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Disposal of spectacles and contact lenses: Optometrist and lens wearer perspectives

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Background: The increase in global waste generation has adverse impacts on the environment. Significant volumes of waste are generated in the lifecycle of spectacles, contact lenses (CLs) and associated products, and there is a lack of published data on their disposal practices.

Aim: To determine optometrists' recommendations to their patients, and lens wearers' practices regarding the disposal of ophthalmic lenses and associated lens products.

Setting: Optometrists and lens wearers in South Africa.

Methods: Surveys were distributed via online platforms to optometrists and lens wearers and paper copies of the surveys were also available. Data from both surveys were analysed using IBM SPSS version 24.

Results: Responses from 353 optometrists and 603 lens wearers were analysed. Optometrists were highly likely to recommend that patients should discard their old spectacle lenses (24%), and used CLs into wastewater systems (10%), or make no recommendations on either, respectively, (16%, 12%). Lens wearers were highly likely to retain their old spectacles upon new purchase (57%) and dispose used CLs into wastewater systems (37%). Less than 20% of optometrists and lens wearers were highly likely to recommend and engage in recycling of associated ophthalmic products.

Conclusion: The disposal of CLs into wastewater systems, which contributes to microplastic pollution, must be highlighted and avoided. Optometrists should incorporate disposal instructions with all products sold to patients and promote recycling. Lens wearers should also be mindful of the environmental impact of their disposal practices.

Contribution: This study provides previously unknown data on ophthalmic lens disposal practices in South Africa, and emphasises the need for environmental awareness.

Keywords: recycling by optometrists; spectacles; contact lenses; lens disposal; disposal recommendations; ophthalmic lens waste.

Introduction

Approximately 2 billion tonnes of municipal waste are generated globally per annum and this is expected to increase to 3.4 billion tonnes by 2050.[1] Drivers for waste generation include population growth, increasing income levels and rapid urbanisation.[2] Global plastic waste generation doubled in the years between 2000 and 2019 and reports suggest that 50% thereof were landfilled while only 9% were recycled.[3] Methane, wastewater ammonia and nitrous oxides are by-products of landfill waste[4] and approximately 23% of the global annual methane production has been attributed to landfills.[5] Methane, carbon dioxide and nitrous oxides are known as greenhouse gases and rising levels of these gases accelerate the global warming phenomena, thus contributing to climate change.[4]

Environmental risk factors are linked to 25% of the global burden of disease.[6] Climate change has an unequivocal impact on health outcomes and is associated with a predicted increase in direct damage health costs of between 2 and 4 billion United States (US) dollars per annum by 2030.[7] The severe and varying weather patterns precipitated by climate change can cause floods, drought, strong winds or intense heatwaves, thereby resulting in infrastructure damage and food insecurity.[4] There is also an increased risk of water and insect-borne diseases, malnutrition, undernutrition, cardiovascular and respiratory diseases.[7] Consequent systemic diseases can affect ocular health.[7] Direct eye impacts can be attributed to poor air quality from pollution while warmer atmospheric conditions can increase the incidence of allergic conjunctivitis and dry eye.[7] Changes in the quality of sunlight and ultraviolet light exposure can impact on the incidence of

cataracts, pterygia, ocular melanoma and age-related macular degeneration.[7] These are only some of the anticipated eye health risks and when considering the overall health impact, the burden of health costs is predicted to increase substantially unless climate change mitigation is prioritised in all sectors.

An estimated 2.2 billion of the global population have vision impairment that affects their ability to perform daily tasks, and the causative factor in approximately one billion thereof is attributed to unaddressed conditions such as refractive errors.[8] Refractive errors may be corrected with spectacles, contact lenses (CLs) or refractive surgery. Spectacles are usually custom-made for individuals and, upon renewal, old spectacles may be kept as a 'backup' pair or discarded as waste. Spectacle frames can be made of metal or plastics such as acetates, nylon, polycarbonates among others, whereas plastic lenses are typically synthesised from derivatives of methacrylate resins.[9] Contact lenses are categorised as soft or gas permeable and are disposed after a specified period of use, such as daily, biweekly, monthly, or annually. Global unit sales of eyewear were reported to have increased by approximately 1.5 billion units between 2016 and 2021 (eyewear category comprises spectacles, CLs, solutions, and sunglasses).[10] When considering the vision needs of an increasing and ageing population reaching presbyopia,[11] along with predictions of 50% increase in the global prevalence of myopia by 2050,[12] it is anticipated that there will be a substantial increase in the use and disposal of custom- and ready-made spectacles and CLs.

