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Consumption of chilled water stored in a PET bottle multiple times:

ARE WE QUENCHING THIRST OR GULPING PHTHALATES?

Another Pandora's box opened:

The statistics forecast that the production of polyethylene terephthalate (PET) bottles worldwide in 2016 was about 485 billion, and the same in 2021, has been approximately 583 billion. Although such productions in many countries have the ear of prominent political and social leaders, high production rates still reign the global market. In parallel, revered scientists globally conflate plausible and incontrovertible medical canons against the use of PET bottles for the protection of public health. Nevertheless, unwashed masses worldwide dislodge or disparage such public health doctrine but face a myriad of health hazards. For many years, mainly beneath the public's ignorance, the solid collective rhetoric expressed by PET-bottle manufacturing companies has not let such medical dogma take hold in the society, instead purposefully manipulated the market with conflating pure baloneys or fallacies.

One of the firmly believing health-related doctrines against the use of PET bottles would be the migration of phthalates – commonly added as plasticizers to PET during manufacturing. Since the phthalates are not covalently bonded with the polymers that make up the plastic bottle, phthalates could easily detach from the bottling materials and migrate to bottled water under adverse environmental and storage conditions. Phthalates composed of high molecular weights (e.g., di(2-ethyl-hexyl) phthalate - DEHP) are suspected carcinogens and are toxic to organs such as the liver and kidneys. Further, phthalates are lipophilic compounds with increased solubility in lipids, which enhance the adverse effects on human organs. Such compounds and their metabolites can, on the other hand, induce detrimental effects on the reproductive system with negatively affecting semen volume and positively affecting sperm malformation.

Despite such health hazards, quenching thirst with chilled potable water stored in PET bottles has been a global scenario, particularly in tropical weather conditions. In many developing countries, people reuse PET water bottles many times because of convenience, ease, and scarcity of lightweight water carrying containers. Further, the lack

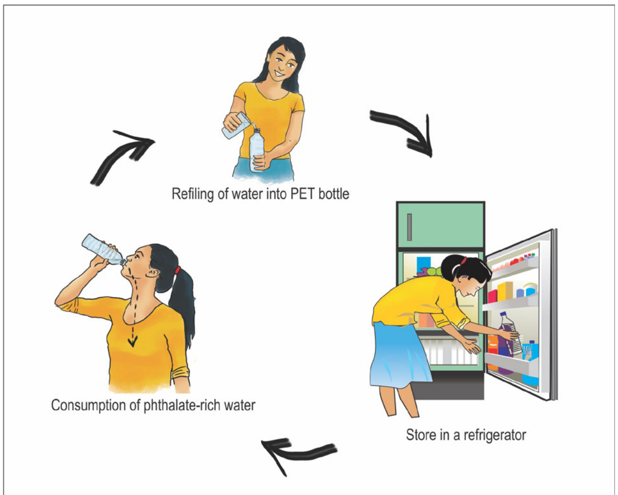

Figure 1. Cycle of refilling potable water into a PET bottle

of awareness on the associated risks of reusing PET bottles does not prevent people from practicing such unhealthy efforts. In many tropical countries, the prevalence of prolonged high temperatures associated with elevated humidity levels persuades people from consuming chilled water to quench thirst. People often consume chilled water stored in the same PET bottles multiple times, and practice of this kind is observed with a majority of the working population, particularly in Sri Lanka (Figure 1). Such a phenomenon has not yet been investigated in detail; hence, this study.

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Our line of actions – something that has never been experimented by anyone

We obtained the PET water bottles of two commercial brands (500 mL) available in the local market, emptied the water in them, and refilled them with phthalate-free potable water from a shallow dug-well. Two desired temperatures (27±2 °C and 4±2 °C) were selected for the study based on the common practice of reusing the PET bottles in Sri Lanka (One to simulate the ambient temperature and the other to represent chilled conditions). After six hours of contact time under each temperature condition, refilled water in bottles was taken out, and a liquid-liquid extraction method was followed to extract the phthalates from the respective water samples. The bottle, as mentioned earlier, refilling and the phthalate extraction procedure was repeated for additional five consecutive identical reuse events using the same phthalate-free water in triplicate. After each reuse effort, refilled water was emptied from the PET bottles, and they were air-dried before the next reuse event. During every reuse event, a control experiment was also conducted in triplicate using glass bottles refilled with the same well water to confirm that the water used to refill the bottles during the experiments was not contaminated with phthalates. We then analyzed six phthalates: DMP, DEP, DBP, BBP, DEHP, and DnOP using a Gas Chromatograph coupled with Mass Selective Detector (GC/MS). We also investigated possible changes of main functional groups of bottled materials during the refilling and reuse events using Fourier transform infrared (FTIR) spectroscopy. Also, we were inquisitive to investigate the possible spillover of materials from the bottles under each reused event using a Scanning Electron Microscope (SEM). We did not forget to estimate carcinogenic risks associated with the whole experiment.

