Potential Impacts of a Ban on Plastics

Bans come with the objective to root out problematic products from the materials economy. In cases such as with CFC's, bans have worked. However there is also the tendency to cause unintended consequences when less environmentally preferable alternatives fill the void. There is potential for this to occur in the case of a plastic bottle ban. Extended producer responsibility programs have already been developed to mimic the effects of a ban by forcing the producer to take responsibility for after-sale product impacts. British Columbia has a well-developed extended producer responsibility program for beverage containers.

Environment & Sustainability

As identified through the literature review, there are trade-offs associated with each container choice. In general, PET and aluminum will have lower transportation costs than glass due to weight differences. Aluminum is highly valued and comes with a high recycling rate, though it seems to have a higher carbon footprint. PET consistently has shown to perform slightly more favourably in life cycle assessments when compared to glass. Yet glass is an inert material and if it does become litter at end-of-life, would pose less environmental concern than PET would. There are positive and negative aspects to each option.

A ban on plastic beverage containers sold at TRU would likely not have substantial positive environmental benefit. A focus on significantly improving recycling rates while reducing the need for disposable containers on campus would likely be a more comprehensive and effective approach.

Suppliers have continually cited high recycling rates as a demonstration of PET's environmental benefits. A major complication with such an extreme focus on recycling is that it does absolutely nothing to limit the amount of disposable material coming onto campus that can end up as litter or landfilled; it only addresses the waste once it is already created. While the BC beverage container recycling rates are good, given the fact that this is a government-mandated, deposit incentive-based system, it is reasonable to expect that recycling rates would increase and continually improve as the program matures.

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2011 Encorp Recovery Rates (%)

	2007	2008	2009	2010	2011	Percentage Change
Plastic ≤ 1L	80.2	74.1	73.2	76.3	73.2	7% decrease
Plastic > 1 L	70.2	84.6	88.2	87.9	87.8	17.8% increase
Glass ≤ 1L	66.9	70.8	76.9	79	80.8	13.9% increase
Glass > 1 L	142.5	160.6	101.5	102.9	116.7	100% recovery
Aluminum	80.2	81.5	83.6	83.5	83.9	3.7% increase

Over the past 5 years, recycling rates have improved for every material except plastic beverage containers smaller than 1 litre. Nearly all of the PET beverage containers sold on campus would fall under this category. In comparison, the plastic recycling rate for plastic bottles greater than 1 litre has steadily increased over the past 5 years. Glass and aluminum containers have also seen a steady increase as the Beverage Container Stewardship program has matured. The fact that more than 20% of the plastic containers are disappearing from the beverage container recycling system in spite of the focused efforts of Encorp is a cause for concern.

Touting the benefits of recycling for this particular case is only reasonable if the bottle container recycling rates in question are increasing, or at the very least, holding steady at a high rate. This is not currently the case with <1 L PET beverage containers in BC.

Contractual

To avoid any contractual limitations a ban or other action against plastic containers can be introduced once the current contract has expired.

Health & Safety

In the area of health and safety there are again some trade-offs and also some inaccuracies that can be addressed. In regards to safety, glass is breakable while aluminum and plastic are relatively unbreakable. There were no other major safety impacts identified through the public consultation or literature review processes.

The health impacts of plastics has been a topic of concern, and rightly so. Studies have suggested that more research is needed to determine the negative human health effects of plastics. It is generally known that phthalate ester plasticizers or orthophthalates can leach out of plastic products because they are not chemically bound to the plastic matrix (Wagner & Oehlmann 2009). Plasticizer phthalates are sometimes used to soften other types of plastic, and could be potential endocrine disruptors. There has also been controversy surrounding the extent to which additives such as dioxin and bisphenol-A can have adverse effects on humans and wildlife. Though the evidence for humans is still limited, there is a strong need for further research (Thompson et al, 2009).

While these potential effects are undeniably concerning, it is not relevant for this particular review as they are not components of the type of plastics in question. Again, the beverage containers at TRU are made with PET. Our research has found that PET does not contain phthalates, BPA, or dioxins (NAPCOR, 2011). These potentially detrimental chemicals are scientifically linked with PVC and other plastic types, not PET (Koch & Calafat, 2009). Some media sources have raised concern about the use of antimony trioxide in the manufacture of PET. Antimony as an oxide is used as a catalyst in the production of PET and has been found to be very low risk by the International Life Sciences Institute (ILSI, 2000). There is not enough evidence to show a ban on PET plastic bottles at TRU would significantly reduce human health impacts.