Waste generated in the ophthalmic sector has been investigated regarding cataract[13] and glaucoma[14] surgeries, and there are limited studies on the environmental impact of spectacles and CL disposal.[15,16,17] It has been reported that 71% of spectacle wearers replaced their spectacle frames between 1 and 2 years and approximately one-third thereof had discarded their old spectacles.[15] Approximately, 21% of CL wearers flushed their lenses into a sink or toilet, thus contributing approximately 20 tonnes of plastic waste into the US waste water systems per year.[16] Non-biodegradable plastics can persist for a long period, potentially impacting the local soil, flora and groundwater.[18] Plastics disposed as litter or in a landfill can fragment into microplastics because of weathering and mechanical forces. These particles, between 100 nm to 5 mm in size, can enter water streams, leach or adsorb contaminants and pose a threat of ingestion by marine species.[18]

A study indicated that most of the paper and plastic waste generated by daily and monthly CL replacement modalities could be recycled in household recycling programmes within the United Kingdom.[17] This study was based on patient compliance to manufacturer's recommendations and replacement schedule.[17] Patients' non-compliance in CL wear is, however, well-reported.[19,20] The recommendations, therefore, made by optometrists regarding lens disposal and the lens wearers' actual disposal practices are important considerations. No published studies could be found that investigated optometrist recommendations and lens wearer practices in terms of ophthalmic lens disposal. In view of the anticipated need for vision corrective devices and concerns about landfill and waste water pollution generated by disposal practices, the goal of this study was therefore to determine optometrist recommendations and lens wearer practices regarding lens disposal.

Research methods and design

A quantitative, descriptive, cross-sectional study was conducted on optometrists and lens wearers in South Africa (SA), between May 2019 and September 2019, using online surveys that were designed for the study.

Study population and sampling

The study population comprised optometrists employed in SA, and spectacle and CL wearers who resided in SA and who were 18 years of age and older. As of April 2019, 3812 optometrists were actively registered with the Health Professions Council of South Africa.[21] The South African population in 2019 was reported as 58.4 million[22] and spectacle and CL usage in SA in 2019 was estimated at 10.9% of the population over the age of 5 years.[22] Based thereon, the minimum sample size for the study, as confirmed by a statistician, was 350 for optometrists and 385 for lens wearers (Dessie Z, 2019, personal communication, February 15). The calculations for sample size for optometrists and lens wearers are depicted in Equation 1 and Equation 2, respectively.

$$Sample\ size = \frac{\frac{1.96^2 \times \left[0.5 * (1-0.5)\right]}{0.05^2}}{1 + \left[\frac{1.96^2 \times \left[0.5 * (1-0.5)\right]}{0.05^2 * 3812}\right]} = 349 \qquad \text{[Eqn 1]}$$

$$Sample\ size = \frac{\frac{1.96^2 \times \left[0.5 * (1-0.5)\right]}{0.05^2}}{1 + \left[\frac{1.96^2 \times \left[0.5 * (1-0.5)\right]}{0.05^2 * 6\,365\,600}\right]} = 384 \qquad \text{[Eqn 2]}$$

Data collection and analysis

Queries from a pilot study, conducted on 12 optometrists and 19 lens wearers, which were not included in the final sample, were addressed before the main surveys were released. Permission was sought from the registrars of 11 universities and technical colleges in SA to distribute the lens wearer survey link to all staff and students. The link to both the optometrist and lens wearer surveys were promoted online while the latter was also available in paper format.

Both surveys were available in English, which is an official language in SA. The surveys comprised questions on the demographic profile of optometrists and lens wearers. The optometrist survey enquired about sales of spectacles and CLs, and recommendations made to patients regarding disposal of lenses and associated products, such as spectacle lens cleaners,

CL solutions, and cases. The lens wearer survey questioned the type of lens wear, purchases and disposal practices of lenses and associated products. Both surveys also queried environmental awareness, interest in lens recycling programmes, and additional comments by respondents were also accepted.

All survey data were analysed using IBM® SPSS® Statistics version 24. The results consisted of categorical variables, for which descriptive analyses were conducted using frequency tables.

Ethical considerations

Ethical approval was obtained from the University of KwaZulu-Natal Humanities and Social Sciences Research Ethics Committee (HSS/1649/018D). The University of the Western Cape in Cape Town and the University of KwaZulu-Natal in Durban, KwaZulu-Natal (KZN) provided gatekeeper permission for the online lens wearer survey and the link was thereafter made available to their staff and student database. The online link directed respondents to an information sheet detailing the study, request for informed consent and the right to decline or withdraw at any stage. Three optometrists, based in the eThekwini municipality in the KZN province, provided consent to distribute a paper copy of the lens wearer survey at their private practices. The paper surveys were secured after the data were transferred to a computer. Data were stored in a password-protected computer and only accessible to the corresponding author. The data will be deleted and/or shredded 5 years after completion of the study.

