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Research on the Carbon Footprint Impact of Using Individual Plastic Bottles in Orienteering Events in China

Yihan Wang

[1]Experimental High School Attached to Beijing Normal University, Beijing, 100032, China

qiaoningyuan@ldy.edu.rs

Abstract:

Global warming is nowadays seriously affecting people's production and life and causing great harm to the natural environment. The main cause of global warming is the greenhouse effect, which is due to the emission of greenhouse gases into the atmosphere. As a measure of an activity's contribution to global warming, the calculation of carbon footprint is essential. In China orienteering events, single-use bottled water is widely used as post-race supplies, which generates a large amount of carbon emissions and carbon footprint. However, although bottled water is convenient, this consumption is still unnecessary, since there are other efficient alternatives. In this paper, the author discusses the possibility of changing the water supply strategy and method for orienteering events in China. Comparing the basic information and carbon footprint results produced by bottled water, barrel water and tap water, the author concludes that plastic materials required for barrel water are much less than bottled water since bottles own larger surface area than barrels when containing same amount of water. The author also summarizes that single-use bottled water system produces much more carbon footprints than municipal tap water system does due to the former one's more complex and energy consuming process. In conclusion, the author considers that replacing single-use bottled water with barrel water and recycled cups or tap water is promising and has great benefits for the environment.

Keywords: carbon footprint, bottled water, global warming.

1. Introduction

Global warming, associated with greenhouse effect, has caused a huge harmful impact on the environment and human societies. Some molecules released to the atmosphere, such as CO_2 and water, intercept the outgoing infrared radiation (IR) reflected by the Earth surface and dissipate it as heat to increase the temperature of the atmosphere [1]. In other words, the outgoing IR is absorbed by greenhouse gases and is converted to heat. The increasing temperature leads to the disappearance of the habitats of animals, causing their extinctions, and poses risks to human's survival. Intergovernmental Panel on Climate Change (IPCC) reports has shown that the abnormal increasing temperature attributes a lot to people's activities rather than natural fluctuation [2]. The Paris Agreement called international efforts to limit the global temperature increase to well below 2 degrees Celsius above pre-industrial levels, with an additional aspiration to cap the increase at 1.5 degrees Celsius. Therefore, the calculation of carbon footprint seems an important measurement to measure to what extent that human activities will affect the world and contribute to global warming. Carbon footprint measures an obvious and direct effects of an activity, but when relating an activity to its environmental impact, global warming potentials (GWP) should be considered carefully in the calculation of carbon footprint. GWP is a direct indication of the extent that a green gas or a substance contributes to global warming.

The use of bottle water is still growing despite improved quality of drinking water in water distribution systems due to its convenience [3]. Bottled water consumption is increasing annually by 7% on average worldwide [3]. As per a 2021 report, the global bottled water market was valued at $198 billion in 2017 [3]. Recent data indicates that one million plastic bottles are sold every minute worldwide, with a projected 20% increase by 2021[3]. In 2016, over 480 billion plastic drinking bottles were sold globally, representing a nearly 60% increase compared to a decade earlier [3]. According to the latest information from Euromonitor International's global packaging trends report, this number is expected to rise to 583 billion by 2021 [3].

In most orienteering events, bottled water is provided as a common supply after a single competition [4]. All participants can gain one water supply in plastic bottle after completing score bars of their competition, no matter it is sprint, middle distance, long distance, sprint relay or relay. The bottled water is provided freely and without charged. In China, dozens of cases of bottled water are produced, transported, given out and discarded to satisfy the demand of hundreds of people, including athletes, referees, coaches and audience, which is a huge consumption and a great release of carbon dioxide.

However, there may be some substitutions of bottled water, such as a barrel of water with recycled cups or direct drinking water with people's own drinking cups. In some international orienteering competitions, such as Junior World Orienteering Championships, athletes are provided paper cups to get water from a barrel of water, which reduces the discard of plastic products. The author views this approach and tap water as promising substitutions in the future development of China's orienteering events.

Now, in China, because of the service awareness, organizers hope to give the participants best experiences, and huge number of participants, a considerable amount of provided water seems unavoidable. In order to be more convenient, most orienteering events provides a plastic-bottled water to every athlete, referees or visiting guest. This leads to an abundant discard of plastic bottles when serving a certain amount of water. Hundreds of bottled water is consumed in one events. The carbon emissions and carbon footprints of each plastic bottle accumulate to make a huge impact.