Choice

A ban on plastic bottle sales would limit choice somewhat. However, TRU is an urban campus and a major grocery chain which carries a wide variety of options is right across the street. A ban would only regulate the sale of plastic beverage containers on campus, not specific beverages. Water is still freely available and it is expected that the beverage supplier would do their best to introduce alternative packaging or fountain systems to ensure the variety of beverages available on campus is not significantly impacted.

Coke has estimated that 38% of the current product (bottled water, vitamin water, Powerade, and Fuze) cannot be replaced by alternatives and would be lost. Those options would presumably need to be purchased off-campus by consumers. The issue of choice arises mainly because TRU has a system of awarding a beverage contract to a single supplier, which then limits the on-campus choices to the offerings of that supplier. It is a very common approach in higher education and has limited TRU’s options.

Economic

There should not be any significant economic impact on students or staff as the result of a plastic ban. There may be loss of revenue to Ancillary Services in the form of additional contract costs due to reconfiguring some vending machines and purchasing new capital equipment. Coke has estimated a total cost of $7664.00 to convert the current vending machines to support glass or aluminum. Coke also estimated a reduction of 50% of sales as a result of a ban on plastic beverages, which would result in a loss of top-line revenue for Ancillary Services. There will also be a loss of full-service vending commission paid to Ancillary Services according to Coke.

Recommendations

As clearly indicated by TRUSU and other concerned members of our campus community, plastic in general is a major environmental sustainability issue. We do note however, that the type of plastic specifically in question—PET—is not markedly detrimental based on the evidence-based review. We have also found substantial contradictory information in current academic literature, and a preferred beverage container solution cannot be conclusively arrived at. The studies all clearly indicated higher container recycling and reuse rates will significantly lessen the environmental impact of all materials. Light weighting of materials was identified as another effective strategy to lower environmental impacts. Larger bottles carried more liquid with less packaging and were also environmentally preferable. The most effective strategy of all, of course, is to eliminate much of the need for these single-use containers in the first place.

Given that there has been positive interaction around this review at TRU and given that TRU is committed both Strategically and Academically to environmental sustainability, this is an ideal opportunity for TRU to take a leadership role and establish a pilot approach which would include all concerned parties.

As a beverage container producer as defined by Schedule 1, sections 1 and 2 of British Columbia Recycling Regulation 449/2004, Coca-Cola is required to implement a product stewardship plan for all beverages sold in British Columbia. The recommendations in this review draw primarily from the regulation and encourage the beverage supplier to more thoroughly comply with regulation guidelines. In BC, beverage producers created Encorp Pacific to comply with this regulation.

Section 5(1)(c)(vii) of this Regulation states product stewardship plans must manage the product "…in adherence to the order of preference in the pollution prevention hierarchy".[7] The pollution prevention hierarchy as defined by Regulation 449/2004 is followed, in descending order of preference such that pollution prevention is not undertaken at one level until all feasible opportunities for pollution prevention at a higher level have been undertaken. It is listed in descending order of preference from (a) – most desirable to (g) – least desirable.

Pollution Prevention Hierarchy

(a) reduce the environmental impact of producing the product by eliminating toxic components and increasing energy and resource efficiency;
(b) redesign the product to improve reusability or recyclability;
(c) eliminate or reduce the generation of unused portions of a product;
(d) reuse the product;
(e) recycle the product;
(f) recover material or energy from the product, or
(g) otherwise dispose of the waste from the product in compliance with the Environmental Management Act.

[7] http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/449_2004#section3.1

Drawing attention to lines (a), (b), (c), and (d) we note that there are four options that must be exhausted before recycling is to be considered

A) Reduce the environmental impact of producing the product by eliminating toxic components and increasing energy and resource efficiency.

Coca-Cola has taken some steps to light weighting plastic bottles, ensuring toxic components are not present and improving production processes, however more should be done.

