Plastics in healthcare: time for a re-evaluation

Article (Accepted Version)

Rizan, Chantelle, Mortimer, Frances, Stancliffe, Rachel and Bhutta, Mahmood F (2020) Plastics in healthcare: time for a re-evaluation. Journal of the Royal Society of Medicine, 113 (2). pp. 49-53. ISSN 0141-0768

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<td>Commentaries</td>
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<td>Date Submitted by the Author:</td>
<td>30-Oct-2019</td>
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<td>Complete List of Authors:</td>
<td>Rizan, Chantelle; Brighton and Sussex University Hospitals NHS Trust, ENT; Centre for Sustainable Healthcare Mortimer, Frances; Centre for Sustainable Healthcare Stancliffe, Rachel; Centre for Sustainable Healthcare Bhutta, Mahmood; Brighton and Sussex University Hospitals NHS Trust, ENT; British Medical Association</td>
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Title: Plastics in healthcare: time for a re-evaluation

Short title: Plastics in healthcare: time for re-evaluation

Authors:

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<tr>
<th>Title</th>
<th>Name</th>
<th>Affiliation(s)</th>
</tr>
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| Miss  | Chantelle Rizan* | 1) ENT Research Fellow, Brighton and Sussex University Hospitals NHS Trust  
2) Surgical Sustainability Fellow, Centre for Sustainable Healthcare  
3) Surgical Research Fellow, Royal College of Surgeons of England |
| Dr    | Frances Mortimer | 1) Medical Director Centre for Sustainable Healthcare |
| Miss  | Rachel Stancliffe | 1) Founder and Director Centre for Sustainable Healthcare |
| Mr    | Mahmood F Bhutta | 1) Consultant and Academic Lead in ENT Surgery, Brighton and Sussex University Hospitals NHS Trust  
2) Founder, BMA Medical Fair and Ethical Trade Group, British Medical Association |

* corresponding author  
Phone: +44 (0)1865 515811  
Email: chantelle.rizan@sustainablehealthcare.org.uk  
Address: The Centre for Sustainable Healthcare, Cranbrook House, 287-291 Banbury Road, Oxford, OX2 7JQ, UK

Competing interests: None to declare

Funding: The lead author’s salary during her PhD is funded through Health Education England and the Royal College of Surgeons of England

Ethical approval: N/A

Guarantor and contributorship: Mahmood Bhutta initiated and developed the article structure, and is the guarantor. Chantelle Rizan performed the literature search and drafted the manuscript, Frances Mortimer and Rachel Stancliffe provided critical input to structure and content. The corresponding author attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

Acknowledgements: None to declare
Introduction

As an increasing variety of plastics have been developed over the last 150 years, they have been exploited in different healthcare applications (figure 1). The global medical plastics market is currently worth US$22.26 billion, or 2% of total plastics production by value, and is growing by 6.1% per year.(1) The US consumes around 40% of medical devices manufactured globally, followed by Europe and Japan.(2) Growth in this sector is likely to be driven by increasing demand for healthcare in developing countries such as Brazil, Russia, India and China,(3) with highest compound annual growth rates (6.9%) in the Asia-Pacific region.(1)

The environmental harm caused by plastics is increasingly acknowledged. The manufacture of all plastics accounts for 8% of global oil production, with oil used both as a feedstock and a fuel in the manufacturing process.(4) Burning fossil fuels such as oil converts carbon to carbon dioxide, a potent greenhouse gas which absorbs infrared radiation, leading to global warming, making plastics manufacture a major contributor to climate change. Many sectors are looking to reduce reliance on plastics, and healthcare is not excused from this agenda.

Plastic products including gloves, tubing and blood sample tubes are amongst the largest contributors to carbon emissions of all those procured by the National Health Service (NHS) in England.(5) Inappropriate disposal means that plastic fragments now comprise 50-80% of shoreline debris,(4) although how much of this is medical waste is not known. One solution is to create a ‘circular economy’ in which the use of plastics is principally reduced, and (where plastic use is necessary) resource utilisation is maximised through reuse of the same item, or recycling into new products (further reducing use of virgin plastic).(6) This contrasts with the linear economic model, whereby medical plastics are used and then disposed of, an approach which is unsustainable where resources are finite.

The aim of this paper is to identify the scale of the medical plastics problem and to outline existing and potential solutions, in alignment with circular economy principles.

