Regenerative Business Development

Choosing a Safe and Sustainable Reusable Serviceware Fleet

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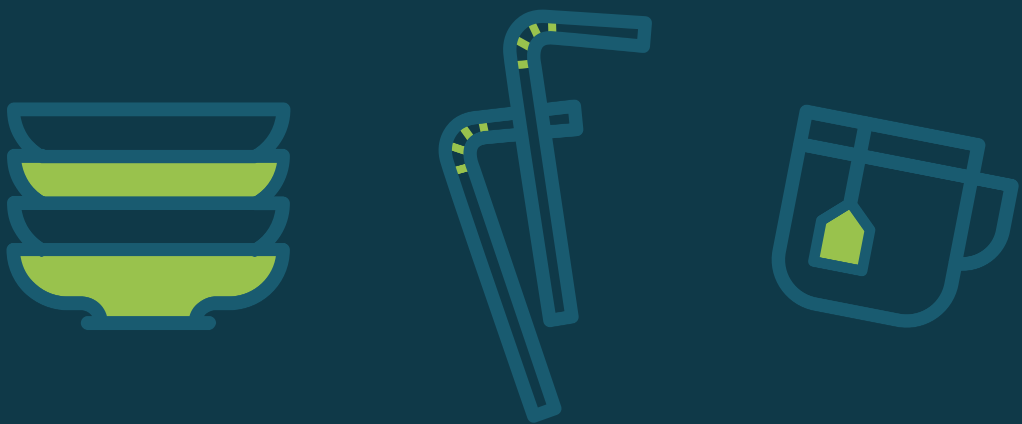

Full Report

December 2023

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Abbreviations

ABS	Acrylonitrile butadiene styrene
AVG.	Average
BBP	Benzyl butyl phthalate
-BDE	-bromodiphenyl ether
BPA	Bisphenol-A
Cd	Cadmium
CE	Circular Economy
DBP	Dibutyl phthalate
DBT	Dibutyltin compounds (Organotin)
DCHP	Dicyclohexyl phthalate
DEHP	Di(2-ethylhexyl)phthalate
DHEXP/DnHP	Dihexyl phthalate
DIBP	Diisobutyl phthalate
DIDP	Diisodecyl phthalate
DNOP	Dioctyl phthalate
DOT	Dioctyltin compounds (Organotin)
DPENP	Dipentyl phthalate
EA	Estrogenic Activity
ECHA	European Chemicals Agency
FCA	Food Contact Articles
FCC	Food Contact Chemicals
FCM	Food Contact Materials
GPPS	General purpose polystyrene
HBCDD	Hexabromocyclododecane (Brominated Flame Retardant)
HERA	Heavy Engineering Research Association
HIPS	High Impact Polystyrene
HoReCa	Hotel, Restaurant, Catering
MCCP	Medium-chain chlorinated paraffins (Flame Retardant)
MF	Melamine Formaldehyde
MIPS	Medium Impact Polystyrene
NZ	New Zealand
PAHs	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PBT	Persistent Bioaccumulative and Toxic
PE	Polyethelyene
POPs	Persistent organic pollutants
PP	Polypropylene
REACh	Registration, Evaluation, Authorisation and Restriction of Chemicals
SCCP	Short-chain chlorinated paraffins
SHIPS	Super-high-impact polystyrene
SML	Specific migration limit
TCEP	Tris(2-chloroethyl) Phosphate (Flame Retardant)
TCPP	Tris(2-Chloropropyl) Phosphate (Flame Retardant)
TDCP	Tris(1,3-dichloro-2-propyl)phosphate (Flame Retardant)

Executive Summary

This report has been commissioned by Takeaway Throwaways to support groups in Aotearoa New Zealand who are establishing reusable serviceware systems to procure the most **sustainable** and **safe** reusable serviceware fleets possible. Events were the context studied for this report, but most of the findings are generally applicable across a range of hospitality contexts.

Serviceware is any vessel, receptacle and container used to hold prepared, ready-to-eat food and drink, either to be consumed on-site or to take away, e.g. cups, plates, bowls, cutlery and lunchboxes.

Reusable serviceware systems offer businesses and consumers an alternative to disposables. When functioning well, with high uptake and high rates of return, reuse systems avoid the creation and disposal of multiple single-use items. This can reduce costs while bringing significant environmental benefits. Public health benefits can also flow from avoiding single-use serviceware, which often contains harmful or potentially harmful chemical additives that can transfer into food and drink.

When designing a new reuse system, the decision of what type of reusable serviceware to buy plays a role in maximising the benefits of reuse and minimising unintended consequences. This report provides an evidence-based review of the key considerations - environmental impact, public health safety, cost and functionality - for investing in low-impact, high-quality reusable serviceware fleets.

A **high-level decision-making matrix** (below) applies these considerations in a New Zealand context, to commonly used serviceware materials (glass, polypropylene (PP), tritan, stainless steel, melamine, ceramics and enamelled metals). The matrix, its selected criteria and ratings are based on the report's research findings, and can be used by anyone in New Zealand looking to invest in a reusable serviceware fleet.

Less Desirable	**Caution**	**Average**	**Good Practice**	**Best Practice**	**Unknown**

Decision-Making Matrix ratings

	Tempered Glass (drink-ware)	Vitrified Glass (dinner-ware)	PP (both)	Tritan (drink-ware)	Stainless Steel (both)	Melamine (both)	Vitrified Porcelain (both)	Enamelled steel (both)
Hazardous Substance Migration	Best Practice	Best Practice	Less Desirable	Caution	Best Practice	Caution	Good Practice	Average
Microplastic Release	Best Practice	Best Practice	Less Desirable	Unknown	Best Practice	Unknown	Best Practice	Best Practice
Hazardous Substance Accumulation	Best Practice	Best Practice	Less Desirable	Unknown	Best Practice	Unknown	Best Practice	Best Practice
Expected Lifespan	Good Practice	Good Practice	Less Desirable	Average	Best Practice	Good Practice	Average	Good Practice
Impact Durability	Average	Average	Best Practice	Good Practice	Best Practice	Best Practice	Caution	Best Practice
Recyclability	Average	Average	Good Practice	Less Desirable	Good Practice	Less Desirable	Caution	Good Practice
Hygiene	Good Practice	Good Practice	Less Desirable	Unknown	Best Practice	Unknown	Average	Average
Lifecycle Assessment	Caution	Caution	Caution	Unknown	Best Practice	Unknown	Unknown	Unknown
Weight	Less Desirable	Caution	Best Practice	Good Practice	Good Practice	Good Practice	Less Desirable	Good Practice

Decision-Making Matrix

In preparing the matrix, extra research was undertaken on material safety (toxicity, migration, shedding and microbial adhesion) because these topics often receive relatively less attention in the grey literature on packaging choices. The findings from this extra research is summarised in **Appendix A** of this report. For the purpose of making decisions about reusable serviceware, it may be useful to note that the research on material safety indicates that:

- Material choice is relevant not only for reusable serviceware, but also for dishwasher accessories, such as racks.
- Decisions about serviceware branding, such as on-product prints, should also be considered carefully as printing inks often contain large numbers of hazardous substances.
- To accredit against certain standards, including the PR3 Reusable Packaging System Standards, reusable packaging systems may need to avoid the use of plastic.

The report also provides a **serviceware cost comparison matrix** (below) that compares the cost of different serviceware options across materials and at different return rates. The matrix shows that the impact of reusable serviceware materials is connected to overall system design, and choices about reusable packaging procurement should take into account the need for high return rates (ideally, 90% or higher).

Serviceware Cost Comparison Matrix

	Tempered Glass	Vitrified Glass	PP	Tritan	Stainless Steel	Melamine	Vitrified Porcelain	Enamelled Steel
Cost Cold-drinkware*	Avg. Cost		Higher Cost	Highest Cost	Lowest Cost	Lower Cost		
Cost Cold-drinkware**	Avg. Cost		Lowest Cost	Highest Cost	Avg. Cost	Lower Cost		
Cost Foodware*		Lower Cost	Higher Cost		Avg. Cost	Lowest Cost	Highest Cost	Highest Cost
Cost Foodware**		Lower Cost	Lowest Cost		Avg. Cost	Lowest Cost	Highest Cost	Higher Cost

* assuming 100% return rate
** assuming 85-95% return rate with 2.5% glass and 5% porcelain breakage

Key findings and decision-making tree

Stainless steel and vitrified or tempered glass options fared the best across most criteria, with the caveat that return rates must be as high as possible (and breakage rates low for glass) or these options can become expensive or fail to meet environmental breakeven points.

Using carefully sourced second-hand serviceware options for any situation can reduce costs and provide the opportunity for return rates to improve before higher monetary investments are made to procure larger fleets.

PP is the lowest cost option for high volumes and low return rates, but would ideally only be considered an interim option while return rates are improved due to its potential health and environmental impacts.

For branding, a fleet without printing is a lower risk option in terms of material safety. Stainless steel can be branded by alternative means (e.g. embossing or engraving), if budget allows. Unbranded fleets can also be considered if other ways of raising the brand profile are explored, such as branding at returned serviceware collection/drop off points, and wash stations. Unbranded fleets can bring other benefits. For example, if stock is updated or the reuse system retires, unbranded serviceware can more easily be utilised in other reuse systems.