Recommendation

The beverage supplier work to further reduce the environmental impact of all beverage container types (aluminum, glass and plastic) sold on campus, by identifying efficiency opportunities in transportation of beverages and increasing energy efficiency at the plant level. This could include a focus on fountain beverage serving stations thereby reducing the transportation requirement of supplying the campus with beverage containers regularly.

B) Redesign the product to improve reusability or recyclability.

While substantial light weighting has occurred in PET plastic beverage containers (Coca-Cola, 2010) energy and resource efficiency can be improved by increasing the amount of recycled PET (rPET) included in PET beverage containers and continuing light weighting efforts. Though there doesn't seem to be available statistics on just how much of a PET bottle sold in BC is recycled content, Coca-Cola's goal of 25% rPET by 2015 suggests that the current content of rPET is lacking and well below the industry standards for both aluminum and glass containers. This is not an acceptable rate and should be corrected.

Recommendation

The beverage supplier publically state the current content of rPET in all PET containers sold at TRU and demonstrate the steps they are taking to increase that content to be more comparable to glass and aluminum recycled content industry standards.

(C) Eliminate or reduce the generation of unused portions of a product that is consumable

Recommendation

The beverage supplier emphasize fountain drink sales on campus in lieu of beverage containers. This would shift the focus towards using reusable bottles instead of disposable containers. This is viable in a situation such as TRU campuses where beverages are usually being purchased and consumed on campus.

(D) Reuse the product

We have not seen any evidence that Coke has taken steps to improve reusability of aluminum, glass, or plastic bottles. Introducing sealable aluminum cans would be one way to address this. Fountain drinks with reusable bottles is another way to address this.

Recommendation

The beverage supplier look into offering fountain drinks with reusable containers at TRU or other reusable options.

(E) Recycle the Product

The Encorp BC recycling rate for small PET bottles is unacceptable. Beverage container recycling rates must increase—in particular for PET bottles less than 1L in size. As noted earlier, the recycling rate of some PET bottles has in fact decreased rather than increased over the past five years.

Recommendation

Recycling rates must increase to closer to 100% recovery for all materials, in particular for PET bottles less than 1L in size.

Implementation

A multi-stakeholder committee with representatives from Coca-Cola, the Purchasing Department, Ancillary Services, TRU Student Union, Environmental Advisory Committee, and the Office of Environment & Sustainability will work towards implementation of the recommendations.

The Committee will work with Coca-Cola to examine the opportunities available under each recommendation and create a timeline for implementation. The committee will review Coca-Cola's progress at mutually agreed-upon points throughout the implementation timeline. If the committee finds that Coca-Cola is not adequately complying with the agreed-upon steps in a timely manner, the committee may initiate a plastic bottle ban request again or take other appropriate action as agreed to by committee members.

Appendix I

Terms of Reference

The Campus Beverage Container Review will be conducted by Dr. Tom Owen, Director of the Office of Environment and Sustainability at TRU. The purpose of the review is to provide the President and Vice Presidents as well as the Board of Governors with a broad base of information to make an informed decision on the best drink container solution for TRU. This review will examine possible drink containers solutions including an analysis for each of the following: environmental and sustainability impact, economic and financial impact, choice, health and safety, and contractual limitations and implications. The review will also provide an opportunity for and extend an invitation to all members of the TRU community and providers of containers to express their views and to bring forward scientific research on the issue.

The process will be transparent and open to all members of the TRU community including students, faculty, staff and suppliers. Written or oral presentations or a combination of both will be welcome. Written submissions will be posted on the website at www.tru.ca/sustain. The details of oral submissions will be available in advance on the same website. In addition to the submissions relevant research will be reviewed.

Appendix II - Plastics

Plastic is a varied material. There are some 20 different groups of plastics, each with numerous grades and varieties (APME 2006). There are two major categories of plastics: Thermosets and Thermoplastics.

Thermosets are polymers that solidify or set irreversibly when heated and cannot be remolded. Because they are strong and durable, they tend to be used primarily in automobiles and construction applications, not food packaging.

