Incorporating sustainability into assessment of oral health interventions

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Key points

Manual toothbrush production can be altered to improve the environmental sustainability and impact on global human health.

This study found that it was continually recycled plastic, rather than bioplastic or bamboo, that was the most environmentally sustainable toothbrush model.

Manufacturers, consumers, health professionals and NHS policymakers should consider environmental sustainability as part of a 'triple bottom line', alongside clinical efficacy and cost.

Abstract

Prior to 1966, consumers purchased food items with very little (if any) nutritional labels. Now, nutritional labelling is an integral part of informed consumer choice. This paper advocates for a similar approach for healthcare-related products, using the toothbrush as an example, with the need to quantify and publish data on their clinical efficacy and environmental impact. In this paper, we consider different manufacturing models and measure the environmental impact (carbon footprint) and also the human health impact (disability-adjusted life years [DALYs]) for the most commonly used oral health product: the toothbrush.

Introduction

In this issue of the *British Dental Journal*, we report the attributional life cycle analysis (LCA), performed by our team, on the environmental impact of the toothbrush. We concluded that a plastic manual replaceable-head toothbrush and bamboo manual toothbrush performed better than the traditional plastic manual and electric toothbrushes in every environmental impact outcome measure used in this study. In this article, we consider the next step – how can this information be used by clinicians and policymakers to make healthcare decisions? If we use toothbrushes as an example, which is the 'best' toothbrush to use? We propose that using the LCA to determine the negative impact on health will provide this information. We suggest the disability-adjusted life year (DALY) measure as an outcome measure for this negative impact on health.

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Environment and health

Improving the carbon footprint is a commonly used commitment to meet environmental goals.[1] Unfortunately, it is a misrepresentation of our total impact on the environment, which also includes other environmental measures, such as loss of biodiversity, ecotoxicity and air pollution. These broader environmental impacts have been linked with deterioration of human health.[2,3] Air pollution continues to worsen, with its detrimental impact on personal health becoming increasingly clear. The LCA methodology generates this additional information; therefore, the logical next step is to use this to include the impacts of environmental damage on human health. A way of measuring this impact is by calculating the human health burden associated with their production, use and end-of-life disposal. Debaveye *et al.* demonstrated how this principle may be used in calculating the human health burden of psychiatric treatment.[4]

DALYs

The human health burden may be expressed in DALYs. DALYs are the number of years of life lost in a human population due to both morbidity (illness and disability) and mortality (early death).[5] DALYs can be calculated using LCA modelling, using the environmental impact associated with a product's manufacture, use and disposal. Using the data for the four toothbrushes in our original study,[6] we calculated the DALYs lost from the act of one individual brushing their teeth over five years (the functional unit of that LCA). DALYs were calculated using ReCiPe 2016 Endpoint.[7] All DALYs attributable to the functional unit were summated. As the numbers were low (five years of toothbrush use equates to just 20 toothbrushes or replaceable heads), the results have been expressed in hours, as seen in Table 1. The results show that an electric toothbrush has the most significant impact on DALYs – a total of ten DALY hours – which is over four times worse than the plastic manual toothbrush. At closer inspection, the majority of the total personal health harm (measured in DALYs) comes from the water consumption used in electricity production.

What is the potential impact of the DALY assessment?

The Cochrane review of electric versus manual toothbrushes highlighted that there is no evidence that any type of toothbrush is superior for caries prevention, although electric toothbrushes showed a 21% better plaque reduction when used for over three months.[8]