Results

The optometrist survey received 353 responses, which represented 9.3% of the total active registered optometrists in SA in 2019. The lens wearer survey received 577 online and 52 paper responses; 26 respondents were removed as they did not wear spectacles or CLs. The final study sample for the lens wearers was therefore 603. The demographic profile will be presented first, followed by the lens sales and disposal recommendations by optometrists, and lens wearer purchases and disposal thereof. Multiple responses were allowed in some survey questions to gain a broader perspective on disposal behaviour.

Demographic profile

Of the optometrists, 67.7% were females and the majority were between the ages of 30 and 39 years (Table 1). Females comprised 73.8% of the lens wearer respondents and 64.8% were between 18 and 29 years of age (Table 1). Over half of the lens wearers had an eye test every 2 years. Approximately, 64% of lens wearers used spectacles only, 32.8% wore both spectacles and CLs, and 2.8% wore CLs only. Results for lens practices are presented per cohort, that is per total number of spectacle wearers (N = 586) and CL wearers (N = 215). Over 50% of spectacle wearers wore spectacles all the time and had anti-reflective coated lenses. Approximately 96% of CL wearers used soft CLs, with the 30-day modality being favoured by 75.8% of this cohort.

Optometrists': Lens sales and recommendations on lens disposal

Approximately 56% of optometrists dispensed more than 10 pairs of new spectacles per week while 83% reported

TABLE 1: Demographic profile of respondents.

Demographic profile	Optometrists (N = 353)		Lens wearers (N = 603)	
	n	%	*n*	%
Gender				
Female	239	67.7	445	73.8
Male	114	32.3	153	25.4
Prefer not to disclose	-	-	5	0.8
Age in years				
18–29	99	28.0	391	64.8
30–39	108	30.6	71	11.8
40–49	97	27.5	63	10.4
50–59	38	10.8	46	7.6
> 60	11	3.1	32	5.3
Current employment status				
Self-employed	156	44.2	-	-
Employed full time	153	43.3	-	-
Employed part time	44	12.5	-	-
Student	-	-	338	56.1
Employed	-	-	222	36.8
Not employed	-	-	19	3.2
Retired	-	-	24	4.0
Optometrists: Years since graduation				
10 or less	143	40.5	-	-
11 or more	210	59.5	-	-
Lens wearers: Frequency of eye tests				
Annual	-	-	94	15.6
Biennial	-	-	341	56.6
Triennial	-	-	44	7.3
Whenever I feel like	-	-	124	20.6
Lens wearers: Type of vision correction				
Spectacle wear only	-	-	388	64.3
Both spectacle and CL wear	-	-	198	32.8
CL wear only	-	-	17	2.8
Spectacle wearers: Frequency of spectacle wear (n = 586)				
All the time	-	-	313	53.4
Distance only	-	-	109	18.6
After CLs are removed	-	-	99	16.9
Near vision and/or computer use only	-	-	59	10.1
When symptomatic (headaches)	-	-	6	1.0
Spectacle wearers: Anti-reflection coat on lenses (n = 586)				
Yes	-	-	298	50.9
No	-	-	195	33.2
Unsure	-	-	93	15.9
CL wearers: Type of CL worn (n = 215)				
Soft	-	-	207	96.3
Gas permeable (corneal)	-	-	5	2.3
Scleral	-	-	3	1.4
CL wearers: CL replacement modality (n = 215)				
30-days	-	-	163	75.8
Annual	-	-	19	8.8
Daily	-	-	16	7.4
1–2 weekly	-	-	6	2.8
Other	-	-	11	5.1

CL, contact lenses.

reglazing of patients' old frames (Table 2). Sales of a 30-day CL replacement modality were reported by 96%. With respect to CL disposal, 80.5% of optometrists were highly likely to recommend disposal into a waste bin, 10.5% into sink or toilet while 12.2% would probably not make any recommendations (multiple responses were allowed).

The dummy lenses from newly glazed frames and expired trial CLs were discarded by 80.7% and 61.5% of optometrists, respectively. Over half were also highly likely to recommend waste bin disposal of associated lens products while around 20% were likely to recommend recycling. Regarding potential sales of biodegradable CLs, 41.4% were highly likely to promote these lenses upon commercial availability while 49.3% indicated that cost factors may be a deterrent to sales of this type of CL. Average environmental awareness was reported by 72.5%, with 21.5% currently participating in recycling programmes and 62.3% of all optometrist respondents would be interested in a lens recycling programme.

Lens wearers': Purchase and disposal of lenses and associated products, environmental awareness, and interest in lens recycling programmes

Upon renewal of spectacles, 61.6% of spectacle wearers were highly likely to purchase a new frame while over half reported previous disposal of spectacles (Table 3). Approximately 57% were highly likely to keep their old pair after a new pair of spectacles was made and 17.9% were highly likely to discard their old spectacles. Frame reuse was reported by 30% and of this cohort, 31.3% were likely to discard the existing prescription lenses. Spectacle lens cleaning sprays were used by 29.2%, and at end-of-use, lens cleaners and spectacle cases were discarded by 89.5% and 48.8% of spectacle wearers, respectively.

