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Article

Mitigating microplastic exposure from water consumption in junior high students and teachers

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SUMMARY

Microplastics (MPs) are inorganic material that have been observed within items destined for human consumption, including water, and may pose a potential health hazard. Here we estimated the average amount of MPs junior high students and teachers consumed from different water sources and determined whether promoting awareness of microplastic (MP) exposure influenced choice of water source and potential MPs consumed. We hypothesized that MP exposure from water would be approximately 40 MPs/day. We conducted three surveys of 57 students and 26 teachers from a junior high school in Calgary, Alberta, Canada, asking participants to estimate how much tap and bottled water they consumed. Following the first survey, participants were given an educational presentation on MPs and their potential effects. At baseline, participants consumed 4-6 L/day of water, mainly tap (≥90%), which translated into MP consumption ranging from 23-83 MPs/day. Males consumed more MPs/day than females, and adults more than students. Male students drank the most bottled water and had the highest MPs/day. Following the educational presentation, <10% of participants changed the source of water consumed. Microplastic consumption remained highest among male students (115.89 MP/day) who drank the most bottled water. Our study's pre- and post-presentation MP consumption estimates for all groups except male students were lower than recent Canadian research that estimated humans' annual MP intake. Although an educational presentation did not influence the source of water intake or MP exposure, individuals' willingness to participate in these surveys and increase MP awareness suggests an interest in reducing plastic exposure.

INTRODUCTION

Microplastics (MPs) are defined as plastic fragments less than five mm along their longest dimension and are categorized as primary or secondary depending on whether they were produced to be less than 5 mm or have degraded from larger objects, respectively (1). Over the past few years, several studies have reported the presence of MPs in treated tap and bottled water, raising questions and concerns about the impact that MPs have on human health (2). In 2019, the World Health Organization (WHO) published a summary of the available research and evidence for potential health risks of MPs from drinking water (2). According to the WHO report, MPs can pose potential hazards in three ways: a physical hazard, a chemical hazard, or as biofilms whereby microorganisms attach onto MPs and colonize (2). Available evidence suggests that chemicals and microbial pathogens related to MPs pose the lowest concern for human health compared to their physical hazards (2). However, more research is needed to understand better what happens to MPs after ingestion and how MP may affect human health.

Bottled water is an avoidable source of MP exposure if clean tap water is available as an alternative to plastic water bottles. In the United States, bottled water sales have risen by 8.25 billion dollars in 2006 and 15 billion in 2020 (3). Discarded bottles, along with other plastics, break down into MPs which can end up in water systems and drinking water. Researchers examining the abundance of MPs within different globally sourced bottled water samples found that 93% of bottles showed MP contamination (4). Another study looking at the presence of anthropogenic (human made) particles in 159 different samples of tap water from around the globe also found that 81% of the samples tested contained MPs (5). Recently, Canadian researchers, Cox et al. evaluated MP exposure from water consumption by conducting a literature review to determine the average amount of MPs found in various food and beverages, including water (6). Cox's study examined 402 data points from 26 studies representing over 3,600 processed samples to create a database of MP exposures in foods and beverages; human exposure estimates were calculated with US dietary data (6). Cox et al. demonstrated that the intake of MPs is about 20 times higher among those who drink only bottled rather than tap water, suggesting that MP consumption could be mitigated by reducing bottled water intake (6).

Although the ecological effects of MPs are not currently known, understanding our exposure to MPs is important because plastic and MP pollution in water is on the rise. Reducing our bottled water intake could be a simple way to reduce our exposure to MPs. The primary objective of our study was to estimate real-world MP exposure from both tap and bottled water consumption among junior high students and teachers. Secondary objectives were to determine: (a) if after a short in-school presentation about (micro)plastics, participants reduce their bottled water consumption/MP exposure, or (b) if bottled water consumption/MP exposure changed due to the COVID-19 pandemic. We considered our survey data in relation to a recent study that estimated the average Americans' MP intake, allowing us to examine if students and teachers are exposed to elevated or decreased levels of plastic.