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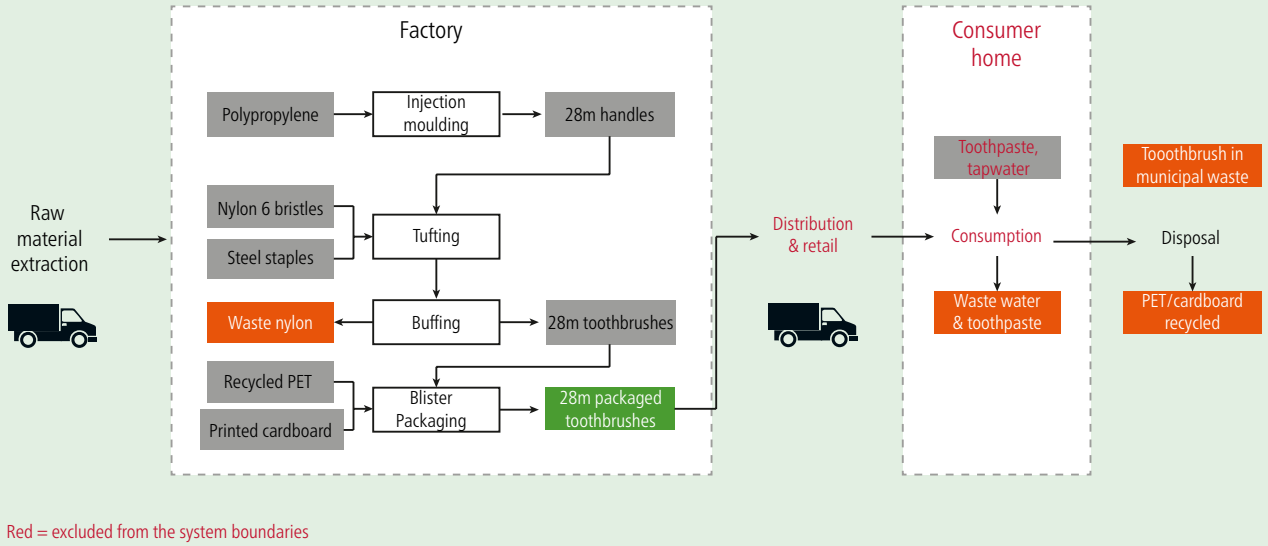
Table 1 DALYs lost due to one individual using a toothbrush over five years (displayed in DALY hours lost). Figures are rounded to four decimal places

Human health impact category	Electric toothbrush	Plastic manual toothbrush	Bamboo manual toothbrush	Plastic manual toothbrush with replaceable heads
Water consumption	9.8112	2.1024	0.4923	0.4359
Ionising radiation	0.0002	0.0001	0.0000	0.0000
Global warming	0.0350	0.0227	0.0031	0.0046
Ozone formation	0.0008	0.0004	0.0001	0.0001
Fine particulate matter formation	0.1878	0.0631	0.0110	0.0127
Human carcinogenic toxicity	0.0007	0.0001	0.0000	0.0000
Stratospheric ozone depletion	0.0000	0.0001	0.0000	0.0000
Human non-carcinogenic toxicity	0.0082	0.0003	0.0001	0.0001
Total hours of DALYs lost over five years	**10.0439**	**2.1892**	**0.5066**	**0.4434**

Fig. 1 System boundaries for current manufacturing practice of producing 28 million plastic manual toothbrushes in a single year



If direct oral health management is largely a constant, the broader environmental impacts associated with each type of brush are the variable. The question that the reader, and in turn society, needs to consider is whether the marginal reported superiority of the electrical toothbrush is worth the DALY harm caused as part of the production, use and disposal process.

Modelling an 'ideal' toothbrush

Taking into consideration the two sides of the scales (DALYs vs environmental degradation), the research team at Trinity College Dublin and UCL decided to model the best possible manual toothbrush. This research decision was also influenced by the recent 'greener NHS' call for innovative solutions to reduce carbon emissions in healthcare.[9] The manual toothbrush was chosen, as it was clearly shown in our original study that an electric toothbrush was a long way from being environmentally friendly.

Our analysis started with the standard plastic manual toothbrush from the original LCA, which is manufactured in Switzerland. The functional unit was defined as the manufacture of 28 million manual toothbrushes over a 12-month period. The system boundary is shown in Figure 1.

The same LCA methodology as the original toothbrush study was used,[6] following EU Product Environmental Footprint guidelines.[10]

To simplify the results, and in keeping with our thoughts above, we focused on two elements: the climate change impact (measured in kg carbon dioxide equivalents [CO2E], also known as carbon footprint) and the DALY impact (measured in years). The results showed that production of manual plastic toothbrushes in one year produced over 2.5 million kg CO2E and over 43,000 DALYs. In addition, the analysis showed that the polypropylene plastic toothbrush handle had the greatest contribution to the overall carbon footprint (62%).

We then modelled potential changes to this current practice of toothbrush manufacture, in order to improve both the carbon footprint and DALY impact. The functional unit and location (a factory in Switzerland) were kept consistent in all the models. We investigated the impacts of using different materials for the handle, such as bioplastic, bamboo, aluminium and recycled plastic. We also considered the