The following decision tree provides a guideline for what direction works best in different situations based on the criteria outlined:

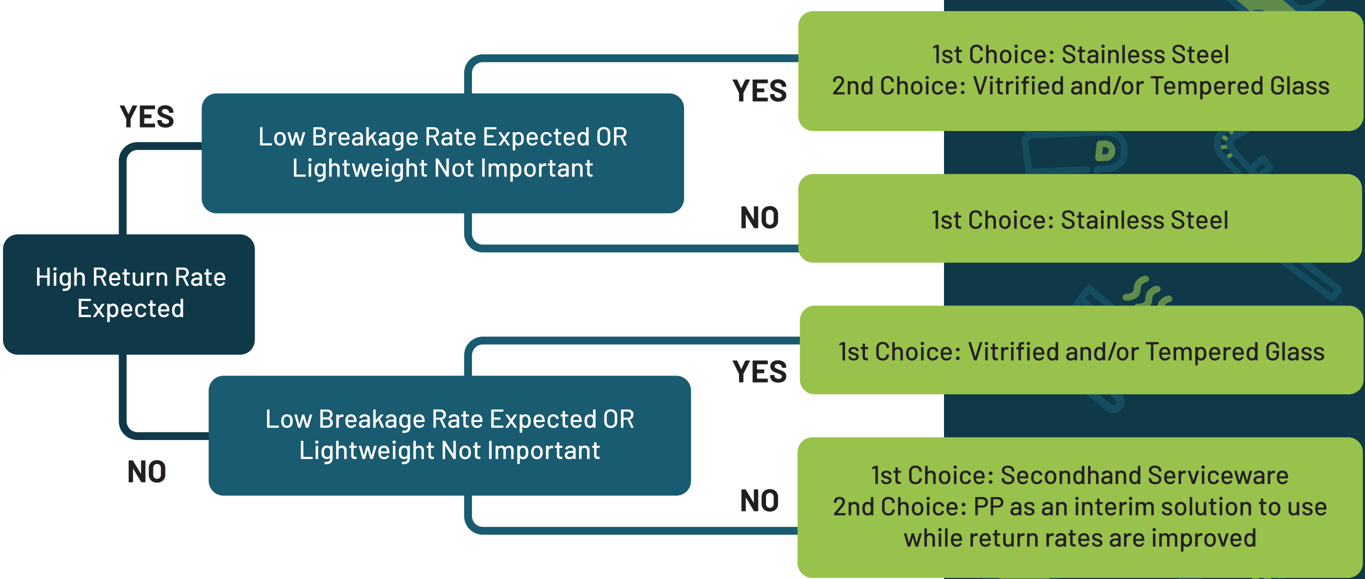

Figure 1: Decision Tree for Serviceware Material Choice

1 Introduction and Background

The research presented in this report has been commissioned by Takeaway Throwaways[1] to support groups who are establishing reusable serviceware systems to procure the most **sustainable** and **safe** reusable serviceware fleets possible. Events were the context studied for this report, but most of the findings are generally applicable across a range of hospitality contexts.

For the purposes of this report, serviceware is any vessel, receptacle and container used to hold prepared, ready-to-eat food and drink, either to be consumed on-site or to take away. This includes products such as cups, plates, bowls, cutlery and lunchboxes. Reusable serviceware can be made from a range of materials, including glass, metals, plastics, enamelled metals and ceramics.

With growing talk about the circular economy and zero waste, and widespread concerns about plastic pollution and landfill, reuse systems to replace single-use serviceware items are of increased interest to events, environmental groups and HoReCa (hotel, restaurant, catering) businesses across New Zealand (NZ). However, there is a lack of independent, evidence-based information to support groups (and funders) to choose the best reusable serviceware fleets based on a holistic set of considerations.

This report seeks to fill this gap, providing an evidence-based review of the key considerations - environmental impact, public health safety, cost and functionality - for investing in low-impact, high-quality reusable serviceware fleets. It provides **a high-level decision-making matrix** based on the research findings that anyone looking to invest in a reusable serviceware fleet can use.

The evidence drawn on includes published research, and conversations with individuals and organisations with experience in event-based hospitality, waste minimisation and/or the operation of reusable serviceware systems. The holistic criteria in the matrix extend the focus beyond waste reduction to reflect the three pillars of the Circular Economy (CE):

- Design out waste and pollution
- Keep products and materials in circulation
- Regenerate nature.

The key areas of interest covered by this report include:

1. Sensitivity to the need for new reuse systems to operate within existing carbon budgets (i.e. minimising the creation of 'new stuff').
2. Consideration of the latest research about public health safety of different materials and fleet options (including whether any materials/product types should be ruled out on these grounds).

[1] Takeaway Throwaways is an independent organisation that supports the shift from single-use serviceware towards reuse systems.

3. Comparison of the impact of common serviceware materials, in terms of general environmental, cost and functionality considerations

Extra research was conducted on the topics of material safety (toxicity, migration, shedding and microbial adhesion) because these topics often receive relatively less attention in the grey literature on packaging choices. For the benefit of increased understanding, the research findings on material safety are summarised and presented in Appendix A of this report.

2 Prioritising well-designed, best-practice reuse systems to support human and environmental health

2.1 Reusable serviceware systems and their contribution to a zero waste, low-carbon, toxic-free future

Reusable serviceware systems offer businesses and consumers an alternative to the practice of using a disposable item for every serving of food and drink. Reuse systems involve managing a fleet of durable serviceware items (capable of withstanding multiple reuse cycles) in a system of reuse that ensures that each item is ***repeatedly used*** to serve food and drink by:

- Loaning the serviceware to the person who has ordered the food/drink
- Ensuring the serviceware is returned once empty
- Washing and sanitising returned items
- Redistributing clean items back to food/drink vendors to be used again.

Reuse systems are a means of achieving the same level of food and drink service with fewer natural resources because every time a reusable serviceware item is reused, it displaces the need for a single-use item. For example, a ceramic plate that is reused 2000 times, avoids the creation of 1,999 single-use plates.

Therefore, when functioning well, with high uptake and high rates of return, reuse systems avoid the creation and disposal of multiple single-use items. This can **reduce costs** by eliminating the need to keep buying serviceware (Peeters *et el*., 2023; Gordon, 2020). It also brings **significant environmental benefit** because the ongoing manufacture of single-use serviceware items (designed to be disposed of after just one use) has negative impacts in terms of resource depletion, pollution, emissions and waste (REUSE AOTEAROA, 2022; TAKEAWAY THROWAWAYS, 2022). Provided the reusable serviceware items are used a sufficient number of times, reuse systems are almost always more ecological than single-use (Blumhardt, 2023).

The avoidance of single-use serviceware and other single-use packaging can also have **public health benefits**. Numerous studies are highlighting the potential or actual toxicity of single-use serviceware, which often contains and releases harmful chemical additives and/or microplastics into the food and drink it is designed to hold (Fox, 2019; Muncke *et al.*, 2020; BEUC - THE EUROPEAN CONSUMER ORGANISATION, 2021; Muncke, 2021; Napierska, 2023). Examples include the migration into food of PFAS (a toxic 'forever chemical' used to enable plastic-free fibre-based serviceware to perform like plastics) (Ackerman *et al.*,2020; Strakova, 2021; THE PACKAGING FORUM, 2022), or single-use hot drink cups lined with plastic releasing thousands of microplastic particles into each beverage, along with any additives or other contaminants contained in the plastic (Ranjan *et al.*, 2021).

2.2 Why system design and serviceware choices matter

Reusable serviceware systems should be well-designed in order to maximise their potential environmental, economic, and human health benefits, and to avoid unintentionally replicating the problems of single-use serviceware. The 'key ingredients' for a well-designed, best-practice system are set out by Reuse Aotearoa, and relate to ensuring: high reuse rates; efficient washing and transportation systems; non-toxic material choices for reusables; and affordability and accessibility (REUSE AOTEAROA, 2022b).

Several of these 'key ingredients' have implications for serviceware choice. To reduce costs and increase environmental benefit and affordability, reusable serviceware systems should achieve high reuse rates in practice – or at least enough times to reach the breakeven point with the equivalent number of single-use items (in terms of cost and environmental impact). The minimum number of uses varies depending on the chosen material for the serviceware.

High reuse rates depend both on uptake of the system by businesses and consumers, and high return rates after use. The PR3 Standards for reuse systems requires return rates of 90% within the first 3 years of the system's operation, and 95% within the first 5 years. This equates to average per container reuse rates of 10 and 20 times, respectively. To achieve these outcomes in practice, systems and the chosen serviceware must be accessible, functional, easy-to-use and appealing for all users, with incentives to participate in the returns process.

To ensure public safety and reduce preventable pollution from use and washing, serviceware made from non-toxic/benign/inert materials should be chosen. It is not a given that a serviceware item is non-toxic just because it is reusable, but there are a greater range of viable reusable options made from benign materials. As reuse systems require the upfront purchase of a reusable serviceware fleet, this presents an opportunity to choose to invest in high-quality materials that are safer than single-use equivalents (GREENSCREEN, no date).

Finally, the creation of any new product, including a reusable serviceware fleet and the infrastructure to service it, has an environmental impact, even if this is less than the impact of a single-use system. While not always possible, finding ways to identify and incorporate existing serviceware and infrastructure into reuse systems is likely to decrease the overall cost and environmental impact of a new reuse system. Examples of existing serviceware include those salvaged from secondhand stores (e.g. ceramics), leftover fleets from retired reuse systems, or deadstock reusables from privately held fleets or reuse systems that have upgraded their stock.