Up to four boxes of CLs per year were purchased by 70.2% of CL wearers. Just over 37% were highly likely to dispose of used CLs into the wastewater systems. Approximately 95% reported use of CL care solutions, and around 83% were highly likely to discard empty solution bottles and CL cases into the bin. Upon availability, 32.6% were highly likely to purchase biodegradable CLs. Of the total lens wearer population, 62.2% reported average environmental awareness while 51.4% would be very interested in participating in a lens recycling programme.

Discussion

Multiple responses were allowed for some disposal questions as it has been reported that disposal behaviours are not constant and may change based on circumstances.[23] For example, disposal behaviour may vary in the home environment compared with when on a holiday[23]; therefore, multiple responses can allow for further information on disposal behaviour. In addition, highly likely responses were discussed as it was felt that this provided a baseline indication of lens wearers' current disposal practices.

Demographic profile

The demographic profile of the respondents was similar to previous surveys conducted on optometrists and lens wearers in SA[24,25,26] thereby suggesting that this study was representative of the general optometrist and lens wearer populations in SA. With respect to the majority of respondents in both surveys being female, this trend was also observed in previous studies[25,26,27] and aligned with active registration of 61.6% of female optometrists in SA by the Health Professions Council of South Africa (Daffue Y, 2021, personal communication, September 30). The survey findings will be discussed with respect to sales and disposal of spectacles, CLs, and associated lens products from the perspective of both optometrists and lens wearers.

More than half of the optometrists reported sales of over 10 new frames per week while 61.1% of spectacle wearers were highly likely to purchase a new frame. Upon new frame purchase, over half were highly likely to keep their old spectacles, and approximately 18% were highly likely to discard their old spectacles, and this finding was slightly lower than a previous study in which 31% of respondents reported disposal thereof.[15] Anecdotal evidence from optometrists suggests that some lens wearers prefer to have a 'backup' or spare pair in the event of their current pair of spectacles being damaged or lost. The average life expectancy in SA in 2021 was 60 years[28] and considering that most respondents were younger than 30 years of age, it can be expected that, based on timeous replacement of spectacles, these respondents would purchase approximately 10 pairs in future. Although several lens wearers reported that they retained their old spectacles, they would probably dispose older pairs at some point as spectacles are renewed over the years.

Approximately 76% of the lens wearers in this study were between 18 and 39 years of age. This cohort born between 1981 and 1996, are referred to as 'Millennials' or 'Generation Y,'[29] and were anticipated to comprise almost 50% of the consumers purchasing ophthalmic products by 2020.[30] They are also reportedly more influenced by fashion and trends, consider spectacles as an accessory and have more than one pair.[31] It was interesting to observe that 87% of optometrists indicated reuse of patients' own frames while only 30% of spectacle wearers reported likewise. This study had a majority of younger respondents, which may account for the relatively low report of reuse of frames. In spite of these two groups (optometrists and spectacle lens wearers) being unrelated, this difference in results is noteworthy and should be investigated in future studies that document retrospective data of prescribing trends in professional practice rather than optometrists' perspectives. Upon reglazing of frames, optometrists were highly likely to recommend retention of old lenses (53.3%) while spectacle wearers did not show strong preference for either discarding (31.3%) or retaining (30.7%) old lenses. To maintain frame shape and quality, there is a limit to how often new lenses could be glazed into old frames; therefore, reglazing of frames has a threshold of

TABLE 2: Optometrists' lens sales, recommendations to patients regarding lens disposal, environmental awareness, participation, and interest in recycling programmes.