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Based on a recommended daily intake of approximately two liters of water, the "What we eat in America (WWEIA)" survey estimated that 17% of water consumed is bottled and 83% tap, and MP concentrations in water reported in the Cox et al, our main hypothesis was that MPs exposure from water sources would be approximately 40 MPs/day (6). Furthermore, we speculated that adults, having higher disposable income, would consume more bottled water and hence, more MPs, than youth, while gender would have a minimal effect on exposure as seen in the Cox et al study (6). Finally, we anticipated that bottled water consumption might decrease with increased awareness of (micro)plastics; while the COVID-19 pandemic might have caused an increase in bottled water consumption at the one-year follow-up time point since many consumers stockpiled essential supplies including bottled water.

RESULTS

A total of 83 participants were surveyed. The breakdown of participants by age and gender includes 57 students and 26 teachers, of which roughly 65% were female. At baseline, participants consumed approximately four and six litres of water daily, the majority of which was tap (**Figure 1**).

Estimates of participants' consumption of MPs at baseline indicated that except for male students, all individuals consumed fewer MPs than the average American (**Appendix Figure 1**) (6). In the present study, the majority of MP exposure came from bottled water, with estimates suggesting that males consumed more MPs than females while students consumed more than adults (**Appendix Table 1**). Our results showed that adult females drank the least bottled water and as a result had the lowest MP exposure from water. The highest MP exposure at baseline was among male students, who consumed the most bottled water. Reductions in the participants' average MP consumed from water intake per day relative to average Americans' consumption was driven primarily by relatively less bottled water consumed by the surveyed individuals (6).

After being given an educational presentation to increase awareness of plastic pollution and MPs, very few participants changed their source of water consumed (**Figure 1**). Therefore, MP exposure from water also changed very little (**Figure 2**). MP consumption was still highest among male students (115.89 MP/day) who continued to drink the most bottled water.

One year after the initial survey, a final version of the survey was sent out to determine MP consumption during the pandemic. We observed that the total water consumption had decreased significantly in all groups (**Figure 1**). Males still consumed more water than females, the majority of which was still tap water. An increase in bottled water consumption was observed among female students (from 4.87% to 19.05%) and adults (from 0.55% to 5.83%). Although all groups drank mainly tap water, the main source of MPs in the final survey was still bottled water (**Figure 2**). At baseline, male students were estimated to consume the highest amount of MPs; however, at the 12-month time point, the most substantial decrease in total MP consumption occurred among male students. A notable portion of this decrease occurred within their consumption of bottled water, which was less than female students at the same 12-month time point (**Figure 2**).

DISCUSSION

Our research demonstrates how surveys can be used to estimate real-world MP consumption from water among junior high students and teachers. The majority of participants in our study consumed less MPs than we hypothesized and fewer MPs than estimated by recent literature (6). This reduction in estimated MP intake was primarily attributed to the surveyed participants drinking more tap water than the average American. In the first survey, adults consumed less MPs than students, and males consumed more than females. Our educational, in-class presentation to increase awareness of the possible harmful effects of MPs, had minimal influence on the source of water intake among participants. Participants' willingness to be educated on the topic was accompanied by limited alterations in their behavior indicating that choosing to drink bottled water is influenced by other factors such