The scale and harms of healthcare plastics

The volume of plastics used in healthcare is not known, but in studies from a number of different countries and settings, plastics have been estimated to account for 30% of all healthcare waste, and around a third of waste in Intensive Care or anaesthetics.(7) Given that the US produces around 5.9 million tonnes of medical waste per year(6) this suggests that around 1.7 million tonnes of this will be plastics. The UK NHS is estimated to dispose of 133,000 tonnes of plastic each year.(8) The proportion of hospital waste which is composed of plastics varies between countries, for example this constitutes 12% in Peru, 27% in Jordan, and 46% in Italy, and differences probably relates to the differential use of single-use plastics.(9)

In addition to the potential harm from the production and disposal of large volumes of plastics, there are potential unique risks to health from the additives Bisphenol A (BPA) and Di-2-ethylhexylphthalate (DEHP), which are used to soften polyvinyl chloride (PVC). Moderate serum or urinary levels of BPA or DEHP have been correlated with the duration or frequency of connection to tubing, bags or other medical components made of PVC, in neonates and adults in intensive care units.(10) Because these compounds are lipophilic they cross cellular membranes with ease. Safe levels of exposure to BPA and DEHP are debated, but in animal and in vitro studies higher concentrations of BPA and DEHP have been linked to reproductive or endocrine disruption, and behavioural abnormalities.(10) There is a need to look at further
potential health effects of using BPA, DEHP or other additives in intravenous devices and to examine alternatives. DEHP free blood bags are commercially available, but are not widely used.

Reduce, Reuse, Recycle

The scale and growth of plastics in healthcare is alarming. The growth of single-use devices is largely responsible, driven by concerns of potential infection from contaminated medical equipment, by convenience, and by the growth of healthcare in emerging economies. We found that a single adenotonsillectomy operation in a UK hospital generated 101 separate pieces of single-use plastic (figure 2).

We need to apply the principles of the circular economy (reduce, reuse and recycle) to healthcare.

Reduce

Reducing use of plastics links to wider principles of sustainable clinical practice, including lean service delivery and use of low carbon alternative materials and process.(11) For example, previous studies have found that 12 out of 40 disposable items in a pre-packaged kit for tonsil surgery were unnecessary.(12) An Australian study found that single wrapping of sterilised instruments with plastic was as efficacious as double wrapping in preventing bacterial contamination.(13) Clinicians can open plastic healthcare items (or items wrapped in plastic) only once their need is certain, rather than ‘just in case’. A program to reduce the environmental impact of renal dialysis included stopping routine unpacking of saline bags and tubing during haemodiafiltration (since a fluid bolus is available via the machine in case of emergency).(14)

Substitute materials for plastic have also been described. One hospital in the US replaced disposable plastic polypropylene wrap with reprocessed hard metal cases for surgical instruments, with a cost saving of US$51,000 per year.(10) A UK hospital replaced plastic with paper-based hazardous waste bins with financial savings, less transport and incineration emissions, and a 30 tonne reduction in waste.(15) Biodegradable plastics engineered from corn or molasses feedstock have been utilised for tissue engineering, orthopaedic devices and wound management.(16) However such materials can interrupt food supply chains, and their biodegradation is slow and (unlike non-biodegradable plastic) emits methane, a potent greenhouse gas.(4)

Reuse

Our reliance on single-use rather than reusable medical products to a large extent stems from concerns of infection risk. In many cases the risk of infection is hypothetical or infinitesimal, and poorly evidenced. The risk of infection from reprocessing and reuse of an intravenous cannula may be unacceptably high, whereas the risk of infection from reuse of suction tubing used to clean ear wax seems negligible, yet in some healthcare facilities both items are classified as single-patient use items.

Reuse rather than disposal of a device is often, but not always, the better option for reducing environmental harm. Quantification of this harm can be through life cycle assessment (LCA), an approach that takes into account all stages of a product’s life, including production, sterilisation, maintenance and disposal. For example LCA has shown that reusable plastic
anaesthetic trays have lower water requirements, carbon footprint, and costs, compared with single-use equivalents. Extending use of anaesthetic breathing circuits from 24 hours to 7 days does not impact on bacterial contamination, and was associated with energy, water and financial savings in an Australian setting. However in a study from Australia, reusable central venous catheter kits were found to be less expensive, but more environmentally harmful, largely because the hospital where the study was conducted used coal-based electricity. To date such studies have been few and far between. Full environmental LCA and financial analyses should be expanded to other contexts.

It is noteworthy that in the US, the Food and Drugs Administration (FDA) allows reprocessing of many single-use devices, because risk of infection is considered low. However, awareness and uptake of such initiatives is currently suboptimal and not universally accepted. In the UK such activity is less supported, where the Medicines and Healthcare Products Regulatory Agency states, ‘anyone who reprocesses or reuses a device intended by the manufacturer for use on a single occasion, bears full responsibility for its safety and effectiveness’. Reprocessing of single-use items is legally prohibited in China, but survey data indicate reuse is common in practice, and such reprocessing is widespread in low and middle income countries such as India and Brazil. Some devices are difficult to reprocess, for example those with fine channels, shafts within lumens, seals, and mated articulating surfaces. In other instances adherence to reprocessing guidelines may be suboptimal. There is much potential for reuse of healthcare devices if manufacturers are encouraged to produce equipment designed for reprocessing, and if we take a balanced view of infection risk, where regulatory guidelines are reviewed and revised to be sensitive to scenarios where reuse may be low risk.