3 Comparing Common Serviceware Material Options for Events based on various public health safety,[2] environmental, cost and functionality considerations

3.1 Glass

Glass is a very attractive material for serviceware in general because it does not affect the flavour of its contents, and resists staining. As glass is manufactured at very high temperatures, most trace amounts of heavy metals (refer to section A.1 for more explanation of risks) are oxidised and because glass is virtually inert, it does not present any significant health and safety or environmental concerns from a material perspective (Mahinka, S et al., 2013). However, breakages and/or use as a weapon can pose a health and safety risk in certain situations.

3.1.1 Composition and Migration of Substances

Three key types of glass are used for food applications: Type I Borosilicate Glass (also known as pyrex); Type II Treated Soda Lime Glass and Type III Soda Lime Glass. (KOPP GLASS, 2016).

Type I borosilicate glass is made from sand, soda ash, and Boron oxide. It is distinguished by its low coefficient of thermal expansion, which makes it resistant to thermal shock and less likely to break and shatter when exposed to sudden temperature changes. As such, it is used for things like cookware. However, it cannot be tempered to significantly increase its impact resistance, it can only be heat strengthened. This does not achieve the same strength as tempered glass nor the breakage properties that make it safer when it shatters under impact. It is non-porous and does not absorb flavours or odours. This makes it a good choice for food and milk bottles, as it will not retain any flavours from previous contents. Additionally, borosilicate glass is dishwasher safe, making it easy to clean and sanitize. (KOPP GLASS, 2016).

Type II treated soda-lime glass, the most common type of glass, made of soda ash, limestone, and sand, is the more cost-effective option and is a food-safe glass that has been treated to resist staining and leaching. The surface of this type of glass is treated with sulfur which neutralises the alkaline oxides making it more weathering and chemical resistant. This type of glass is often used in food packaging, such as jars and bottles, and in food service applications, such as plates and bowls. It can be tempered to increase its impact resistance and will be much thicker and heavier than type I borosilicate glass. The tempered version is often used for oven doors, microwave doors, and food storage containers that need extra durability. Tempered glass is also known as safety glass because it shatters without resulting in sharp shards (KOPP GLASS, 2016). This would be the safer option for reusable serviceware in situations where breakages could occur through dropping. However, it is also the heaviest glassware option, meaning it is less desirable if transportation is required.

[2] See Appendix A for a full summary of the research on material safety.

Type III soda-lime glass is a food-safe glass often used in food packaging and is safe for most food-related uses, but is not recommended for highly acidic foods or beverages. It is also not recommended for hot foods or drinks, as it can break or shatter. (KOPP GLASS, 2016)

For serviceware, vitrified glass is also common. It is opaque (usually white) rather than clear and is more expensive than tempered glass, but slightly lighter in weight and a popular choice for dinnerware as it is very durable and shatters in the same way as tempered glass if it does break.

3.1.2 Hygiene

Microbial contamination can compromise food quality and safety (refer to section A.3 for more detailed information). Glass is hydrophilic, which discourages bacterial adhesion (Bower, C et al., 1996), making it ideal for Food Contact Materials (FCMs). However, in the reuse situation, as the surface of glass becomes scratched or abraded, bacteria can be harboured. Glass should always be stored with the opening facing upwards to help the air inside the glass circulate (HOBART GMBH, 2009) or if stored upside down should be on racks that allow air movement.

3.1.3 Life-cycle Impacts and Lifespan

Gallego-Schmid *et el.* (2018) demonstrated that in Europe the lifespan of glass containers must be upwards of 3.5 times that of reusable plastic containers to ensure the same or lesser environmental footprint. Breakages are the most common reason for the lifespan of glass to be shortened, but tempered glass can reduce the number of breaks.

The durability of dinnerware with respect to dishwashing can be determined through standards EN 12875-1:2005 and EN 12875-2:2001 where dishware is washed for a minimum of 125 domestic dishwasher cycles. Most high-quality glasses can be expected to withstand at least 1,000 cycles if care is taken in their handling (Riedel, 2023). For example, the use of well-designed racks that stop glasses contacting each other during washing can prolong their life as well as the use of detergents that are appropriate for glass.

3.1.4 Recyclability at End-of-life

Currently only bottles and jars, which are non-tempered, are collected for recycling in New Zealand. Specialised serviceware, noting that tempered and vitrified glass is not as easily recycled, would need special arrangements made with the suppliers of the serviceware.

3.1.5 Use of second-hand glass serviceware

Purchase of modern second-hand glass fleets that are in good condition is a good way of reducing cost and removing the need for more energy and resources to be expended to produce new products. Lead crystal contains lead as did some older glass items and would not be recommended, but any modern vitrified glass or Pyrex would be a low-risk option and generally easy to find in uniform sizes which is great for dishwashers and general handling. Use of jars or similar as bowls or glasses is another option but because these are often not tempered, consideration should be made as to how these products may break or shatter on impact.

3.2 Polypropylene (PP)

Properties that make PP a popular option for reusable serviceware include good chemical resistance, toughness, heat resistance, ease of moulding and cost effectiveness (FEDERATION BRITISH PLASTICS, 2023).

3.2.1 Composition and Migration of Substances

PP, a petroleum-based plastic, is made from the polymerisation of propylene gas in the presence of a catalyst system, usually Ziegler-Natta or metallocene catalyst. Polymerisation conditions (temperature, pressure and reactant concentrations) are set by the polymer grade to be produced. Plastics are chemically very complex and contain hundreds of different synthetic compounds of which their hazardous properties are often largely unknown. Some of these may be additives that aid the manufacturing process, but can also be non-intentionally added substances and also products of the material's degradation. Simoneau *et el.* (2012), in comparing various plastics used for baby bottles, showed that bottles made from PP resulted in a greater number of migrating substances compared to plastics such as Tritan. Geueke *et al.* (2023) indicated that FCMs made from **recycled** materials can present additional risks because of the potential for accumulation of hazardous chemicals. Plastics can absorb food components or cleaning agents during their use, and new compounds can be formed as a result of degradation which can then end up in new plastics as a result of recycling. Their research showed 509 Food Contact Chemicals (FCCs) detected in repeat-use plastics. In the EU, recycled plastics used as FCM must have been recycled in accordance with Regulation (EC) 282/2008 (Food Contact Recycled Plastics) and the process must be managed under an appropriate assurance system for Good Manufacturing Practice (GMP) to Regulation (EC) 2023/2006, meaning that FCM plastics that come from Europe may contain recycled plastics. FCM made in New Zealand may not contain recycled plastics.

3.2.2 Hygiene

As the surface of PP degrades and becomes scratched or abraded through use, the surface is more readily able to hold bacteria, compared to glass and stainless steel. Clayborn *et el.* (2015) showed that as well as bacteria attaching itself to reusable plastic containers, it could not be dislodged by either sanitisers or physical scrubbing.

3.2.3 Lifecycle impacts and Lifespan

Gallego-Schmid *et el.* (2018) indicated that if PP were reused as many times as a glass container, it would have a 3.5 times smaller environmental footprint. However a PP cup can only be washed around 250-300 times before the quality starts to deteriorate (EVENT CUP SOLUTIONS, 2023), whereas a glass item can withstand around 1000 wash cycles minimum. This means that considering their respective lives, reusable PP has a similar environmental footprint to glass. What may be overlooked here is the impact of microplastics released as the plastic degrades (refer to section A.2 for further detail).However, polypropylene will not break and its lightness means it consumes less energy in transportation (relevant if the serviceware must be transported between different locations).

3.2.4 Recyclability at end of life

PP can be recycled in New Zealand, although serviceware will not be recycled back into more serviceware, so the process is not a closed loop. Instead, PP will be downcycled into things like wheelie bins and fence posts (CONSUMER, 2022).

3.2.5 Use of second-hand PP serviceware

The low cost and lifespan of PP mean that it is not typically available for resale or reuse. However sometimes PP has been purchased as single use item and then reclaimed for reuse to extend its life. If degradation of the plastic appears to be minimal this could be an interim option to temporarily divert PP from landfill or from downcycling.

3.3 Tritan

Tritan has replaced polycarbonate, which contains Bisphenol-A (BPA), a known toxin which is restricted for use in FCM in most countries. Tritan, an alternative to Polycarbonate, was introduced by the Eastman Group in 2008. It is popular as serviceware due to its glass-like transparency coupled with its durability, impact resistance and its light weight (much lighter than glass). However, as a relatively new material with more niche uses, very few studies explore its properties and potential hazards in detail.

3.3.1 Composition and Migration of Substances

Tritan is presented as a BPA-free plastic (EASTMAN CHEMICAL COMPANY, 2023). Tritan is manufactured from three monomers, di-methylterephthalate (DMT), 1,4-cyclohexanedimethanol (CHDM), and 2,2,4,4-tetramethyl-1,3-cyclobutanediol (TMCD) (Osimitz *et al.*, 2012). DMT, while a phthalate (refer to section A.1 for detail of the known risks of some phthalates), is not currently considered a chemical of concern. However, transient BPA release has been observed from Tritan drinking bottles, thought to be the result of surface contamination in the manufacturing process or hydrolysis of the polymer, but studies have shown that the BPA in this situation is often removed through dishwashing (Holmes *et al.*, 2021). A study on migration of chemicals from babies' bottles concluded that while PP released a number of substances, in these tests there were comparatively no issues found with Tritan in relation to the release of chemical substances (Onghena *et al.*, 2016). However, it should be noted that these tests often look for specific substances, and what is not expected to be there is often not looked for (refer to section A.1 for further detail). Bittner *et al.* (2014) showed that although Tritan is promoted as EA (estrogenic activity)[3] -free, after exposure to UV radiation in the form of natural sunlight an increased release of EA chemicals occurred. In summary, there is not sufficient information available currently to really understand the health implications of this material.