Our disclosure – a smoking gun or a technical critique

Among six phthalate compounds tested, only DEHP was detected in the levels greater than the detection level for every reuse event. Our results manifested copious traces of DEHP in both brands after every event of reuse (Figure 2).

In the practical sense, what it triggers is that when a healthy person consumes 3.0 L of chilled water for a given day, he will ingest about 74.4 and 96.6 μg of DEHP from brands 1 and 2, respectively. Assuming a person with a bodyweight of 25 kg (probably, a child) consuming chilled water, if we put these levels in the form of comparable norms with permissible levels, these values then come down to 3.0 and 3.9 μg/kg.bw/day for brands 1 and 2, respectively. Conversely, most European and North American countries report that DEHP levels in bottled water, when used only for one time under different storage conditions, are incredibly lower (<0.2 μg/kg.bw/day). In contrast, the tolerable daily intake (TDI) for DEHP established by the European Food Safety Authority is 50 μg/kg.bw/day, which is estimated for a bodyweight of 70 kg. One can be complacent that this scenario guarantees that no acute health hazard is plausible by quenching thirst with

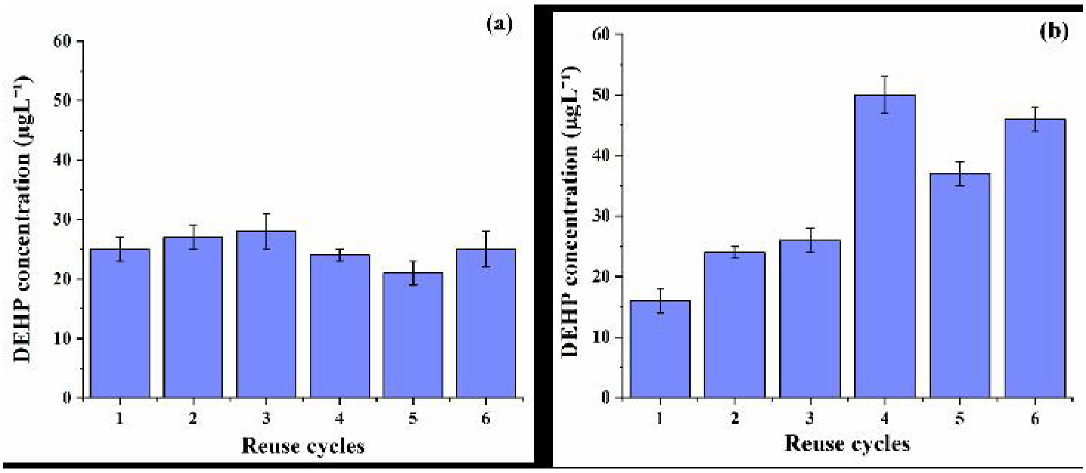

Figure 2. DEHP levels in refilled water in PET bottles of (a) brand 1 and (b) brand 2 after each reuse event with chilled water at 4±2 °C

chilled water stored in PET bottles. However, this hindsight from today's perspective is conspicuously inconclusive, and there exist many yawning gaps in understanding the biochemistry of such material and their fate at the human cell level.

Another argument that can be laid out is that micro- and nano-plastic particles are detached from the inner walls of the bottles when subject to repeated temperature-drop events. Figure 3 shows tell-tale signs of such detachments from the inner surfaces of both brands after six rounds of reuse events. Such detachments were also confirmed with FTIR spectra by way of diminishing functional groups of virgin PET bottles (data not shown for the brevity of this feature article).