Based on the datasets, the carbon footprint and CO_2 emission of a barrel of water is much less than plastic bottled water when providing same amount of water to people. Especially in the process of production and recycling (processing). The similar difference is also shown on the compare between single-use bottled water and tap water: tap water owns much less carbon footprints due to its simpler and less energy-consuming steps. Therefore, it is promising to replace plastic-bottled water with a barrel of water or tap water in order to reduce total carbon footprints of Chinese orienteering events.

2. Methods

2.1 The Methods of Carbon Footprint Calculation

The Life Cycle Assessment (LCA) is a crucial and systematic method used to thoroughly assess the environmental effects of products, processes, or services throughout their complete life cycle [5]. This approach meticulously examines all phases, including raw material extraction, production, transportation, use, and eventual disposal or recycling [5]. Providing a comprehensive viewpoint, LCA reveals the environmental impact associated with a particular product or activity [6].

The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product [7]. The carbon footprint of an activity is calculated by multiplying the activity data by the emission factor for that activity [8]. Then, the total carbon footprint is calculated by summing the individual carbon footprints for all activities in equation [8].

$$\text{Carbon Footprint} = \Sigma \text{Activity Data} \times \text{Activity Emission Factor} \quad (1)$$

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Global warming potential (GWP) is a measure of how much heat a greenhouse gas traps in the atmosphere over a specific time compared to a similar mass of carbon dioxide (CO_2) [9]. CO_2, with a global warming potential of 1, is used as the base figure for measuring global warming potential [9]. The higher the global warming potential number, the more heat a gas traps [9]. When calculate carbon footprint and carbon emission of an activity, it is important to use the correct GWP of measured gas (CO_2).

It is important to mention that polyethylene terephthalate (PET) is the most commonly-used plastic of producing containers of packed drinking water. It takes 400 years to naturally decompose in the nature [3]. Although PET is highly recyclable, just 7% of them are being recycled [3]. However, because of its low cost, easy transportation, low weight, and high resistance, PET is widely used [3].

2.2 The Compared Data of Single Plastic Bottles and a Barrel of Water

2.2.1 Basic information of bottled water and barrel water

Table 1 shows the volume, surface area and the amount needed in 1000 gallons for a single plastic bottle and a barrel of water. The volume of a barrel of water is way larger than that of a single bottle of water. Although the surface area of a barrel is larger, the number of barrels needed in 1000 gallons is much smaller than the number of bottles needed in 1000 gallons. Therefore, raw materials needed for single-bottled water will be much more than that of the production of barrels of water, and thus more carbon emissions.

Table 1. Basic information of bottles and barrels as containers for water

	A single bottle of water	A barrel of water
Volume (gallons)	0.132	5
Surface area (m^2)	0.03643	0.4644059
The amount needed in 1000 gallons	7575.76	200

2.2.2 The carbon footprints of bottled water and tap water

2.2.2 .1A case study specific to Italy water supply system

In a case study comparing the integrated footprints of tap water and bottled water in Italy, the researchers compare the carbon footprints of the public water available in Siena (Italy), called tap water, and pet-bottled natural mineral water [10]. In addition, the functional unit is a volume of water of 1.5 L [10]. The research points out that the average carbon footprint of bottled water value was about 0.26 gm^2 [10]. The major contribution came from the carbon footprint of materials used in packaging (0.198 CO_2 eq kg, 76% of carbon footprints of bottled water) [10]. Another two contributions to total carbon footprints of bottled water was carbon footprints of transportation and energy-use [10]. The research finds that higher carbon footprints of bottled water values were related with lower volumes of water bottled per year [10]. By contrast, the carbon footprint of tap water was 9.10E-04 CO_2 eq kg [10]. The carbon footprint of energy-use (mainly the production of electricity) mostly affects the carbon footprint of tap water (97.19%) [10]. It is easy to conclude from the study that the carbon footprint of tap water is much lower than the bottled water, and water packaging in larger containers may produce less carbon footprint than that packaging in smaller containers.

2.2.2 .2 A more general research

All calculation processes encompass the delivery of plastic-bottled, single-used water in 500 ml to consumers.

In Table 2 below, variant 1 represents regional sales of 1000 gallons bottled water [6]. The distribution network is limited to 100 miles of transport from the bottler to a distributor, 20 miles of transport from the distributor to a retailer and 8 miles of transport from the retailer to arena [6]. In this case, spring water is packaged in a virgin PET bottle and disposed by landfilled [6]. Variant 2 represents national sales of bottled water [6]. The distribution network is limited to 1500 miles of transport from the bottler to a distributor, 20 miles of transport from the distributor to a retailer and 8 miles of transport from the retailer to arena [6]. In this case, spring water is packaged in a bottle that incorporated 25% recycled PET (rPET) and disposed by landfilled [6]. Variant 3 represents national sales of bottled water [6]. The distribution network is limited to 6300 miles of transport from the bottler to a distributor, 20 miles of transport from the distributor to a retailer and 8 miles of transport from the retailer to arena [6]. In this case, spring water is packaged in virgin PET and disposed by landfilled [6].