[3] Chemicals having estrogenic activity (EA) reportedly cause many adverse health effects, especially at low (picomolar to nanomolar) doses in fetal and juvenile mammals.

3.3.2 Hygiene

EASTMAN CHEMICAL COMPANY (2014) in their technical datasheet for Tritan™ EX401 state that the material meets infant care sterilisation requirements via boiling water or microwave steam sterilisation. However, no independent studies to verify this information have been found.

3.3.3 Lifecycle Impacts and Lifespan

Tritan has a better LCA outcome than Polycarbonate (Tople, 2010), but there is not sufficient research to indicate how it would compare to glass, stainless steel or PP. Tritan containers can withstand over 500 wash cycles with no cracks or hazing (Beavers, R, 2007), so won't last as long as glass when it comes to washing, but have the advantage of not breaking if dropped and being significantly lighter in weight.

3.3.4 Recyclability at end of life

Tritan is challenging to recycle in New Zealand so arrangements would need to be made with the supplier.

3.3.5 Use of second-hand Tritan serviceware

Tritan can be difficult to identify as it is not usually marked on the product what it is. Many older clear plastics are likely to be polycarbonate and will contain BPA. If the product is marked as BPA-free then it is most likely Tritan. Obtaining either polycarbonate or Tritan second-hand is a possibility but a dishwasher test should be performed. Some early materials/products did not fare well in dishwashers and hazing (small lines and cloudiness) was common.

3.4 Stainless Steel

Stainless steel's longevity and stability has made it a popular food contact material in many areas.

3.4.1 Composition and Migration of Substances

Food grade stainless steel is generally grade 304 or 316. These both contain Iron, Carbon, Manganese, Silicon, Phosphorus, Sulphur, Chromium and Nickel, and vary in the amount of nickel and Chromium they contain. Grade 316 also contains Molybdenum, which increases its corrosion resistance. The Chromium content of stainless steels limits the bioaccessibility of the heavy metals in most environments (Taxell *et el.*, 2022). Nickel and cobolt are generally of particular concern (refer to section A.1 for further detail), but a study performed by Santonen *et el.* (2010) suggests that stainless steel products are still able to provide the anticipated low toxicity they are known for. A Swedish study using test guidelines provided by the Council of Europe determined release rates of metals from stainless steel were considered safe based on the guideline limits and that any migration diminished upon repeated use and over time due to a gradually improved passivation[4] of the surface (Hedberg *et al.*, 2014). One point of note is the use of lead solder in double walled cups

[4] According to ASTM A967, the definition of passivation is "the chemical treatment of stainless steel with a mild oxidant, such as a nitric acid solution, for the purpose of the removal of free iron or other foreign matter."

which could potentially migrate from the cup if the seal were to become damaged over time (refer to section A.2 for further detail). Additionally, care should be taken to ensure that the stainless steel is not lined or coated with plastics (e.g. for branding purposes), which would present similar risks to the use of plastics.

3.4.2 Hygiene

Like glass, stainless steel, through passivation, can become hydrophilic (refer to section A.3 for further detail). The passivation process will also happen naturally over time. This property discourages bacterial adhesion. Studies have shown that overtime, stainless steel is better able to retain its hygienic properties as it can resist damage caused by the cleaning process when compared to glass and various plastics (Bower *et al.*, 1996).

3.4.3 Lifecycle impacts and Lifespan

Upstream, a US-based nonprofit supporting the shift from single-use to reuse, commissioned a life-cycle assessment to examine the environmental impacts (looking at energy consumption, carbon dioxide emissions, air acidification, water eutrophication and landfill impact) of single-use and reusable cups including those made from PP and stainless steel. They concluded that these two materials were the most sustainable options for large outdoor events. They concluded that PP cups could be washed hundreds of times and stainless steel cups thousands of times, meaning they far exceeded the breakeven point for single use materials, and further concluded that stainless steel was the preferred choice as it could be used many more times than PP, and was better for the environment and people, all round. (Wentz, no date).

3.4.4 Recyclability at end of Life

Reck (2015) concluded that globally, on average, 85% of stainless steels are recycled once they reach their end of life, either to become new stainless steels (56%) or a valuable iron source for carbon steels (29%). In New Zealand the Steel Recycling report (HERA, 2021), shows all of New Zealand's scrap metal is shipped off shore and in 2020, this amounted to 31.3 kiloTonnes of stainless steel. In general, steel is reported by HERA to have a recycling rate of 74 percent and they note that New Zealand no longer recycles post-consumer steel scrap. This is sent off-shore.

3.4.5 Use of second-hand stainless steel serviceware

Stainless steel products are ideal to obtain second-hand because of their long lifespan and the fact that they become more hygienic overtime. However, caution should be taken if obtaining double walled stainless steel, which may contain lead solder, or any stainless steel items that are lined or coated with plastics (e.g. branded/printed exterior). It should also be noted that foodgrade stainless steels must contain a minimum level of Chromium as this is what prevents migration of heavy metals. Therefore, only stainless steel vessels that were intended for food contact should be used and caution should be taken if the source of the vessels is dubious or unknown. Testing can be performed to ensure the material is suitable for food use.

3.5 Melamine

Melamine is a very lightweight durable option for reuseable serviceware and is currently popular as a picnic or barbeque option.

3.5.1 Composition and Migration of Substances

Melamine, also known as Melamine Formaldehyde (MF), is a thermosetting synthetic resin prepared by polymerising melamine (a crystalline solid derived from urea) and formaldehyde (a highly reactive gas derived from Methane). It has excellent hardness, heat resistance, and physical and chemical stability (Kim *et al.*, 2021).

Poovarodom *et al.* (2014), showed that migration of substances from melamine used for tableware when used in the microwave, consistently increased with increasing number of microwave heating and washing cycles and after 25 - 67 cycles, depending on the heating time, the European Union regulatory limits were exceeded. Therefore it is strongly recommended that MF articles are not used in microwaves. However, formaldehyde was either not detected or found at low concentrations. García *et el.* (2016) analysed migration of melamine in a range of serviceware items and although migration was detected in 8 of the 18 food contact articles, none of the samples exceeded the specific European migration limit (SML) on the third exposure. However, formaldehyde migration was detected in all of the samples analysed, and in 56 % of the samples, formaldehyde levels were above the SML established in European Regulation. Mannoni *et al.*, (2017) showed that the migration of monomers from Melamine was related to progressive degradation of the resins. Ageing studies demonstrated that the potential degradation of the resins and the consequent migration of the monomers may continue throughout the service life of the product. The specific migration limit (SML) of melamine was also exceeded after ageing.

3.5.2 Hygiene

Unlike PP, melamine can retain heat so can dry faster. Limited information was available with regards to bacteria adhesion.

3.5.3 Lifecycle Impacts and Lifespan

While detailed LCA data was unavailable, Poovarodom *et el.* (2012) estimated the useful lifespan of melamine tableware based on how often they could wash it before the levels of formaldehyde migration exceeded the specific migration limit (SML), or samples were damaged and not suitable for further tests. Their testing results correlated with real practice giving a number of 1500 washes.

3.5.4 Recyclability at end of life

Melamine is not commonly recycled because of its heat-resistant qualities and any recycling would need to be arranged in advance with the supplier.

3.5.5 Use of second-hand melamine serviceware

Melamine products are often available second-hand. Because of the excessive migration that can occur after aging, testing for formaldehyde migration could be advisable along with dishwasher testing for durability.

3.6 Ceramics

Ceramics are typically used in the home and are widely available in second-hand stores which can provide a low-cost option for reusable fleets for events.

3.6.1 Composition and Migration of Substances

Plates are commonly made from ceramic materials such as bone china, porcelain or earthenware. Earthware is the most common due to its low cost, but vitrified porcelain is less likely to chip and is favoured by restaurants. It is also lighter in weight. According to Li (2020), the release of lead from ceramic ware, generally from the glaze, is the most reported concern with this material option. Commercial ceramics companies routinely test their ware for lead leaching, but for ceramics made by hobbyists, more care should be taken. Other heavy metals can also be present and can leach from incorrectly fired ceramics. A study conducted at Waikato University on various ceramics available in New Zealand, including second hand ceramics, showed that the pH of food, temperature and duration of exposure to acidic foods played a key role in the leaching of metals from glazes (Velayudhan, 2013). Although leaching of lead, barium, cadmium, cobolt and chromium were found, these were well below accepted limits. They also commented that damage of the glazes is likely to influence the leaching rate of metals which was evidenced by the differing results from the second-hand products rather than the unused ceramic wares. They further suggested that the lower amount of lead leaching found in the modern ceramic wares suggests that they are passing through improved safety testing before being sold in New Zealand. Testing by Gould *et al.* (1990) showed that multiple dishwashings and scrubbings didn't affect the level of lead release from ceramicware.