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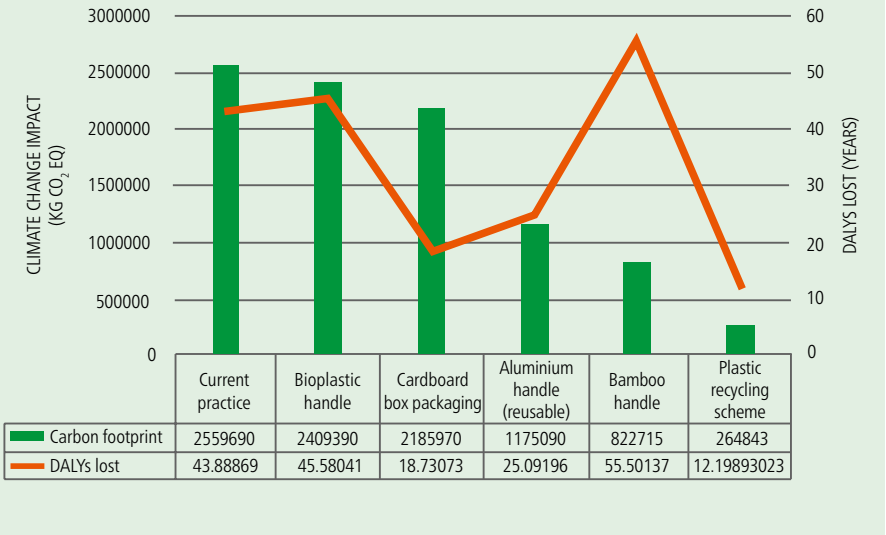
Table 2 Changes to toothbrush manufacture and disposal in each model

Model	Manufacture			Disposal
	Making handle	Attaching bristles	Packaging	
Current practice	Polypropylene is injection-moulded into plastic handles	Nylon 6 and steel staples are used in tufting and buffing machines to make 28 million toothbrushes	Recycled PET: polyethylene terephthalate and a printed cardboard back are blister-packaged together to make 28 million packaged toothbrushes	The consumer puts the toothbrush in municipal waste, and the packaging in plastic and paper recycling waste
Bamboo handle	Bamboo is grown in China and transported to factory in Europe. It is shaped and heat-treated into bamboo handles	No change to current practice	No change to current practice	Bristles removed and put into municipal waste by consumer and wood handle recycled. Packaging put into paper and plastic recycling waste
Bioplastic handle	96% corn starch-based biopolymer is mixed with 4% polypropylene and injection-moulded into bioplastic handles	No change to current practice	No change to current practice	No change to current practice
Cardboard packaging	Polypropylene is injection-moulded into 28 million handles	No change to current practice	A single printed cardboard box packages 28 million toothbrushes	Cardboard box recycled and toothbrush put into municipal waste
Plastic recycling scheme	The manufacturer collects used toothbrushes and packaging from consumer. The nylon bristles and any degraded plastic (estimated 10%) is removed into municipal waste. The remaining plastic is cleaned, shredded and autoclaved. It is mixed with 10% new polypropylene to make new toothbrush handles and packaging	New tufting machine that does not require metal staples	Plastic packaging is recycled as per handle manufacture	Manufacturer collects toothbrush and packaging for recycling
Reusable aluminium handle	Recycled aluminium is cast and anodised into reusable handles. Reusable heads are made with plastic recycling scheme (see plastic recycling model)	New tufting machine that does not require metal staples	Plastic packaging is recycled as per plastic recycling scheme model	Consumer recycles aluminium handle after 20 years. The plastic heads and packaging are recycled by manufacturer

Fig. 2 Toothbrush modelling results for climate change impact and DALYs



packaging material; using a simple cardboard box or recycled plastic packaging. The specific manufacturing and disposal scenarios for each model are described in Table 2. The assumptions in our modelling were taken from our original paper and are explained in more detail in this report. Some assumptions (for example, the plastic recycling processes) were based on discussions with industry experts.

The results for each model are shown in Figure 2. All scenarios considered showed an improvement on the overall carbon footprint compared to the current manufacture of plastic manual toothbrushes; however, the DALY results were variable. Using bioplastic instead of polypropylene for the toothbrush handle yielded unfavourable results, as this only improved the carbon footprint by 6%, but increased the DALY by 4%. Although using a bamboo handle (compared with polypropylene plastic) improved the carbon footprint by 68%, the DALY actually increased by 26%. The most optimum balance between carbon footprint and DALYs were from the model that utilised a plastic recycling scheme (90% and 72% improvements, respectively). The details for this model are shown in Figure 3.