Optometrists (N = 353)	Highly likely		Somewhat likely		Not likely		N	%
	n	%	*n*	%	*n*	%		
New spectacles dispensed per week								
Less than 10	-	-	-	-	-	-	154	43.6
More than 10	-	-	-	-	-	-	199	56.4
Number of frames that are reglazed per week	-	-	-	-	-	-		
None	-	-	-	-	-	-	60	17.0
1–5	-	-	-	-	-	-	282	79.9
More than 5	-	-	-	-	-	-	11	3.1
Recommendations to patients regarding disposal of old spectacle lenses†								
Discard lenses	85	24.1	151	42.8	117	33.1	-	-
Keep lenses‡	188	53.3	133	37.7	32	9.1	-	-
Donate lenses‡	76	21.5	166	47.0	111	31.4	-	-
No recommendations made	56	15.9	159	45.0	138	39.1	-	-
Types of CL dispensed as per replacement modalities†								
30-day	-	-	-	-	-	-	339	96.0
Daily disposable	-	-	-	-	-	-	311	88.1
2-weekly	-	-	-	-	-	-	246	69.7
Conventional soft (annual)	-	-	-	-	-	-	125	35.4
Gas permeable (n = 263)	-	-	-	-	-	-	104	39.5
Recommendations to patients regarding disposal of CLs†								
Bin	284	80.5	51	14.4	18	5.1	-	-
Water system: sink and/or toilet	37	10.5	79	22.4	237	67.1	-	-
No recommendations made	43	12.2	88	24.9	222	62.9	-	-
Disposal of associated lens products§								
Dummy lenses‡								
Bin	-	-	-	-	-	-	285	80.7
Optical laboratory	-	-	-	-	-	-	52	14.7
Other	-	-	-	-	-	-	16	4.5
Expired trial CLs								
Bin	-	-	-	-	-	-	217	61.5
Return to supplier	-	-	-	-	-	-	121	34.3
Other	-	-	-	-	-	-	15	4.2
Recommendations to patients regarding disposal of associated products§†								
Bin	187	53.0	118	33.4	48	13.6	-	-
Recycle	70	19.8	176	49.9	107	30.3	-	-
No recommendations made	71	20.1	155	43.9	127	36.0	-	-
Promotion of biodegradable CL (when available)	146	41.4	148	41.9	59	16.7	-	-
Likelihood that cost of biodegradable CL would be a deterrent to sales	174	49.3	164	46.5	15	4.2	-	-
Environmental awareness								
High	-	-	-	-	-	-	79	22.4
Average	-	-	-	-	-	-	256	72.5
Low to none	-	-	-	-	-	-	18	5.1
Participation in recycling programmes								
Yes	-	-	-	-	-	-	76	21.5
No	-	-	-	-	-	-	277	78.5
Type of recycling programmes (N = 76)								
Lions International	-	-	-	-	-	-	42	55.3
Redistribute to indigent patients and NGOs at no charge, or use for spare parts	-	-	-	-	-	-	21	27.6
Local municipality	-	-	-	-	-	-	7	9.2
Other	-	-	-	-	-	-	6	7.9
Likely disposal advice to patients from optometrists engaged in recycling programmes (n = 76)								
Bin	25	32.9	4	5.2	-	-	-	-
Recycle	24	31.6	18	23.7	-	-	-	-
No recommendations made	5	6.6	0	-	-	-	-	-
Interest in participating in lens recycling programme								
Very interested	-	-	-	-	-	-	220	62.3
Neutral	-	-	-	-	-	-	131	37.1
Not interested	-	-	-	-	-	-	2	0.6

CL, contact lens; NGO, non-governmental organisation.

†, multiple responses allowed; ‡, percentages do not total to 100% because of rounding of decimals; §, associated products=spectacle cases, lens cleaning sprays, CL solution bottles and cases.

TABLE 3: Lens wearers' purchase and disposal practices of lenses and associated products, environmental awareness, interest in lens recycling programme, and additional comments.