3.6.2 Hygiene

Most common ceramic applications in everyday use are susceptible to becoming pathogen spreaders ((Reinosa *et al.*, 2022). As ceramic is porous, it does not offer the same hygiene benefits as glass or stainless steel and the quality of the glaze greatly influences the adhesion of bacteria.

3.6.3 Lifecycle Impacts and Lifespan

Chipping is the most common reason for ceramic dinnerware to be retired and this can happen fairly. Ceramics are generally a less durable option compared to vitrified glass. However, the tendency to chip is highly dependent on the glaze type and quality as well as whether the ceramic is earthenware or porcelain and if it is vitrified. Vitrified glass will still be stronger than vitrified porcelain. The lifespan of ceramics is dependent on the quality of its glaze, but breakages will have the bigger effect on the lifespan of the item.

3.6.4 Recyclability at end of life

Ceramics can in theory be recycled but this is not done in New Zealand currently and ceramics are mostly landfilled.

3.6.5 Use of second-hand ceramic serviceware

The general long life of ceramics has resulted in a large amount of ceramic plates and cups being available on the second hand market. These are generally partial sets as a proportion of the products have been disposed-of due to chipping and breaking overtime. There is a small risk related to heavy metals in the glazes of secondhand ceramics but if the glaze appears to be in good condition the risk may be relatively low. Care should be taken when purchasing non-commercial ceramics or some antique ceramics where it is less clear if appropriate glazes and firing was used.

3.7 Enamelled Metals

Enamelled Steel is a common camping serviceware option. It is durable and relatively light weight.

3.7.1 Composition and Migration of Substances

A European survey looking at the release of metals from porcelain enamels intending to come in contact with food indicated that over half the tests showed exceeded limit values for cobalt and lithium (based on the limits set for testing food contact plastics) followed by cadmium, aluminium, nickel and arsenic (Golja *et al.*, 2018). The survey proposed that limits for enamelware be set urgently, particularly for cobalt and lithium. Some modern high end enamelware has a stainless steel base which removes most of the risk associated with heavy metal release and the enamelware can continue to be used if chipped, although chips and scratches may be able to harbour bacteria.

3.7.2 Hygiene

As the porcelain coating of enamelled products suitable for food contact are effectively a foodgrade glass, it is expected that the hygiene benefits, when the product is undamaged, would be similar to glass.

3.7.3 Lifecycle Impacts and Lifespan

Traditionally dishwashing of enamelware was best avoided because over time it could wear away the enamel. However there are now some higher end enamel serviceware options that are said to be dishwasher safe. When the coating does become damaged or cracked, ideally the product would no longer be used for food. Manufacturers of high-end dishwasher safe Enamelware such as Swiss Advance recommend that enamelware is dried by hand as air-drying can cause water stains. The lifespan of enamelware, much like that of ceramics, is related to the quality of the product and its coating.

3.7.4 Recyclability at end of life

Enameled serviceware can be recycled as scrap metal.

3.7.5 Use of second-hand enamel serviceware

Second-hand enamelware should be dishwasher tested to check for any visible change and the surface should be inspected for any cracks or chips. Older enamelware may not hold up when washed in a dishwasher.

4 Printing of Serviceware

Adding a logo or branding to reusable serviceware is a common consideration that can have environmental, cost, functionality and public health impacts. **Pad printing** is likely to be the cheapest option, although it may only last 250 use cycles before discoloration or fading appears. For polypropylene (PP), for which the lifespan is only 250-300 cycles, this would not be a concern for the overall longevity of the product. However, for serviceware made of materials that can withstand many more than 250-300 use cycles (e.g. stainless steel), the printing could be expected to partially or fully disappear over the life of the product.

Ideally, the placement of any ink printing would not come in contact with food. Groh *et al.* (2021), found the highest numbers of FCCs in global inventories were for printing inks, which in total contained 2926 unique substances. These substances were most closely correlated to those found in plastics. Printing inks were also found to contain the largest numbers of hazardous substances (refer to section A.1 for more detail) compared to other materials with over half of the 515 potentially genotoxic and/or carcinogenic FCC database substances found in food contact printing inks. While ensuring that these inks do not contact food directly may mitigate the likelihood of migration into food, further study is needed to understand how migration of inks in dishwashers affects waste water and how it may potentially contaminate plastic or other items in the dishwasher. Heavy metal free/food grade inks should be used for any serviceware.

Guo *et al.* (2023) noted that inks can also be considered contaminants in plastics and potentially affect the properties of recycled product.

For stainless steel, other options such as **engraving** or **embossing** could be a possibility with the added advantage of no fading, migration of substances or recycling contamination. Glass can be **etched**, although this may affect bacterial adhesion and if custom tooling were made for the manufacture of PP serviceware, logos could be inserted into the mould to provide an embossed logo.

5 Serviceware Geometry

5.1 Size

Size of serviceware should be optimised for washing the maximum number of items per load and for compact storage.

5.2 Shape

Products that are stackable can make gathering up of used serviceware, storage and transportation easier. Stackability can also improve uptake from commercial serviceware users (i.e. food and drink retailers) as the reusable serviceware can be placed in the same location as the single-use serviceware without requiring additional space or significant workflow adaptations.

5.3 Weight

From an environmental perspective, weight is more of a consideration if the fleet needs to be transported to site as heavier items will consume more energy to transport. For fixed locations where the serviceware can be stored, weight is less of an issue. However, for workers managing the reuse system at events, serviceware weight can become a health and safety issue for activities such as carrying and lifting full loads of returned or stacked serviceware, and proper protocols must be implemented, including the provision of trolleys and racking systems.

6 Should Plastic be used for reusable serviceware?

Many reusable serviceware systems currently in existence use plastic-based serviceware fleets. The evidence summarised in Appendix A indicates that plastic serviceware releases chemical additives into food and drink, and into the water during the washing process. Plastic serviceware also sheds microplastics. The scale of harm and risk is not clearly established.

In New Zealand, the 2019 report *Rethinking Plastics* by the Office of the Prime Minister's Chief Science Advisor (2019) made the following statements regarding plastic use:

1. "Plastic causes physical harm to marine life and other species" – "we don't know the extent of that impacts"
2. "Additional risks come from chemicals added to plastic" – "the concentration of chemicals – and any associated toxicity - can increase up the food chain"
3. "We don't fully understand the impacts caused by microplastics"
4. "We know less about the impact of even smaller plastic particles (nanoplastics)"
5. "Plastics may contribute to antimicrobial resistance" (through microbes that colonise microplastics)

Given the current state of uncertainty, some organisations may be inclined to adopt the precautionary principle and avoid the use of plastic serviceware for reuse schemes. Or, at least, to rule out plastic serviceware that contains particular substances (if this can be verified).

The draft standard on **Reusable Packaging System Design** (PR3 Committee, 2023) created through a partnership between corporate, government and NGO stakeholders to create standards for reusable packaging systems,[5] **recommends that containers be plastic-free and requires that the following 15 substances not be present**[6]:

1. Benzophenone and its derivatives
2. Bisphenols
3. Cadmium and cadmium compounds
4. Formaldehyde
5. Halogenated flame retardants
6. Hexavalent chromium and compounds
7. Lead and lead compounds
8. Mercury and Mercury compounds
9. Ortho-phthalates
10. Perfluoroalkyl and polyfluoroalkyl substances (PFAS)
11. Polycarbonate
12. Polyvinyl chloride
13. Toluene

[5] Note that the standard is a draft and certain elements are subject to change.
[6] Note that the Chromium used in Stainless Steel is not Hexavalent.

“GreenScreen for Safer Chemicals®”, a comprehensive hazard assessment tool promoting the design and use of safer chemicals, will not certify reusables made of plastic.

Many items can contain or are lined with plastics, even though it may not be obvious, so if plastic-free is what is desired then this should be kept in mind. The findings in Appendix A also highlight the relevance of considering material choices for dishwashing machine components and accessories (including dishwasher racks), where possible, as these items complete many more wash cycles than individual serviceware and may also release microplastics and chemical additives.

7 Cost

The initial cost of a reusable serviceware fleet can be compared by the purchase price of the various serviceware types. However, the true cost of a reusable serviceware fleet overtime is affected by the number of times the serviceware is reused, which is in turn influenced by the return rate (and attrition through loss/breakages) of the serviceware.