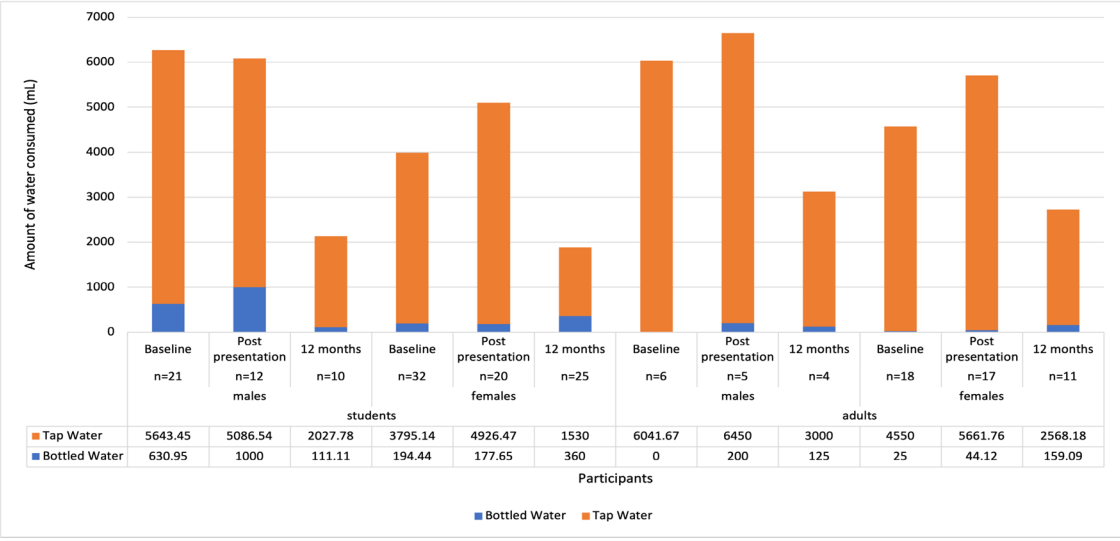

Figure 1. Total water consumption from all sources at all timepoints (pre/post-presentation and 12 months later). The average MP consumption/day pre- and post-presentation by age & gender. After my presentation to increase awareness of MP, few participants changed the source of water consumed. Microplastic consumption remained highest among male students who consumed the most bottled water

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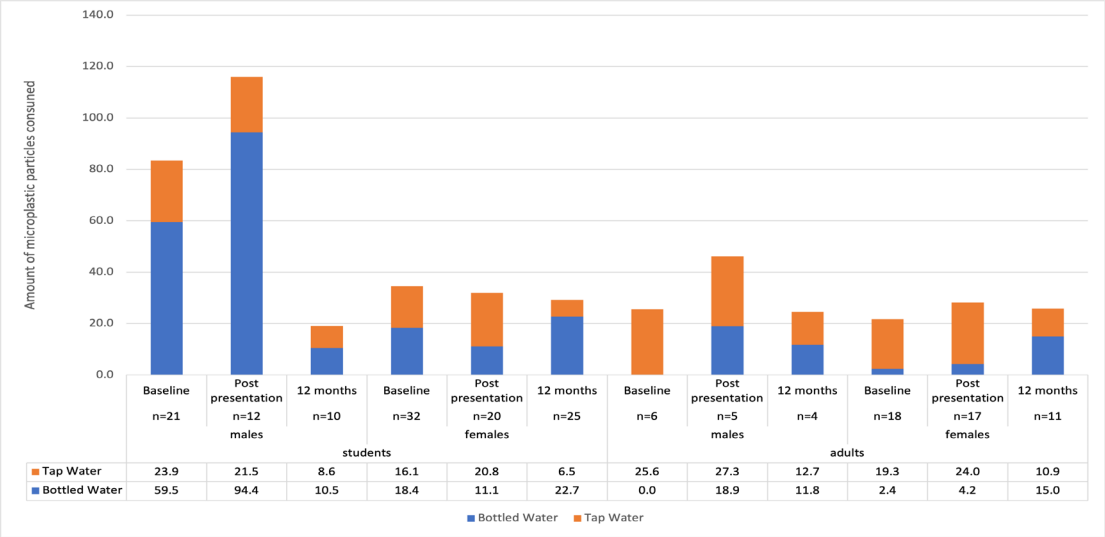

	Baseline n=21	Post presentation n=12 males	12 months n=10	Baseline n=32	Post presentation n=20 females	12 months n=25	Baseline n=6	Post presentation n=5 males	12 months n=4	Baseline n=18	Post presentation n=17 females	12 months n=11
	students						adults					
Tap Water	23.9	21.5	8.6	16.1	20.8	6.5	25.6	27.3	12.7	19.3	24.0	10.9
Bottled Water	59.5	94.4	10.5	18.4	11.1	22.7	0.0	18.9	11.8	2.4	4.2	15.0

Figure 2 Comparison of MP consumption (MP/day) from all sources at all timepoints (pre/post-presentation and 12 months later). After 12 months, total water consumption decreased significantly for all groups. The majority of water consumed was still tap water, though there was an increase in bottled water consumption among females.

as convenience or concern about tap water and parental influence. Finally, 12 months after the initial survey, during the COVID-19 pandemic, bottled water consumption decreased significantly in male students, but there was a slight increase among both female students and adults. During the pandemic, participants may have consumed less bottled water because everyone spent more time at home where tap water was readily available. As well, while at home, participants may have been more sedentary and drank less water overall therefore reducing observed MP exposure. However, due to the small sample size at the 12-month timepoint, water consumption and MP exposure estimates require further examination in a larger group. Regardless, present values indicate that most people drink tap water within their residences, and campaigns to reduce bottled water consumption should focus on areas outside of the home, such as work and school.