Table 2. Carbon footprints of single-use bottled water system

Carbon Footprints (kg CO_2 eq)			
	Varient 1	Varient 2	Varient 3
Container Production	571.8 [6]	506.9 [6]	571.8 [6]
Bottling Operations	40.2 [6]	40.2 [6]	40.2 [6]
Distribution	159.6 [6]	737.1 [6]	1248.8 [6]
Consumer Transport	19.1 [6]	19.1 [6]	19.1 [6]
End-of-Life (ctrs, pkng)	26.8 [6]	2.8 [6]	26.8 [6]
2º Pkng Production	108.1 [6]	108.1 [6]	108.1 [6]
Total	925.7 [6]	1414.2 [6]	2014.8 [6]

In the Table 3, the carbon footprint is measured under the conditions: 1000 gallons tap water is served in a reusable stainless steel 18 oz [6]. The bottle is transported 6570 miles plus 1500 miles of truck travel to reach the arena, and the steel bottle is subject to 63.3% recycling and 36.7% land fill disposal at the end of its useful life [6].

Table 3. Footprints of municipal tap water system

Carbon Footprints (kg CO_2 eq)			
Municipal Water Treatment	5.21 [6]	Municipal Water Treatment	5.21 [6]
Reusable ctr	2.39 [6]	Reusable ctr	2.39 [6]
Washing (residential)	54.93 [6]	Washing (residential)	54.93 [6]
Total	62.53 [6]	Total	62.53 [6]

Comparing the carbon footprints of single-use bottled water system and municipal tap water system, the author concludes that most phases of municipal tap water system produce less CO_2 emissions than single-use bottled water system. Also, the steps are fewer in the second system, which results in fewer factors that contributes to the results. In comparable distance of distribution, variant 3 in single-use bottle system has a carbon footprint of 2014.8 kg CO_2 eq. However, the municipal tap water system only has a carbon footprint of 62.53 kg CO_2 eq. Although there may be some reasonable error in the calculation, the former system is indeed producing much more carbon dioxide emissions than the later one.

3. Results and Discussion

3.1 Results of LCA

As the Fig.1 shown, the life cycle system of single-use bottled water begins with material production. During this process, raw materials are extracted from the earth and transformed into the desired finished materials [6]. Then, it goes into container fabrication process [6]. Finished materials (mainly PET in the case of plastic-bottled water) undergo fabrication processes that convert them into containers [6]. During the bottling operation, water treatment, container filling and packaging of individual bottles into packs are finished [6]. Then the distribution or delivery process includes the travel from the bottling plant to a distribution facility, travel from the distributor to a retailer and travel from retailer to the competition arena [6]. The distances and modes of travel are varied in different situation, but most packages are transported by trucks or cars [6]. This involves the distribution of 1000 gallons of water.

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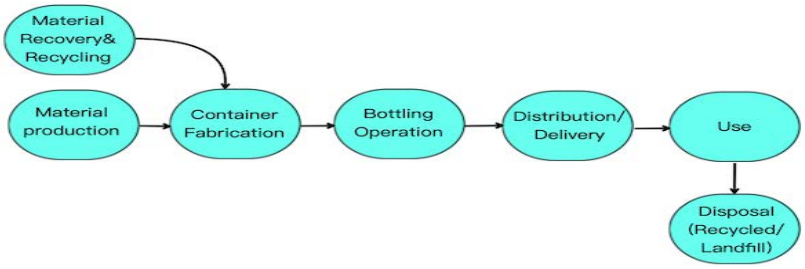

Fig. 1 The LCA of single-used bottled water system

As shown in the Fig.2, the life cycle system of municipal tap water begins with the conversion of raw materials into finished materials. The raw materials are extracted from the earth and transformed into the desired finished materials [6]. This phase represents the material production activities for the reusable drinking vessel (stainless steel, glass) and cap (polypropylene) [6]. During the fabrication phase, finished materials undergo fabrication processes that convert the materials into containers. This phase includes stainless steel container fabrication, PP injection molding to produce cap and class fabrication [6]. The water treatment and distribution treatment encompass the treatment at a municipal water treatment plant and the distribution of 1000 gallons of drinking water to a consumer household [6]. The life-cycle impacts associated with more frequent washing in washing-residential process [6]. In addition, the disposal burdens of disposal phase include those associated with transportation from consumer to final disposal and process related burdens [6].