If we were to assume a 100% return rate on all reusables, then cost could be weighted up against the estimated lifespan of the different serviceware types. The costs below have been found through a quick internet search and have not been explored in detail but give a ball park figure. As indicated, the estimated lifespan does not take into account the potential of serviceware not being returned by the user or additionally the breaking of items during use:

Tumblers (for cold drinks)	Cost per 12 items	Estimated Lifespan (uses)	Cost/use for set of 12 items ($)
Stainless Steel	$36 (The warehouse 500mL)	2000	$0.018
Melamine	$31.56 per unit (Dick Smith 300mL)	1500	$0.021
Tempered Glass	$24 (Nisbets 350ml)	1000	$0.024
PP	$10.50 (The warehouse)	300	$0.035
Tritan	$104.97 (equipoutdoors 350ml)	500	$0.21

Table 1: Cost per Lifespan of Tumblers assuming 100% return rate and no breakages

Dinner Plates	Cost per 12 items	Estimated Lifespan (uses)	Cost/use for set of 12 items ($)
Melamine	$21 (the Warehouse)	1500	$0.014
Vitrified Glass	$33 (savebarn)	1000	$0.033
Stainless Steel	$84 (the kitchen warehouse)	2000	$0.042
PP	$18 (the warehouse)	300	$0.06
Vitrified Porcelain	$103.26 (Nisbets)	1000	$0.10
Enamelled Steel	$103.26 (Nisbets)	1000	$0.10

Table 2: Cost per Lifespan of Dinner Plates assuming 100% return rate and no breakages

The PR3 standards for reuse systems require a minimum of 90% average return rate in the first three years of a system's operation, and 95% average return rate within the first five years. If we assumed an 85% return rate for each item, then the average number of reuses would only be 6.67 times. Assuming a breakage rate of 2.5% for glass and 5% for porcelain, this would mean glass would be used 5.7 times and porcelain 5 times. Assuming a 95% return rate we have an average number of reuses of 20. Assuming the same breakage rate for glass and porcelain this would give 13.33 uses for glass and 10 for porcelain. Using these numbers, the cost per use for a set of 12 gives a different picture:

		Assuming 85% return rate and 2.5% glass breakage rate		Assuming 95% return rate and 2.5% glass breakage rate	
Tumblers	**Cost per 12 items**	**Estimated uses**	**Cost/use for set of 12 items ($)**	**Estimated uses**	**Cost/use for set of 12 items ($)**
Stainless Steel	$36 (The warehouse 500mL)	6.67	$5.40	20	$1.80
Melamine	$31.56 (Dick Smith 300mL)	6.67	$4.73	20	$1.58
Tempered Glass	$24 (Nisbets 350ml)	5.7	$4.21	13.33	$1.80
PP	$10.50 (The warehouse)	6.67	$1.57	20	$0.53
Tritan	$104.97 (equipoutdoors 350ml)	6.67	$15.74	20	$5.25

Table 3: Cost per use of 12 Tumblers assuming 85% and 95% return rates and 2.5% breakages for glass

		Assuming 85% return rate and 2.5% glass and 5% porcelain breakage rate		Assuming 95% return rate and 2.5% glass and 5% porcelain breakage rate	
Dinner Plates	**Cost per 12 items**	**Estimated uses**	**Cost/use for set of 12 items ($)**	**Estimated uses**	**Cost/use for set of 12 items ($)**
Melamine	$21 (the Warehouse)	6.67	$3.15	20	$1.05
Vitrified Glass	$33 (savebarn)	5.7	$5.80	13.33	$2.48
Stainless Steel	$84 (the kitchen warehouse)	6.67	$12.59	20	$4.20
PP	$18 (the warehouse)	6.67	$2.70	20	$0.90
Vitrified Porcelain	$103.26 (Nisbets)	5	$20.65	10	$10.33
Enamelled Steel	$103.26 (Nisbets)	6.67	$15.48	20	$5.16

Table 4: Cost per use of 12 Dinner Plates assuming 85% and 95% return rates and 2.5% breakages for glass, 5% breakages for porcelain

In these scenarios, for Stainless Steel to be as cost effective as PP, for example, the return rate would need to be 99.9%.

These scenarios demonstrate the importance of understanding return and breakage rates from a budget perspective. However, it should be noted that the purchase or acquiring of second hand serviceware has the potential to provide a different cost benefit outcome.

8 Decision Making Matrix and Procurement Specification

The background information in the previous sections have been summarised in a table based on the criteria outline below.

8.1 Explanation of Criteria

- **Migration of Hazardous Substances** – the ease at which potential hazardous substances can migrate from the material during use or washing overtime
- **Release of Microplastics** – the potential for micro or nano plastics to be released during washing or as a result of general degradation
- **Propensity to Accumulate Hazardous Substances** – the likelihood of the material absorbing and accumulating hazardous substances over its lifetime to create a more toxic material
- **Expected Lifespan** – Under typical use and cleaning conditions, the number of uses possible before the product is damaged or degraded
- **Impact Durability** – The ease at which the item will break under impact such as dropping onto a hard surface
- **Recyclability** – The possibility for recycling of the material in New Zealand at end of life
- **Hygiene** – The ability of the material not to hold on to pathogens or bacterias
- **Lifecycle Assessment** – An indicative approximation of the environmental footprint of the product over its lifespan
- **Weight** – For transportation, weight can be a major consideration. For fixed events where the fleet is stored onsite this is less of a concern from an environmental perspective, but still important from the perspective of worker health and safety.
- **Cost** – Cost estimate of the material when new, taking into account the expected lifespan (cost/uses) and various return rates

8.2 Ratings

The below ratings provide a comparison of each of the materials considered. As noted at the beginning of this report, all reuse options that are built into a functional reuse system, regardless of material-type, are expected to have better overall outcomes than single use options.

Less Desirable	Caution	Average	Good Practice	Best Practice	Unknown

Table 5: Ratings

8.3 Summary of Findings

	Tempered Glass (drink-ware)	Vitrified Glass (dinner-ware)	PP (both)	Tritan (drink-ware)	Stainless Steel (both)	Melamine (both)	Vitrified Porcelain (both)	Enamelled steel (both)
Hazardous Substance Migration	Best Practice	Best Practice	Less Desirable	Caution	Best Practice	Caution	Good Practice	Average
Microplastic Release	Best Practice	Best Practice	Less Desirable	Unknown	Best Practice	Unknown	Best Practice	Best Practice
Hazardous Substance Accumulation	Best Practice	Best Practice	Less Desirable	Unknown	Best Practice	Unknown	Best Practice	Best Practice
Expected Lifespan	Good Practice	Good Practice	Less Desirable	Average	Best Practice	Good Practice	Average	Good Practice
Impact Durability	Average	Average	Best Practice	Good Practice	Best Practice	Best Practice	Caution	Best Practice
Recyclability	Average	Average	Good Practice	Less Desirable	Good Practice	Less Desirable	Caution	Good Practice
Hygiene	Good Practice	Good Practice	Less Desirable	Unknown	Best Practice	Unknown	Average	Average
Lifecycle Assessment	Caution	Caution	Caution	Unknown	Best Practice	Unknown	Unknown	Unknown
Weight	Less Desirable	Caution	Best Practice	Good Practice	Good Practice	Good Practice	Less Desirable	Good Practice

Table 6: Decision-Making Matrix

	Tempered Glass	Vitrified Glass	PP	Tritan	Stainless Steel	Melamine	Vitrified Porcelain	Enamelled Steel
Cost Cold-drinkware*	Avg. Cost		Higher Cost	Highest Cost	Lowest Cost	Lower Cost		
Cost Cold-drinkware**	Avg. Cost		Lowest Cost	Highest Cost	Avg. Cost	Lower Cost		
Cost Foodware*		Lower Cost	Higher Cost		Avg. Cost	Lowest Cost	Highest Cost	Highest Cost
Cost Foodware**		Lower Cost	Lowest Cost		Avg. Cost	Lowest Cost	Highest Cost	Higher Cost

* assuming 100% return rate
** assuming 85-95% return rate with 2.5% glass and 5% porcelain breakage

Table 7: Serviceware Cost Comparison Matrix

The above costs relate to the purchase of new products, but it has been indicated that second-hand glass, ceramics and metal could reduce costs and provide the additional benefit of diverting product from landfill through giving it a second life. The challenge is finding uniform sizes of products, but for tempered glass and vitrified glass, which may be made available from the HoReCa sector at low or no cost, this consideration may easily be addressed.

8.4 Decision Tree for Serviceware Materials Choice

Based on the above criteria results and the consideration of cost, the following decision tree may be a useful guideline for choosing a fleet material. The rationale is as follows:

1. Stainless steel is an excellent all-round option but can prove expensive if return rates are low.
2. Where return rates are potentially at the lower end, but breakage rates are not likely to be high and weight is not an issue then vitrified or tempered glass is a nice option that is very acceptable to consumers.
3. For street events or similar where return rates can be low, breakages are common and weight can be an issue, second-hand serviceware, preferrably the most durable options can help to control costs. If large volumes are needed, uniform second-hand serviceware may be more challenging to procure and in that instance PP would be an improvement in comparison to single use equivalents, but in the long term the desire would be to move away from plastics for various health and environmental reasons (see the summary on material safety issues in Appendix A) so the focus in this situation would be the design of the system that allows return rates to be improved overtime.

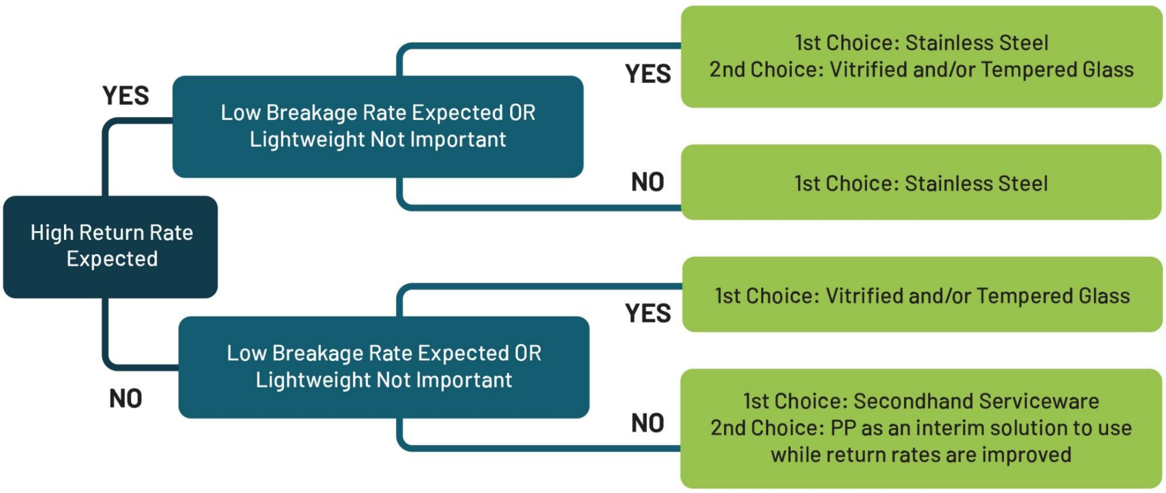

Figure 2: Decision Tree for Serviceware Material Choice

9 Discussion and Recommendations

Stainless steel has come out on top with regards to durability, environmental and health protection and hygiene and has the potential to be very cost effective assuming that risks such as the non-returning of serviceware can be addressed. The downside is the initial large outlay for such a fleet and a good strategy may be the purchase of a small fleet (or a restricted number of items of a fleet) to trial the materials at smaller events for the purpose of learning and adjusting the reuse strategy as needed.