This study has several limitations that must be considered concurrently with the findings to interpret the data adequately. A larger sample size across timepoints would have permitted more in-depth statistical analyses to characterize whether any of the differences observed were statistically significant. Although the baseline surveys examined 83 participants, at the second- and third time points only 76 (93%) and 54 (65%) of the baseline participants responded, reducing the reliability of results over time. Our survey was limited to junior high volunteers, and thus did not include a comprehensive range of participants, limiting the ages, socioeconomic groups and geographic regions examined. Similarly, we did not collect other demographic factors such as activity level, which may influence water consumption and in turn, MP exposure. Limited variability among participants likely influenced water consumption and the sources of water consumed. Due to time constraints, a point estimate was used for water consumption in both the first and third surveys which would not account for day-to-day fluctuations. Water consumption data would have been more accurate with a multi-day survey, at all timepoints. Similarly, because participants were asked to recall how much water they consumed and the source rather than keep a diary of water consumption, our estimates of MP exposure from water may not have been entirely accurate. Finally, the concentrations of MPs/L in bottled and tap water were estimates from a literature review and not actually measured from bottled/tap water (6). We know that there is variability in MP concentrations across different brands and bottles of water as well as from different sources of tap water (4,6).

Although the effects of MPs on humans aren't entirely known, understanding our exposure to MPs remains important because plastic pollution in water is rising, with MPs increasingly observed within model marine taxa and critical fisheries (8-10). Furthermore, mounting evidence indicates MPs are being retained within human tissues (11,12). The potential impacts of MPs vary considerably across taxa; although smaller organisms such as larval fish may be more susceptible, valid concerns surrounding human health have been raised (e.g. immune function, neurotoxicity, and inflammation) (13,14). Our study shows that people are interested in considering their MP intake and potential impacts. However, mitigating the public's exposure to MPs will require more than just increasing awareness. We propose that national and international campaigns to limit MPs should explore ongoing education and policy routes concurrently.

A 2018 National Geographic cover story described society as "drowning in plastic" and highlighted the fact that 18 billion pounds of plastic end up in the oceans each year (15). A substantial portion of this pollution is attributed to the growing demand for plastics, which has caused MPs to now be pervasive globally (16,17). By 2050, it is estimated that there will be more MPs than fish in the ocean (18). Reducing bottled water intake is a simple way to reduce MP exposure. Our results suggest a one-time presentation on the potential harms of plastic/MP is not sufficient to change participants' choice of sources of water to consume. However, we did not assess participants' knowledge of MPs prior to the baseline survey hence the one-time presentation may not have introduced new information that would affect change among those surveyed. Alternatively, since habits and attitudes can be hard to change and behavioral changes take time, longer, more in-depth educational presentation(s) and/or

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repeat messaging about MPs and their possible effects on human health through different media platforms may be more likely to influence individual choice for sources of water to consume. Pairing education with broad policy changes may also increase the effectiveness of efforts to mitigate plastic pollution. Individuals' willingness to participate in surveys and information sessions suggests the public is keen to understand their exposure and learn about how their consumption habits affect MP intake. Successfully integrating the public into plastic mitigation strategies will require overcoming several logistical challenges; however, people's willingness to participate indicates they are motivated to tackle this mounting environmental threat.

MATERIALS AND METHODS

We hypothesized the number of MPs consumed would be approximately 40 MPs/day. This estimate was calculated based on the WWEIA survey which estimates 17%/83% of all water consumed is bottled/tap; the recommended daily intake of water which is approximately two L; and MP concentrations taken from the Cox study in which MP exposure from bottled water = 94.37 MPs/L vs tap water = 4.23 MPs/L (6).