Variable	Highly likely		Somewhat likely		Not likely		*N*	%
	n	%	*n*	%	*n*	%		
Spectacle wearers (*N* = 586)								
Purchase of new frame upon update of prescription (*n* = 586)	361	61.6	130	22.2	95	16.2	-	-
Number of spectacles discarded to date (*n* = 586)								
None	-	-	-	-	-	-	252	43.0
1–4 pairs	-	-	-	-	-	-	236	40.3
> 4 pairs	-	-	-	-	-	-	98	16.7
Disposal practice of existing spectacles upon new purchase (*n* = 582)†, ‡								
Bin	104	17.9	97	16.7	381	65.5	-	-
Keep	335	57.6	172	29.6	75	12.9	-	-
Donate	86	14.8	161	27.7	335	57.6	-	-
Reuse of existing frame (*N* = 586)								
Yes	-	-	-	-	-	-	176	30.0
No	-	-	-	-	-	-	410	70.0
Disposal practice of old lenses upon reuse of frame (*n* = 176)†, ‡								
Bin	55	31.3	33	18.8	88	50.0	-	-
Keep	54	30.7	42	23.9	80	45.5	-	-
Donate	33	18.8	45	25.6	98	55.7	-	-
Purchase of lens cleaning sprays (*n* = 586)								
Yes	-	-	-	-	-	-	171	29.2
No	-	-	-	-	-	-	415	70.8
Number of lens cleaning sprays purchased per year (*n* = 171)								
1–4	-	-	-	-	-	-	151	88.3
> 4	-	-	-	-	-	-	20	11.7
Disposal of lens cleaning sprays (*n* = 171)								
Bin	-	-	-	-	-	-	153	89.5
Recycle and/or refill	-	-	-	-	-	-	18	10.5
Disposal of spectacle cases (*n* = 582)								
Bin	-	-	-	-	-	-	284	48.8
Reuse	-	-	-	-	-	-	252	43.3
Other	-	-	-	-	-	-	46	7.9
Contact lens wearers (*n* = 215)								
Number of boxes purchased per year								
1–4	-	-	-	-	-	-	151	70.2
≥ 5	-	-	-	-	-	-	57	26.5
Other	-	-	-	-	-	-	7	3.3
Disposal of CLs†								
Bin	155	72.1	26	12.1	34	15.8	-	-
Water system: sink and/or toilet	81	37.7	36	16.7	98	45.6	-	-
Use of CL solutions								
Yes	-	-	-	-	-	-	204	94.9
No	-	-	-	-	-	-	11	5.1
Number of CL solution bottles purchased per year (*n* = 204)								
1–4	-	-	-	-	-	-	139	68.1
> 5	-	-	-	-	-	-	65	31.9
Disposal of CL solution bottles and cases (*n* = 204)†								
Bin‡	170	83.3	17	8.3	17	8.3	-	-
Recycle	35	17.2	46	22.5	123	60.3	-	-
Likelihood of purchasing biodegradable CLs (when available)	70	32.6	89	41.4	56	26.0	-	-
Likelihood that price of biodegradable CL would be a deterrent to purchase	128	59.5	70	32.6	17	7.9	-	-
All lens wearers (*n* = 603)								
Environmental awareness								
High	-	-	-	-	-	-	167	27.7
Average	-	-	-	-	-	-	375	62.2
Low to none	-	-	-	-	-	-	61	10.1
Interest in participation in lens recycling programme								
Very interested	-	-	-	-	-	-	310	51.4
Neutral	-	-	-	-	-	-	249	41.3
Not interested	-	-	-	-	-	-	44	7.3

Table 3 continues on the next page →

TABLE 3 (Continues...): Lens wearers' purchase and disposal practices of lenses and associated products, environmental awareness, interest in lens recycling programme, and additional comments.

Variable	Highly likely		Somewhat likely		Not likely		*N*	%
	n	%	*n*	%	*n*	%		
Additional comments								
No comment	-	-	-	-	-	-	347	57.6
Increased awareness and education are required on recycling	-	-	-	-	-	-	97	16.1
Recycling programmes need to be easily accessible	-	-	-	-	-	-	73	12.1
Had not previously considered recycling but will do so in future	-	-	-	-	-	-	64	10.6
Biodegradable materials should be used for lenses	-	-	-	-	-	-	8	1.3
Lenses should not be made of recycled materials as they will be of inferior quality	-	-	-	-	-	-	8	1.3
Optometrists and distributors should offer discounts as incentive for lens recycling	-	-	-	-	-	-	6	1.0

CL, contact lens.

†, multiple responses allowed; ‡, percentages do not total to 100% because of rounding of decimals.

use, and old frames and lenses would have to be disposed eventually.

Dummy lenses and expired CLs were discarded into the waste bin by over 80% and 60% of optometrists, respectively. Furthermore, 57% of spectacle wearers had already discarded spectacles while over 30% were highly likely to dispose of old spectacle lenses upon reuse of frames. This suggests that significant volumes of ophthalmic lens waste could enter landfill through solid waste disposal. The biodegradability and biocompatibility of spectacle frames has been investigated previously.[15] Heavy metals, such as lead and chromium among other essential elements, were found in some frames.[15] Unsound landfill practices could result in leaching of these heavy metals into the soil thus resulting in environmental toxicity.[15] Plastic spectacle lenses are typically manufactured from derivatives of methacrylates or polycarbonate,[9] and no published studies were found confirming the environmental impact upon disposal of these lenses. Therefore, the consequences of landfill disposal of spectacle lenses warrant further investigation.

In 2019, reports on global fitting trends indicated that 89% of new fits or refits comprised of soft CLs.[32] Soft CL wear were reported by 96.3% of CL wearers in this study and the 30-day CL replacement modality was most frequently reported by optometrists (96%). Accordingly, 75.8% of CL wearers reported the same replacement modality. The usage rate of the monthly replacement modality in SA was previously reported as between 64% and 82% [24,26] and was higher than the international trend of 39% in 2019.[32] This is possibly because of a price sensitive South African market, as the daily and 2-weekly disposable CL modalities are generally considered to be more expensive.