For fixed events with smaller numbers where the serviceware will be stored on site and the risk of breakages is low, glass serviceware (with stainless steel cutlery) is a good all round option and commonly used by catering companies. Porcelain or ceramics are also good options but can be less durable and more easily chipped and damaged.

With plastic serviceware, we are still learning about the environmental and health impacts and as this information becomes more available overtime, it is likely that customers will become less comfortable with these options. However, where existing fleets are available within or close to the community in which the reuse system is to be established, this could provide a low-cost short term transition step to alternatives such as stainless steel or glass as the process around collecting and cleaning the fleet and educating the consumer is refined. Major investments in large fleets of plastic serviceware should be approached with caution, or an explicit strategy to phase-in a non-plastic fleet over time, e.g. through a policy that items lost to attrition or end-of-life will be replaced with non-plastic alternatives.

The actual impacts related to having printing on serviceware is largely unknown, but a fleet without printing is a lower risk option. There may be alternative options to raise the brand profile without needing to brand each item, such as branding at the points of collection and drop off of the serviceware for the consumer and on any mobile wash stations. Unbranded fleets can also be more easily utilised in future reuse systems if stock is updated or the reuse system retires, for whatever reason. Stainless steel offers additional options to brand without the addition of potentially hazardous chemicals (e.g. embossing or engraving), if budget allows.

The use of second-hand serviceware offers a number of advantages including a low cost and low risk way of trialing the reuse process at events before any larger investments are made. Some caution is needed because the origins, era and manufacturing practices of the items are usually unknown, but items such as vitrified or tempered glass in particular are low risk in terms of migration of substances and general health and environmental impact.

Finally, the choice of serviceware should recognise that reusable packaging operates in a system where factors such as return rates, transportation distances, the efficiency of transportation and washing processes, and the functionality and accessibility of the reusables all play a role in ensuring a best-practice outcome. High return rates will lower the overall costs of the system (spreading the costs of the fleet purchase across multiple uses) and ensure that reusables breakeven with the impact of their initial production. A system that is performing well, with return rates of 90% or higher, and that makes use of serviceware that already exists in the community (where appropriate), will give organisations purchasing new fleets more confidence to choose serviceware types that have better/more certain public health outcomes.

APPENDIX A: Material Safety - Toxicity, Migration, Shedding and Microbial Adhesion

Reusable serviceware products, such as cups, plates, bowls, cutlery and lunchboxes can be made from a range of materials, including glass, metals, plastics and ceramics. Sometimes more than one material will be used to make a product. For example, a stainless-steel cup may be branded with a plastic-based print. Often, different components of the product will be made of different materials, such as a glass lunchbox with a plastic lid.

The act of taking any mineral or organic compound and, through the use of energy and processing, transforming them into useful everyday products, such as serviceware, has provided us with much convenience and comfort. However, the combining and concentrating of substances, and the process of extracting materials and manufacturing products, can also have adverse effects on our health, and the planet that provides the foundation for our survival. Some impacts, such as resource depletion, waste and climate change are well-established. In relation to the use and concentration of substances, our knowledge of the nature and scope of these potentially adverse outcomes is still evolving.

What we do know is that the substances we use to make materials are not necessarily benign or safe for human and environmental health, and materials behave in different ways when used for holding food and drink or when they are washed. This can create different types of risks and hazards, including migration of hazardous substances into food and drink or waterways, shedding of microplastics or microbial contamination. While knowledge of the nature and extent of the risks remains incomplete, enough is known to have led various countries and economic regions to mandate restrictions on particular materials and substances for specific uses (see Textbox 1 on the European Chemicals Agency and the REACh regulation).

There are also known or suspected health and/or environmental implications associated with a number of chemicals that may be added to or found in materials and prints. Table 1 below lists some substances commonly found in prints and plastics that could pose a hazard. Table 2 lists additional substances that are commonly found in plastics either as an additive or contaminant. For non-plastic materials, general heavy metal migration and lead content (as outlined in Table 2) are also relevant.

These tables indicate the legal limits for use of these substances, as provided in the referenced regulations or similar. These are mostly European regulations and do not apply in New Zealand. Furthermore, some limits are set based on what is believed to be achievable within modern manufacturing processes or that can be detected by a laboratory; this is not necessarily the same as a “safe” limit, but provides a starting point for a reduction in the use of hazardous chemicals.

Textbox 1: Monitoring and Regulating Chemicals in Europe

The European Chemicals Agency (ECHA) implements chemicals legislation specifically to protect health and the environment. ECHA hosts the largest database of chemicals in the world (containing more than 245,000 chemicals). The ECHA acknowledges that regulation of harmful chemicals can protect workers, consumers and the environment as well as making recycling easier and safer.

One such regulation managed by ECHA is known as “REACh” (Registration, Evaluation, Authorisation and Restriction of Chemicals). REACh applies to all chemical substances; not only those used in industrial processes, but also in our day-to-day lives, for example in cleaning products, paints, and in articles such as clothes, furniture and electrical appliances that are marketed in Europe. REACh considers the health risks to the end user and to those involved in manufacture, as well as the impacts related to products’ end-of-life disposal or treatment. Although REACh does not apply in NZ, understanding what substances are restricted is a helpful starting point (see Tables 1 and 2).

Table 8: Common substances found in both Prints and Plastics that could pose a hazard

Substance	Reference in Regulations or Standards	Recommended limits	Risk
Heavy Metal Organotin DBT	REACh ANNEX XVII 20: 5.a (EUROPEAN PARLIAMENT AND COUNCIL, 2023)	The concentration in the article, shall not be greater than 0.1 % by weight of tin	This substance is fatal if inhaled, toxic if swallowed, causes severe skin burns and eye damage, may damage fertility and may damage the unborn child, cause damage to organs through prolonged or repeated exposure, is very toxic to aquatic life with long lasting effects, is harmful in contact with skin and is suspected of causing genetic defects. Through municipal waste these chemicals can end up in water ways and can enter the food chain.
Heavy Metal Organotin DOT	REACh ANNEX XVII 20: 6.a (EUROPEAN PARLIAMENT AND COUNCIL, 2023)	Not to be used in products can come in prolonged contact with the skin. Limit as above.	Similar to the above.
19 key Heavy Metals	Directive 2009/48/EC Consolidated (EUROPEAN PARLIAMENT AND COUNCIL, 2022)	Various migration limits set in the directive	Heavy metals can in some instances migrate from products into the environment and can affect development in children.

Table 9: Common substances found in plastics that could pose a hazard (continued over 2 pages)

Substance	Reference in Regulations or Standards	Recommended limits	Risk
Heavy Metal Cadmium	REACh ANNEX XVII 23 and RCW 70.240 (EUROPEAN PARLIAMENT AND COUNCIL, 2023)	The concentration of cadmium shall be less than 0.01 % by weight of the plastic material	Fatal if inhaled, is very toxic to aquatic life with long lasting effects, may cause cancer, causes damage to organs through prolonged or repeated exposure, is suspected of causing genetic defects, is suspected of damaging fertility or the unborn child.
Heavy Metal Nickel	REACh ANNEX XVII 27 (EUROPEAN PARLIAMENT AND COUNCIL, 2023)	0.5 µg/cm2 /week migration limit for skin contact	Causes damage to organs through prolonged or repeated exposure, may cause cancer by inhalation, is toxic to aquatic life with long lasting effects, may damage fertility, is suspected of causing genetic defects, is suspected of causing cancer, may cause an allergic skin reaction and may cause allergy or asthma symptoms or breathing difficulties if inhaled.
Heavy Metal Lead	REACh ANNEX XVII 27 (EUROPEAN PARLIAMENT AND COUNCIL, 2023)	0.05 % by weight or rate of lead release does not exceed 0.05 µg/cm2 per hour	May damage fertility or the unborn child, causes damage to organs through prolonged or repeated exposure, is very toxic to aquatic life with long lasting effects, may cause cancer, and may cause harm to breast-fed children.
Flame Retardant Diphenylether, octabromo derivative	REACh ANNEX XVII 45 (EUROPEAN PARLIAMENT AND COUNCIL, 2023)	Concentration to be less than 0.1 % by weight	Substance may damage the unborn child and is suspected of damaging fertility.
Flame Retardants Tetra-BDE, Penta-BDE, Hexa-BDE, Hepta-BDE, Deca-BDE	Regulation (EU) 2019/1021, 2015/2030/EC, 2016/293/EU ANNEX I (EUROPEAN PARLIAMENT AND COUNCIL, 2020)	Sum off all less than 350 mg/kg	These chemicals are persistent organic pollutants. Persistent organic pollutants (POPs) are organic substances that persist in the environment, accumulate in living organisms and pose a risk to our health and the environment. They can be transported by air, water or migratory species across international borders, reaching regions where they have never been produced or used.
Flame Retardant SCCP	Regulation (EU) 2019/1021, 2015/2030/EC, 2016/293/EU ANNEX I (EUROPEAN PARLIAMENT AND COUNCIL, 2020)	Concentrations of 0.15 % or less by weight of article	POP and Persistent Bioaccumulative and Toxic (PBT). very toxic to aquatic life with long lasting effects and is suspected of causing cancer.