Our assertions mentioned above then become ludicrous and need to be revisited because the actual DEHP ingested in dissolved form is attributed to another fraction of solid form, which we have stunningly underestimated or unknown. Our simple scientific critique is that, in total, one may gulp DEHP in higher quantities than one may imagine at all, with actual health consequences being far more severe. In pursuit of this mind-boggling rid-

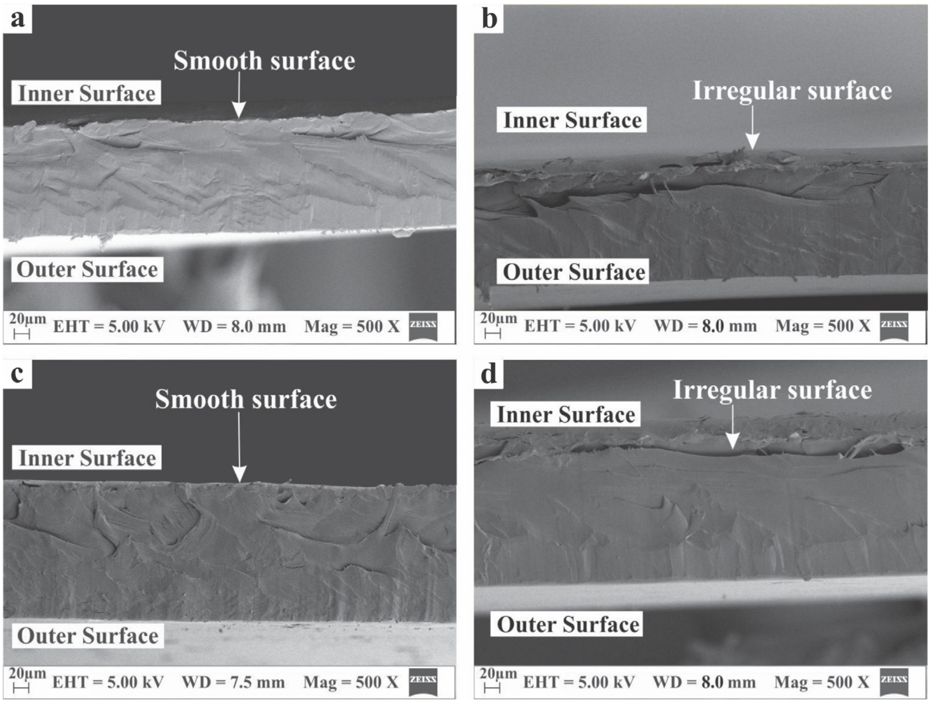

Figure 3. SEM cross-section morphologies of brand 1 (a) before reuse (b) after six consecutive reuse events with water at 4±2 °C and of brand 2 (c) before reuse (d) after six consecutive reuse events with water at 4±2 °C

dle, one has to establish the maximum DEHP levels inserted in manufacturing PET bottles. The chronic cancer risk evaluation revealed that there is no incontrovertible evidence on the likelihood of inflicting cancer. Still, yearslong consumption certainly creates an inkling in one's mind to do away with such habitual practices.

Our message to the society – a stirring rallying call

A defining mark of any good piece of scientific work would be going to great pains to establish a story that would uncover the crux of the unknown enigma, at least with reasonable conjectures than throwing out thick clouds of obfuscation. We, with this study, observed a stirring rallying call against the consumption of chilled water stored in a PET bottle multiple times. Our findings asserted that the reuse of empty PET bottles multiple times for chilled water storage should be averted altogether. The daily phthalate ingestion by a Sri Lankan is more than ten times the same recorded in developed countries. We, therefore, constantly ensue a high-stakes uproar against the use of PET bottles for storing any beverage in Sri Lanka. Our humble request for the scientific fraternities of this country is to remain proactive against the use of PET bottles rather than largely being off-limits. We, then, only believe that the beaming light will shed to stem the infusion of PET bottles into the Sri Lankan market – even not a single bottle in a remotely located, scruffy boutique in sight – in the foreseeable future.

Article by
Mahesh Jayaweera[1], Hasini Perera[2],
Gimhani Dhanushika[1], and Buddhika Gunawardane[1]
[1]Department of Civil Engineering, University of Moratuwa, Sri Lanka.
[2]Department of Forestry and Environmental Science,
University of Sri Jayewardenepura, Sri Lanka.