Participants were recruited from a junior high school in Calgary, AB, Canada and surveyed three times over 14 months. Following an initial baseline paper survey (December 2019), participants were given a short 15 minute in-class educational presentation on plastic pollution, MPs, and their potential effects on human health. The didactic in-class slide presentation included an overview of the global problem of plastic pollution, an introduction to what MPs are, where they come from, and the possible dangers to human health. A follow-up post-presentation survey was emailed to participants asking to log their water consumption and source over 7 days. After one year, a repeat survey was emailed to the participating students/teachers. Demographic information was summarized. The average amount of water (tap vs. bottled and total) consumed per day by age and gender was calculated. To determine MP exposure from water, the amount of water consumed by participants multiplied by the concentration of microplastics (MPs/L) from each source (tap and bottled) as described in the Cox study (6). Graphs were made to compare MP consumption according to the source of water, by age and gender, and at all timepoints, from which all results were compared to the Cox study (6).

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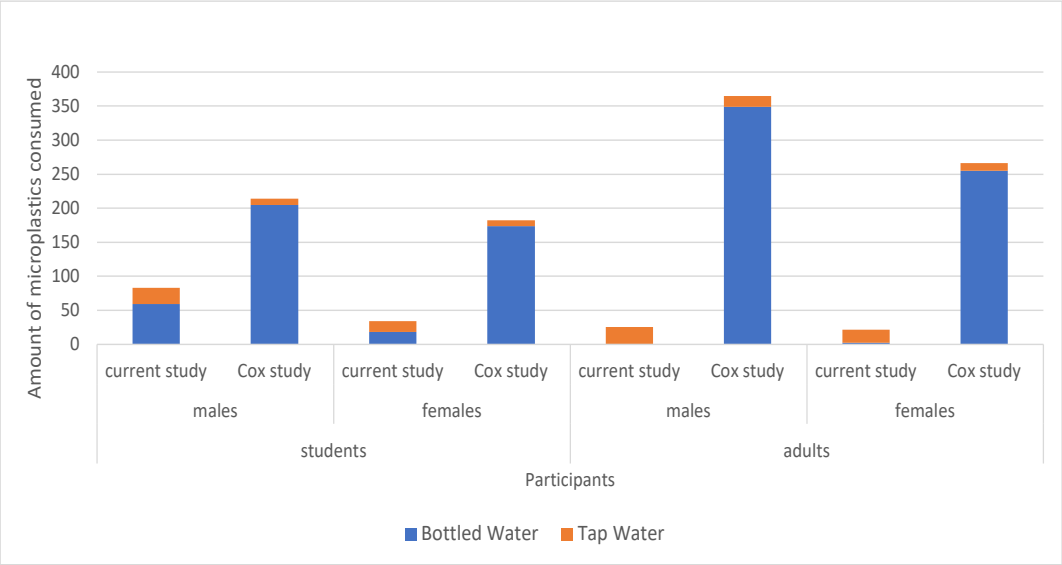
Appendix



Appendix Figure 1: Comparison of Average MP Consumption from Bottled vs. Tap Water (Baseline). Average amount of MP consumed/day by age & gender and compared with the Cox study (6). The majority of MP exposure comes from bottled water. Males consumed more MPs than females while students consumed more than adults. Overall, the average MP consumed from water/day was lower in my study than in the Cox study.

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Appendix

Water Source	No. of participants	Average Baseline MPs/day		No. of participants	Average Post-Presentation MPs/day		No. of participants	Average 12 mo. MPs/day	COX STUDY (MPs/day)
BOTTLED									
male student	21	59.54		12	119.60		10	9.44	205
male adult	6	0.00		5	4.72		4	11.80	349
female student	32	20.64		20	27.72		25	22.65	174
female adult	18	2.62		17	2.31		11	15.01	255
TAP									
male student	21	23.87		12	18.20		10	8.14	9
male adult	6	25.56		5	10.47		4	12.69	16
female student	32	18.06		20	6.85		25	6.30	8
female adult	18	21.39		17	9.27		11	10.86	11
TOTAL									
male student	21	83.41		12	137.80		10	17.58	48
male adult	6	25.56		5	15.19		4	24.49	55
female student	32	38.70		20	34.57		25	28.95	47
female adult	18	24.01		17	11.58		11	25.88	51

Appendix Table 1: Average student and adult exposure to microparticles per day at initial, post-presentation, and twelve month surveys.