In this most balanced model (a plastic recycling scheme), the biggest impact was from the nylon bristles (responsible for 90% of the carbon footprint). In this model, and indeed with all the models in this study, the greatest contributing factor to the DALY result was the water used to produce electricity, which is in turn used in the manufacturing processes (responsible for 50–90% of the total DALY result, depending on the model). The generation of electricity consumes significant amounts of water (power plants use a steam turbine to generate electricity, which also requires water for cooling). It is possible that

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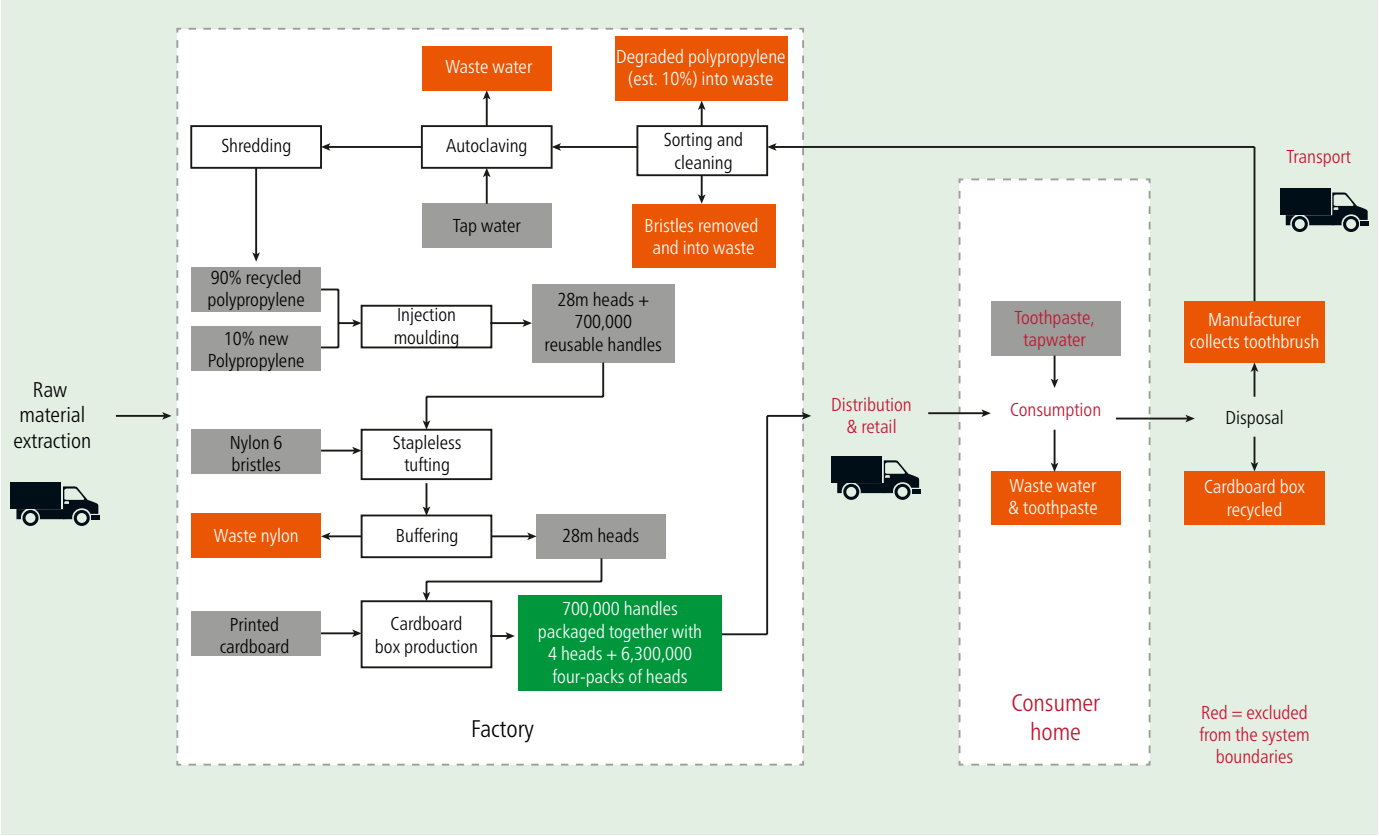
Fig. 3 The LCA system boundary model for toothbrush manufacturing that uses a recycling scheme to reuse plastic from previous toothbrushes



alternative electricity production, such as solar photovoltaic and wind power, would have used less water and could have an impact on the results.[11] However, we have drawn our water consumption values from the database Ecoinvent v3.6, which are based on real-life electricity production in the countries of toothbrush manufacture (Switzerland and China).

The recycled plastic toothbrush model also assumed that the manufacturer takes responsibility for the collection and recycling of toothbrushes. This would likely have a big impact on their marketing and production costs, and relies on consumer compliance to return the recycled toothbrushes. It is unclear how well consumers would comply with this scenario, and the authors could not find evidence for how likely UK consumers are to comply with different recycling schemes and incentives. There is evidence that compliance plastic recycling can be as efficient as 80–95%, admittedly with small financial incentives (for example, the plastic bottle deposit schemes that are currently used in many countries worldwide).[12] Another way to model this scenario would have been the manufacturer purchasing used plastic from national recycling schemes.