Substance	Reference in Regulations or Standards	Recommended limits	Risk
Flame Retardant HBCDD	Regulation (EU) 2019/1021, 2015/2030/EC, 2016/293/EU ANNEX I (EUROPEAN PARLIAMENT AND COUNCIL, 2020)	500 mg/kg	POP and PBT
Flame Retardants TCEP, TCPP and TDCP	Directive 2009/48/EC Consolidated (EUROPEAN PARLIAMENT AND COUNCIL, 2022)	5 mg/kg content limit	May damage fertility, is toxic to aquatic life with long lasting effects, is harmful if swallowed and is suspected of causing cancer.
Flame Retardants: MCCP		No current restrictions	PBT and is very toxic to aquatic life with long lasting effects and may cause harm to breast-fed children
Additives PAHs	REACh ANNEX XVII 50: 8 (EUROPEAN PARLIAMENT AND COUNCIL, 2023)	Restricted	POP, PBT, may cause cancer, is very toxic to aquatic life with long lasting effects.
Additive Phenol	Directive 2009/48/EC Consolidated (EUROPEAN PARLIAMENT AND COUNCIL, 2022)	5 mg/l (migration limit)	Toxic if swallowed, is toxic in contact with skin, causes severe skin burns and eye damage, is toxic if inhaled, is suspected of causing genetic defects and may cause damage to organs through prolonged or repeated exposure.
Additive Phthalates DBP, BBP, DEHP, DIBP (found in plastics excluding ABS, PE, PP, GPPS, HIPS, MIPS and SHIPS)	REACh ANNEX XVII 51 (EUROPEAN PARLIAMENT AND COUNCIL, 2023)	Total of all phthalates to be less than 0.1 % by weight of the plasticised material	May damage the unborn child and is suspected of damaging fertility and is very toxic to aquatic life. Suspected PBT.
Additive Phthalates DBP, BBP, DEHP, DINP, DNOP, DIDP, DHEXP/DnHP, DIBP, DPENP, DCHP (found in plastics excluding ABS, PE, PP, GPPS, HIPS, MIPS and SHIPS)	Proposition 65 (State of California, 1986)	Requires warnings	May damage the unborn child and is suspected of damaging fertility and is very toxic to aquatic life. Suspected PBT.

Substance	Reference in Regulations or Standards	Recommended limits	Risk
Additive Bisphenol-A (BPA) (found in polycarbonate)	Directive 2009/48/EC Consolidated (EUROPEAN PARLIAMENT AND COUNCIL, 2022)	0.04 mg/l (migration limit)	May damage fertility, is very toxic to aquatic life with long lasting effects, causes serious eye damage, may cause an allergic skin reaction and may cause respiratory irritation.
Formaldehyde (found in Melamine)	Regulation (EU) No 10/2011 (EUROPEAN COMMISSION, 2011)	15mg/kg (migration limit)	Toxic if swallowed, is toxic in contact with skin, causes severe skin burns and eye damage, may cause cancer, is suspected of causing genetic defects and may cause an allergic skin reaction, is fatal if inhaled and causes serious eye damage.

A.1 Migration Risk of Substances from Material to Food/Drinks and in Recycled Products

Food Contact Materials (FCMs) are defined as those materials that are intended or expected to come into contact with food. FCMs must not change the food they are in contact with or endanger health. In major markets, materials are classified as FCMs based on risk assessments related to exposure to substance migration into foods. The toxicological profile of each substance dictates the safety limit. The microbiological properties are also assessed.

Substance migration from FCMs is generally a product of temperature, time, the contact surface properties and the food type (PLASTICS EUROPE, 2019). However, recent research indicates that reuse and recycling of materials, particularly plastics, can contribute, concentrate and exacerbate migration of hazardous chemicals (Geueke *et al.*, 2023); the associated risks are largely unknown currently.

While the focus of restrictions on substances in FCMs is to manage chemicals that are known additives, Geueke *et al.*, (2022) found that two-thirds of Food Contact Chemicals (FCCs) identified as being present in Food Contact Articles (FCAs) were not known to be intentionally added or associated with the manufacturing of FCMs. When it comes to regulation and testing, it is relevant to note that what is not expected to be found is generally not looked for.

Additionally, Turner *et el.*, (2021) suggest that despite the restrictions indicated in the below tables, hazardous plastic additives such as heavy metals remain prevalent in the market because of contamination of recycled goods and because they are found in products that are around for a long time. In-vitro studies have shown that the mobilisation of Cadmium (Cd) and Lead (Pb) from older plastics, or potentially recycled plastics, can greatly exceed concentrations deemed safe according to migration limits specified by the current European Toy Safety Directive (EUROPEAN PARLIAMENT AND COUNCIL, 2022), which considers migration of chemicals though mouth or skin contact.

Stainless steel, a popular choice for serviceware, contains a number of heavy metals. However the Chromium content of food grade stainless steels limits the bioaccessibility of those metals in most environments (Taxell *et el.*, 2022). The nickel and cobolt in Stainless Steel are generally of particular concern, but food-grade stainless steels are shown to be of low toxicity (Santonen *et el.*, 2010). However, for more complex product constructions, such as double walled stainless steel cups, additional materials may be present to aid in the construction, such as the use of a lead “dot” to seal the two layers of the stainless steel. If the lead is not sufficiently covered, users can be exposed to lead. While this may present a risk to users, it might not be caught by regulations on FCMs if the lead dot is exposed on the cup’s exterior, rather than the interior that is in contact with the cup’s contents.

The Food Contact Regulation (EUROPEAN PARLIAMENT AND COUNCIL, 2021), requires materials that are safe for food contact to be marked as such, either with the symbol shown below or similar. For plastics, this means that the article does not transfer more than 10mg of its total constituents per dm^2 of food contact surface (EUROPEAN COMMISSION, 2011). The regulation also sets substance specific migration limits.

Figure 3: Safe for Food Contact Symbol (EUROPEAN PARLIAMENT AND COUNCIL, 2021)

However, as already outlined, this approval is based on looking for substances that are expected to be found or are expected to be in contact with the food. In plastics, in particular, many FCC may be present that we do not know are there, and/or for which we know little about their potential impacts.

A.2 Hazards Resulting from Cleaning of Serviceware

In addition to what might be considered passive migration of chemicals from materials through skin, food or mouth contact, the dishwashing process itself can both enhance leaching of compounds, and introduce some additional compounds – this is particularly the case for plastics or prints. In a study involving dishwashing of polyethylene reusable drink bottles (Tisler *et el.*, 2022), dishwasher-related compounds[7] were shown to adsorb more to plastic than to glass, and then were able to leach into the water in the bottle on refilling. The dishwashing, boiling and brushing of polycarbonate baby bottles showed a significant increase in the migration of Bisphenol-A as a result of polymer degradation through use and cleaning (Brede *et al.*, 2003).

Lead solder has been shown to migrate into water when used to solder water pipes (Subramanian *et el.*, 1991) so it could be assumed that it may also be released into the waste water when products that contain lead solder are put in the dishwasher, if the lead solder becomes exposed over time. This could be the situation with some double walled stainless steel products and care should be taken to ensure the lead solder is not exposed through damage or poor design, e.g. through regular inspection.

In addition to migration of substances, Sol *et al.* (2023) showed that the dishwashing process of plastics releases microplastics each wash from general degradation of the plastic components of the dishwasher itself, not only from the objects being washed. Temperature had a big effect on microplastic release with higher temperatures leading to more microplastic released. This study indicates that not only the material of the fleet itself requires consideration, but also the dishwasher accessories, such as racks, which are often plastic.

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[7] Dishwasher related compounds were those chemicals that were introduced as a result of the dishwashing process either from the detergents used or from materials within the dishwasher itself.

A.3 Ease of Drying and Discouraging Bacteria

Microbial contamination of serviceware can compromise food quality and safety. Biofilms can form in moist non-sterile environments so it is important that serviceware is properly dried and stored so as to allow airing. Materials such as glass, ceramics, enamelled products and stainless steel are self-drying as they heat up during the sterilisation process and that heat helps them to dry rapidly. Plastics do not heat up sufficiently during sterilisation and therefore require additional drying time in favourable conditions.

Hydrophilic materials such as glass are known to discourage bacterial adhesion, which makes them a good option for FCMs (Bower *et al.*, 1996). Stainless steel surfaces, through passivation, can also become hydrophilic. Stainless steel passivates naturally over time and therefore is better able to retain its hygienic properties compared to glass and plastics as it can resist damage caused by the cleaning process (Bower *et al.*, 1996).

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