Approximately 38% of CL wearers were highly likely to dispose used CLs either into a sink or toilet. Of further concern is that 10.5% of optometrists were highly likely to suggest likewise while 12.2% would probably not make any CL disposal recommendations to their patients. It has been estimated that 20 tonnes of plastic entered US wastewater systems annually because of CL disposal.[16] These lenses have the potential to fragment and subsequently escalate microplastic pollution.[16] Microplastics are easily dispersed because of their minute size, can adsorb contaminants and impact on soil and aquatic systems.[33] They can be ingested by marine organisms and animals, posing a threat to these species, and can be transferred to other animals via the food chain.[33] At present, disposal recommendations on CL packaging are lacking; therefore, it is imperative that optometrists advise their patients not to flush CLs into a sink or toilet. Optometrists and their staff should repeat these instructions to their patients upon each CL visit and purchase. Similarly, they should dispose of unwanted trial CLs appropriately. Empty blister packs are recyclable and should be included along with solution bottles and CL cases for recycling.

Waste bin disposal of recyclable lens cleaning spray bottles was reported by 89.5% of spectacle wearers. Of interest, only two respondents reported that they refilled these bottles at their optometrist. This is a useful initiative to reduce plastic waste and should be considered by other optometrists as well. This fits into the waste hierarchy management of waste avoidance, reduction, and reuse.[34] Approximately 49% had discarded spectacle cases while 40.5% had reused or repurposed them. These cases do have a limited lifespan of use and are likely to be discarded when they are damaged. Spectacle cases are manufactured from a variety of materials such as fabric, acetates, and polyurethanes, and recycling thereof is either not currently possible or economically feasible. Biodegradable or compostable materials should be incorporated in the manufacture of these cases to promote soil renewal upon disposal and minimise landfill emissions from overburdened landfills.

Approximately 83% of CL wearers were highly likely to discard CL solution bottles and cases and only 17.2% were highly likely to recycle these. Optometrists were almost equally probable to either recommend recycling of products associated with lens wear (19.8%) or not make any recommendations thereon (20.1%). Most of the products associated with lens wear are manufactured from recyclable plastics and the landfill disposal thereof represents a loss of valuable recyclate material as well as increases landfill emissions and fossil fuel consumption in the long term. This suggests that optometrists should increase patient awareness thereon and provide appropriate disposal instructions to their patients.

Only 21.5% of optometrists were currently engaged in recycling programmes and 55.3% of this cohort collected old spectacles for the Lion's International spectacle recycling programme. This initiative collects disused spectacles for redistribution to individuals in need. Traditional spectacle recycling programmes have been previously questioned because of the low uptake on used spectacles.[35] The International Agency for the Prevention of Blindness has a position article recommending against redistribution of used spectacles, with the environmental impact from the disposal of unusable spectacles being one of their concerns.[36]

Currently there are no lens recycling facilities in SA. Such initiatives exist in the United States (US), where an organisation collects and recycles unwanted lenses into safety spectacles and helmet shields.[37] Only 51% of lens wearers were very interested in participating in a lens recycling programme compared with 62% of optometrists. Creation of such programmes in SA would require investment from the suppliers, optometrists, and lens wearers, to be successful. Aside from the necessary technology and start-up capital, recycling programmes require constant volumes in order to be economical; therefore, buy-in from optometrists and lens wearers is vital. However, most of the packaging waste from products associated with lens wear can be recycled,[17] and increased awareness and advice to patients thereon could be impactful.

Research is ongoing with respect to biodegradable materials for ophthalmic lenses and incorporation of such materials would help to reduce the adverse impacts of plastic solid waste. Patent literature describes potential biodegradable lens materials synthesised from renewable sources such as isosorbide from corn.[38,39] Less than half of the optometrists (41%) were highly likely to promote the use of biodegradable CLs if these were available while less than one-third of CL wearers (32%) indicated that they would be highly likely to purchase these CLs. Furthermore, approximately 50% of optometrists and around 60% of lens wearers responded that cost factors were highly likely to deter the adoption of biodegradable CLs. In a price-sensitive ophthalmic market, this could be a barrier to potential sales, and distributors providing lens products made of biodegradable materials would need to be cognisant thereof. Eight CL wearers provided additional comments that they thought this lens would be made of recycled material and would be of an inferior quality that may affect their vision, hence they would not purchase them. However, CLs are medical devices that are manufactured under regulated processes with stringent quality control and materials undergo strict testing and trials before being made available to consumers.[40] Improved education and awareness with respect to the advantages of biodegradable and recyclable materials is indicated for both optometrists and CL wearers. Reassurance of safety and environmental benefits will be vital to ensure lens wearers' acceptance of biodegradable lenses.

Just over 10% of lens wearers reported having 'low to none' environmental awareness. This could present an opportunity for climate-conscious optometrists to promote environmental awareness through print or video materials in the waiting room. An appropriate environmental message could also be inserted into the footer of the practice email or website page. Lens wearers felt that there should be more awareness and education programmes to promote recycling (16%) and that recycling programmes should be easily accessible to encourage local recycling (12%). It has been reported that recycling programmes are effective when contributors are environmentally conscious and incentivised, and where clear recycling instructions are provided.[41] Knowledge of which items are recyclable, implementation of kerbside recycling schemes and convenient recycling drop-off zones are necessary to improve recycling rates in SA.