Thermoplastics are polymers that soften upon exposure to heat and return to their original condition at room temperature. Can be easily shaped and molded as bottles, jugs, and films, and so are ideal for food packaging. Virtually all thermoplastics are recyclable, although separation poses some practical limitations for certain products.

Common Types of Consumer Plastic

PP (Polypropylene and polyethylene) is the single most widely used thermoplastic globally, discovered in 1954. Examples of PP include flexible barrier film pouches (chips), stackable crates for transport and storage, caps for containers, bottles, thin walled containers (margarine, yogurt) used in the food industry, fork handles, water or sewage pipes. PP is also used in bowls, kettles, cat litter trays, combs, hair dryers, film wrap for clothing and other packaged goods.

PE (Polyethylene) This commodity plastic, discovered in 1933 by Reginald Gibson and Eric Fawcett is the second most widely used class of resin globally. There are several different grades according to the average density of the resin linear, but are typically divided between low-density and high-density polyethylene. About half of PE resin produced is used to make plastic film. Typical applications of PE are in blow-molded containers with volumes ranging from a few millilitres such as detergent bottles and milk jugs to hundreds of litres such as water and chemical barrels. Film applications include sandwich bags, cling wrap, irrigation pipes, and field liners. PE is also widely used as a dielectric insulator in electrical cables.

HDPE (High-Density polyethylene) In 1953,Karl Ziegler of the Kaiser Wilhelm Institute (renamed the Max Planck Institute) and Erhard Holzkamp invented high-density polyethylene (HDPE)This type of plastic is stiff, strong, and resistant to chemicals and moistures, permeable gas. It is also easy to process. It is typically used to make bottles for milk, juice, and water. HDPE is less flexible but also stronger and more rigid than PE.

PVC (Polyvinyl chloride) First created in 1872 by Eugene Baumann but commercial production began in late 1920's in USA. Most commodity plastics have carbon and hydrogen as their main component elements, but PVC differs by containing chlorine (around 57% by weight) as well as carbon and hydrogen. Approximately 40 per Cent of global demand is in Asia. Its chlorine content makes it essentially non-combustible and PVC is therefore used in buildings and furniture including window shutters, piping, and upholstery. PVC is more complex and difficult material to recycle, partly because of PVC's inherent thermal instability. A wide range of PVC compounds exist, because of plasticizers and other additives, there is no such thing as a standard PVC bottle.

PS (Polystyrene) started commercial production in 1930s by BASF and was introduced into the USA in 1937. It is clear, hard and brittle with a relatively low melting point. It can be mono-extruded with other plastics, injection molded or foamed to produce a range of products. Foaming produces an opaque, rigid lightweight material with impact protection and thermal insulation properties. Expanded PS cups and trays are commonly used for consumer goods, while industrial packaging protects high-value goods such as TV's, washing machines, and lighting during transport.

PET (Polyethylene terephthalate) was discovered in 1941 by the chemists Whinfield and Dickson. It was eventually licensed to DuPont for use in the USA and to ICI for use in the rest of the world. In the 1950s they produced the first polyester films and in the early 1970s the first polyester bottle resins. Of the few polymers that are potentially suitable for bottles, PET is the only plastic with a balance of properties such as transparency, gloss, lightweight, and resistance to carbon dioxide penetration. It provides a good barrier to gases and moisture and also provides good resistance to heat, mineral oils, solvents, and acids. It retains carbonation, making it ideal for soft drinks, and is shatter resistant. This has resulted in the nearly full replacement of glass in Europe for all but the most demanding applications that require both an oxygen barrier and UV resistance to protect the contents. World demand is 14.5 million tonnes per annum (Pastics Europe 2008). Recycled PET from soda bottles is used as fibres, insulation, and other non-food packaging applications.

PEN (Polyethylene naphthalate) PEN is a condensation polymer of dimethyl naphthalene dicarboxylate and thylene glycol. It is a relatively new member of the polyester family with excellent performance because of its high glass transition temperature. PEN's barrier properties for carbon dioxide, oxygen, and water vapor are superior to those of PET and PEN provides better performance at high temperatures, allowing hot refills, rehashing, and reuse. However PEN costs 3-4 times more than PET. Because PEN provides protection against transfer of flavors and odors, it is well suited for manufacturing bottles for beverages such as beer.

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