Recycle

In general, plastics may be disposed of through landfill, incineration (with or without energy recovery) or recycling. The proportion of medical plastics disposed of by different means will vary with the facilities available in each healthcare unit, region, and country, as well as the knowledge and attitudes of the staff in those units. Less than 5% of plastic healthcare waste is recycled in the UK. The main plastics in hospitals are polyethylene (such as plastic bottles for saline solutions and sterile irrigation fluids), polypropylene (such as surgical instrument wraps), their co-polymers (found in syringes and suckers), and PVC (used for items such as IV fluid bags and oxygen tubing). These plastics can potentially be recycled where facilities exist. One study indicated that 64% of operating theatre plastics could be recycled. A study from South Korea found that 40% of hospital waste was disposable syringes, tubing or intravenous and blood bags, all of which have potential for recycling.

A survey of UK and Australian anaesthetists found that the major perceived barriers to recycling were inadequate facilities (49%), staff attitudes (17%) and inadequate information (16%). Additional challenges to recycling may include the need to separate plastics by type, inadequate labelling of plastics, and differential processing of plastics contaminated with bodily fluids or other potentially infectious waste. An Australian study found 8% of contaminated waste in anaesthesia could be recycled.

Some of these barriers can be overcome. Recycling facilities in hospitals are highly variable, yet good recycling systems are, in most circumstances, both environmentally and financially preferable which should encourage development. There are also specific examples of good
practice. In the UK, a recycling scheme was piloted for PVC anaesthetic masks, oxygen masks and tubing, which were downcycled into horticultural products such as tree ties.(15) Such schemes are often zero cost to the hospital, in contrast to significant costs associated with traditional disposal. Novel recycling methods include the use of hydrometallurgy to separate aluminium from PVC, enabling recycling of pharmaceutical blister packs in China.(28) However, it must be acknowledged that in low-income settings plastic recycling may be poorly developed or non-existent and incineration of plastics may be low-tech, leading to incomplete combustion and release of hazardous pollutants such as dioxins and heavy metals.

Regulated medical waste may be disposed of through incineration (59-60%), steam sterilisation (20-37%), or other treatment methods (4-5%).(29) If steam sterilisation is used, such waste can subsequently be recycled, where facilities can work together. Notably, an audit of anaesthetic waste indicated the need for optimising segregation: 16% of waste disposed of in infectious waste streams was not contaminated, whilst 7% of waste disposed of in general waste streams was in fact infectious.(26)

Manufacturers and suppliers can also play a role, by labelling the plastic type used in their products to enable easier recycling. They can also minimise use of more than one plastic type in a single device, which will make recycling of that device easier.

Where it is not possible to convert used healthcare products into plastics of the same grade (recycling) or lower (downcycling), efforts can be made to recover the embedded energy. A novel waste management strategy which requires further research is plasma pyrolysis, which can convert plastic waste into useful products such as alternative fuels. Because temperatures of 1,100°C are used, this is an option also suitable for regulated medical waste.

Discussion

We estimate that over 1.7 million tonnes per annum of plastic waste is generated by the healthcare industry in the US alone. Reduce, reuse, and recycle are all strategies to minimise such use, but to date have received little academic or practical attention. The UK has committed to reduce single-use plastics within the NHS Long Term Plan,(30) but further global public health actions and firm evidence-based strategies are required.

The responsibility and potential for change needs engagement and support from healthcare professionals and organisations, who can for example look at improving awareness, using reusable items where possible, and supporting development and use of recycling or reprocessing facilities. The change also needs to include the healthcare manufacturing industry, who, (through either voluntary or legislative changes) can partner in easier reprocessing or recycling of their products, reduction or replacement of plastic packaging, and contribution to LCA analyses. The academic community, and funding bodies, should look to answer key research questions, which may be context specific. These include the infection risk associated with reuse of medical devices, LCA assessments of reusable versus disposable devices, and approaches to recovery of materials or energy from plastic healthcare waste.

Conclusion

The frequent and growing use of disposable plastic products due to potential but largely unsubstantiated infection risk, or convenience, cannot be used by healthcare to exempt itself from the broad global imperative to reduce reliance on plastics. This requires us to question
the linear model of plastic production, consumption and disposal. Indeed, we would argue that the demonstrable harms of plastics to human and environmental health are such a pressing issue, that such discussions should now be integral to the provision of healthcare.

References


Figure 1: Development of major plastics and their subsequent healthcare applications along with increase in annual global plastics production over time (adapted from (3)).
Figure 2: 101 single use pieces of plastic, generated by one typical adenotonsillectomy operation