Environmental stewardship

Just over 21% of optometrists engaged in recycling while 20% were highly likely to either make no disposal recommendations to their patients or recommend recycling of associated lens products. This suggests that the majority of optometrist respondents were not engaged in recycling and is also a missed opportunity for optometrists to contribute towards improving recycling rates through patient education. Of the optometrists who engaged in recycling, a similar proportion were highly likely to suggest recycling (31.6%) or waste bin disposal (32.9%) to their patients. It would be anticipated that this group of optometrists would advocate strongly for recycling as they engage in this practice. It is possible that some optometrists do not make recommendations as they feel their patients will not follow their suggestions. A report indicated that while optometrists believed that only 49% of patients followed their recommendations, 76% of patients reported following optometrist instructions.[42] This perhaps suggests that optometrists may underestimate patient adherence to recommendations, and this study proposes that optometrists should actively recommend appropriate disposal practices to their patients.

A survey conducted in the US reported that 61% of respondents were unaware of how global warming may affect their health and that they would trust their primary care physician as a source of environmental information.[43] In addition, some patients felt they received inadequate environmental information from their physicians and would be amenable to their advice.[44] Healthcare professionals are encouraged to become environmental stewards as they have a unique platform to bring about positive community change by promoting environmental awareness to patients.[45] Furthermore, healthcare practitioners have a professional duty to keep themselves and their colleagues updated on environmental issues and advocate for positive change.[46] Considering the potential impacts of climate change on overall health, an inter-professional health sciences education that includes environmental health should be incorporated into teaching modules,[47] as the challenges of environmentally sustainable healthcare are beyond the scope of a single discipline.[48]

Recyclable items disposed into waste bins are relegated to landfills. This practice must be avoided because of the global shortage of landfill space, and furthermore, landfills emit methane, which contributes to global warming and climate change. Therefore, to preserve our environment all recyclable items should be collected and reprocessed. This also conserves energy as recycled plastic items consume less energy than virgin plastic materials. Optometrists can play a vital role in preserving our environment by engaging in recycling and educating their patients to do likewise. Consumers also have a vital role in climate change mitigation through sustainable purchasing and adoption of appropriate disposal practices, even in the absence of manufacturer's recommendations. Furthermore, they should be proactive in acquiring knowledge on environmental issues and support recycling programmes.

Limitations of the study

This study used self-administered, online surveys, which may appeal to respondents who were more interested in the topic, and whose behaviour may differ from non-responders (and those not interested in environmental awareness). This was a cross-sectional study, and it is uncertain if the disposal behaviours that were investigated would vary with time. The study enrolled lens wearers over the age of 18 years and cannot account for disposal practices of a younger cohort of lens wearers, which may differ from that of adults. There was a higher proportion of participants between the ages of 18 and 29 years, and the disposal behaviour of this cohort may differ from that of an older cohort. Future studies with a larger proportion of presbyopic participants are recommended, as well as studies investigating patients' compliance with optometrists' disposal instructions.

Conclusion

This study explored optometrists' and lens wearers' perspectives regarding the disposal of spectacles, CLs, and associated products. Findings from this study suggest that optometrists need to actively recommend proper disposal practices of ophthalmic products and packaging to their patients. Advice on recycling and appropriate disposal instructions should accompany all products dispensed to patients.

Optometrists and CL wearers should refrain from disposing CLs into the sink or toilet as this contributes to microplastic pollution.

Over 60% of optometrists would be very interested in participating in a lens recycling programme, and their advocacy and support may encourage interested parties in the optical industry to introduce such initiatives in SA. As primary healthcare practitioners, optometrists have a vital role as environmental stewards, and a valuable platform to educate patients on the environmental impact of improper waste disposal. The study also suggests the inclusion of environmental awareness in health sciences education and for health science practitioners to adopt green friendly disposal practices.

Optometrists and lens wearers should encourage manufacturers to redesign ophthalmic lenses and associated product packaging using biodegradable materials. Keeping abreast of current evidence-based practices, making sustainable purchases, and informing patients on environmental issues can have a positive outcome in attitudes and behaviours to aid in climate change mitigation. Lens wearers, likewise, have a similar responsibility to request and heed disposal instructions and be mindful of the environmental consequences of their disposal practices.

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Authors' contributions

All authors were involved in the conceptualisation and methodology of the article. R.P. completed the literature search, investigation and drafted the research article. R.H. and N.R. were involved in review and editing of the article to the final version.

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Data availability

The data that support the findings of this study are available from the corresponding author, R.P., upon reasonable request.

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