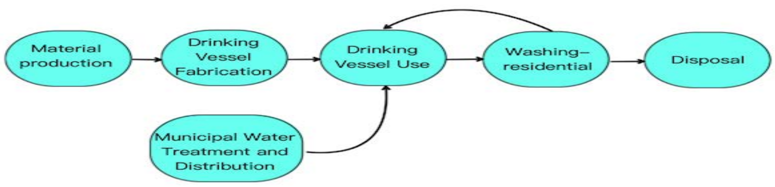

Fig. 2 The LCA of municipal tap water system

3.2 Comparison of Results in This Research with Other Ones

Although different researches and studies are done in different cases, the results and conclusions are similar [6, 10, 11]. The carbon footprint of tap water is much lower than that of bottled water, and the carbon footprint may increase as the volume of containers of water decreases because of the increasing need of plastic materials. When people relate water supply system with global warming, the carbon footprint of bottled water is obviously higher than that of tap water.

4. Further Trends and Suggestion

4.1 The Introduction of European Orienteering Events

Since orienteering springs from Northern Europe, it has developed for longer time there. As a result, many famous large-scale orienteering events are held in Scandinavia, such as the Jukola Relay, the O-Ringen in Sweden and the Swiss Orienteering Week. These large events held every year attract a large number of athletes and participants. Often thousands of people are involved in the organization, the progress process and the closing of the event. Some events last several days and include several events on different days. At the same time, the organizers have to provide water supplies for these thousands of participants, where one bottle of mineral water per person seems to be a huge consumption and is not practical at the same time. Therefore, in some events, the event organizers provide a tap water system and ask the athletes and participants to bring their own cups to catch the water. Another option is to use barrels of water and recyclable paper cups, along with a large number of sorting garbage cans at the venue, to control the carbon footprint and emissions generated.

4.2 The Possibility of Improving or Changing the Strategy of Water Service in Chinese Orienteering Events

In fact, changing the way water is now supplied to orienteering events in China is a big challenge. First, the use of bottled water is very convenient for both organizers and participants. Mass-produced cases of bottled water are easy to load and unload, easy to transport and easy to distribute within the venue. And it requires very little in the way of facilities: only a space is needed for cases of mineral water rather than piped water. If the water is supplied from the tap, it would be difficult to invest in a major renovation for a race in a remote area. Secondly, Chinese participants are now accustomed to receiving a free bottle of mineral water as a post-race supply, a habit that is difficult to change. Thirdly, people do not fully understand and accept the importance of reducing the use of bottled water, so they will be indifferent to such a change.

For the option of using barrels to replace bottled water, the author believes it is very feasible. According to the previous analysis, barrels of water use far fewer materials than bottled water for the same amount of water supplied. This would be a great benefit to the environment. At the same time, barrels of water are not very different from bottled water in terms of transportation and can be carried by trucks, minivans, and manpower. Barrels are also similar to bottled water in terms of space and facility requirements. Barrels of water can also be used conveniently on the race course. All that is required is the use of a pump to draw the water out of the vat into a paper cup. Therefore, from the point of view of operational difficulties, bucket water has great prospects.

In the case of the municipal tap water system, the application conditions are more demanding and require the presence of a water supply line. Therefore, it is more difficult to implement for remote areas (e.g. mountains, suburbs, etc.). However, for urban parks and other areas with well-developed water piping systems, people can enjoy unlimited water supply at the race course by simply placing their cups in the race packet before starting the race. Therefore, this method is promising as well, despite the limitations of its implementation.

5. Conclusion

Based on the tables and figures above, compared with barrel water, bottled water may produces much more footprints and owns higher demand of materials used in packaging water. Compared with tap water system, single-use bottled water system involves in more steps, and each step has a much higher results than that of tap water systems, which means single-use bottled water contributes to the global warming in relatively larger extent than tap water system does. The author believes that using barrels to replace bottled water is very feasible and environmentally beneficial. Barrels use far fewer materials than bottled water for the same amount of water supplied, making them a great option for the environment. They are also easy to transport and can be used conveniently on race courses with the use of a pump. However, implementing this method in remote areas may be more challenging due to the need for a water supply line. On the other hand, municipal tap water systems require well-developed water piping systems but offer unlimited water supply in urban parks and other areas. Despite some limitations, this method shows promise for providing water at race courses by simply placing cups in race packets before starting the race.

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