Discussion

Personal and environmental health impact and toothbrush selection

This research has shown that a toothbrush which comes from recycled plastic is the most environmentally friendly option and produces the lowest DALY loss. This seems to provide a reasonably good fit to our society's current appetite for single-use plastic reduction and a potential market for manufacturers to explore.

Based on our analysis, manufacturers could innovate by focusing on plastic toothbrush recycling schemes. In the winning scenario, the manufacturer would offer a facility to collect used toothbrushes and packaging from consumers, possibly at the point of purchasing (eg collection bins at retailers). The nylon bristles and any degraded plastic (estimated 10%) would be removed and disposed of. Nylon is not currently recycled, but there are no reasonable recyclable alternatives on the market at this time. The remaining plastic could be cleaned, shredded and autoclaved (sterilised). A proportion of degraded, recycled plastic would need to be replaced with new polypropylene (we estimated 10% in this study), and this mix could then be used to make new toothbrush handles and packaging.

Consumer support is essential in creating a successful return scheme; similarities exist with battery and plastic marker pen collection schemes. This system would also require a ground shift in responsibility for recycling. Currently, there are private companies that offer recycling schemes to consumers, but recycling depot boxes cost upwards of £100. Innovative consideration of costs could lead to flexible costing models, including subscription schemes for consumers and retailers alike. This is an opportunity in waiting.

Mapping personal and environmental health impact of an oral health intervention

Health interventions often include a number of unquantifiable variables, which add a layer of complexity in terms of environmental appraisals. The toothbrush example is a rare one, in that it is a fairly straightforward item to model. A purely carbon analysis would have produced entirely different, and incomplete, results. The human impact that this analysis contributed has clearly demonstrated that policy decisions should be made on a balanced consideration of all impacts, not just carbon.

The authors believe that the evidence should now be used to explore the public's

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perception, in discussion with manufacturers. This is a necessary next step in order to test the commercial viability of the proposed solution. Armed with a holistic analysis of environmental and human impacts, together with a substantial market/consumer engagement assessment, it can then be presented to policymakers as an evidence-based intervention that can contribute towards more sustainable consumption patterns. This study has shown the importance of not just focusing on environmental harm such as carbon emissions, but also considering other personal health-related harm such as DALYs.

Incorporating personal and environmental health impact metrics into guidance

When a local planning authority considers granting a permission for a project which may have significant impact on the environment, they can request an environmental impact assessment as part of the decision-making process.

Oral health guidance, such as the Scottish Dental Clinical Effectiveness Programme and the Public Health England guidance, provide an evidence-based structure to support the implementation of optimal oral health interventions.[13] Increasingly, these recommendations are accompanied by evidence of clinical effectiveness (for example, reduction in decayed surfaces) or cost-effectiveness. The Cochrane oral health group publishes complementary reviews of evidence to help support the delivery of effective healthcare at an individual or population level.[8]

With growing evidence of the potential harm of healthcare systems and processes, this is a time to debate the need for an environmental impact assessment to accompany evidence-based guidelines. If an organisation like the Cochrane oral health group recommend a particular intervention (for example, use of fluoride toothpaste), then we recommend that the organisation collate the evidence of an environmental impact assessment and associated human health harm – or, if at the time of writing there is no such information available, recommend one.

In industry, the responsibility to give equal consideration to profit, environment and social impact is often referred to as the 'triple bottom line'. We advocate that healthcare policy should also consider their own 'triple bottom line' to ensure that they produce evidence-based guidelines that are not only clinically effective, but also make financial and environmental sense.

This is particularly relevant in the example used here (toothbrushes), where the evidence does not strongly suggest any intervention is necessarily 'better' than any other. The environmental impact analysis might provide sufficient information to recommend one intervention.

Conclusion

Prior to 1966, consumers purchased food items with very little (if any) nutritional labels.[14] Now, it forms a major part of health-informed consumer choice. Although this paper focused on toothbrushes as an example, the authors advocate for a similar approach for all oral health products and even professionally administered interventions, with the need to measure and publish the data on their clinical efficacy and environmental impact using appropriate standardised methodology, like LCA. Discussion should take place as to whether this data should be included in the packaging of manufactured products or as part of an overall assessment by evidence-based guideline groups for oral health interventions.

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Conflict of interest

The authors declare no conflict of interest.

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