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Trash to energy: A facile, robust and cheap approach for mitigating environment pollutant using household triboelectric nanogenerator

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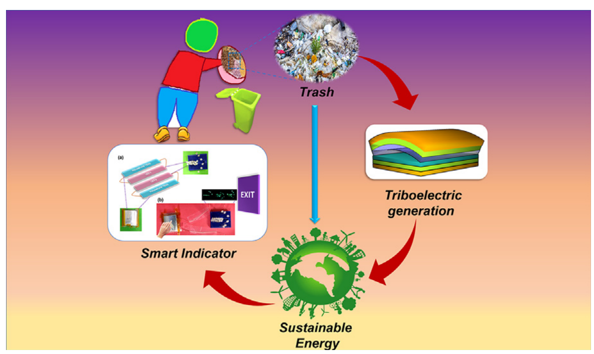
HIGHLIGHTS

- Circumvention of plastic pollution using H-TENG.
- Fabrication is straightforward, cheap and needs < 5 min.
- All the materials used in the fabrication are recycled waste materials.
- Fabrication is possible at any place without the need for scientific equipment.
- Demonstration of the biomechanical energy harvesting, emergency direction system, etc.

GRAPHICAL ABSTRACT



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ABSTRACT

The plastic pollution often observed on seashores is indicative of a greater problem manifesting in the oceans. However, such pollution mostly emanates from land-based sources. To help mitigate the problem of plastic pollution, we describe herein a waste material-based household triboelectric nanogenerator (H-TENG) that operates in the vertical contact-separation mode. The device takes less than 5 min to fabricate and can be made in-house from recyclable materials without the need for scientific equipment or laboratory expertise. The device was made using randomly selected waste materials. The maximum peak-to-peak voltage generated was 44 V, and the corresponding peak-to-peak short-circuit current (I_{SC}) generated was 289 nA. The H-TENG was systematically studied and showed the capability to exploit biomechanical energy to operate liquid crystal displays (LCDs) and light-emitting diodes (LEDs). Furthermore, we demonstrated how the H-TENG could be used as a dynamic force sensor for small dynamic force detection. Finally, we discuss applications of H-TENGs in an in-house emergency direction system, security system and a magnetically attachable/detachable smart chopping board.

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1. Introduction

Plastic waste is currently one of the greatest environmental threats. It is present in all marine environments, ranging from the sea floor to coastlines to the open ocean, and is even found in Arctic Ocean ice [1]. Recent studies have provided evidence that plastic waste accumulates in organisms and may cause the death of marine life and sea birds [2]. A previous review reported that plastic waste in the order of thousands of tons covers the surface of the open oceans [2]. Data collected in the year 2010 from coastal countries indicated that of 275 million megatonnes (MT) of plastic waste produced, 5–12 million MT entered the ocean [1]. Furthermore, only a small proportion of plastic waste is recycled, with most of the waste being dumped in landfills and water. Such disposal methods constitute a significant threat to the environment. Fig. 1 shows global statistics for the generation of plastic waste and the harm it causes to taxa of the ocean [1]. Recently, Orb Media reported test results for 159 samples of drinking water obtained from cities spread among five continents [3]. Of the 33 samples obtained from the United States, 31 contained plastic fibres. The Orb Media data showed that, worldwide, plastic fibres were present in more than 70% of the samples. For example, plastic fibres were found in 82, 81, 76, 75 and 72% of the samples obtained from Delhi (India), Kampala (Uganda), Jakarta (Indonesia), Quito (Ecuador) and Europe, respectively. On the other hand, population growth has led to a sudden increase in global energy demand resulting in the energy crisis. Natural resources are insufficient to meet the energy requirement because they take hundreds to thousands of years to replenish. So, it is of utmost importance to develop an efficient and sustainable energy harvester that can utilize the plastic waste for the generation of energy. In our day to day life, a surplus amount of mechanical energy is producing through physical activities. If we develop an efficient device to harvest the waste mechanical energies through unconventional approaches will pave the way for generating pollution free, eco-friendly and user required electrical energy. Universally, these unconventional energy harvesting devices are the future technologies to partially solve the world energy crises, global warming issues, saving natural fossil fuels and controlling carbon emissions.

The development of the triboelectric nanogenerator (TENG) by the group of Z.L. Wang has revolutionised the field of energy harvesting. Mechanical energy is ubiquitous and includes wind, wave and biomechanical energy [4–10]. The TENG uses triboelectrification coupled with electrostatic induction to harness mechanical energy and can operate in four different modes, i.e. vertical contact-separation, freestanding layer, lateral sliding and single electrode modes [11–14]. In the vertical contact-separation case, an applied force brings two triboelectric materials into frictional contact with each other, which results in oppositely charged surfaces. Upon removal of the external force, the electron cloud shared between the electrodes redistributes unevenly, resulting in the generation of a potential difference between the electrodes. This can be harnessed to generate electrical energy via an

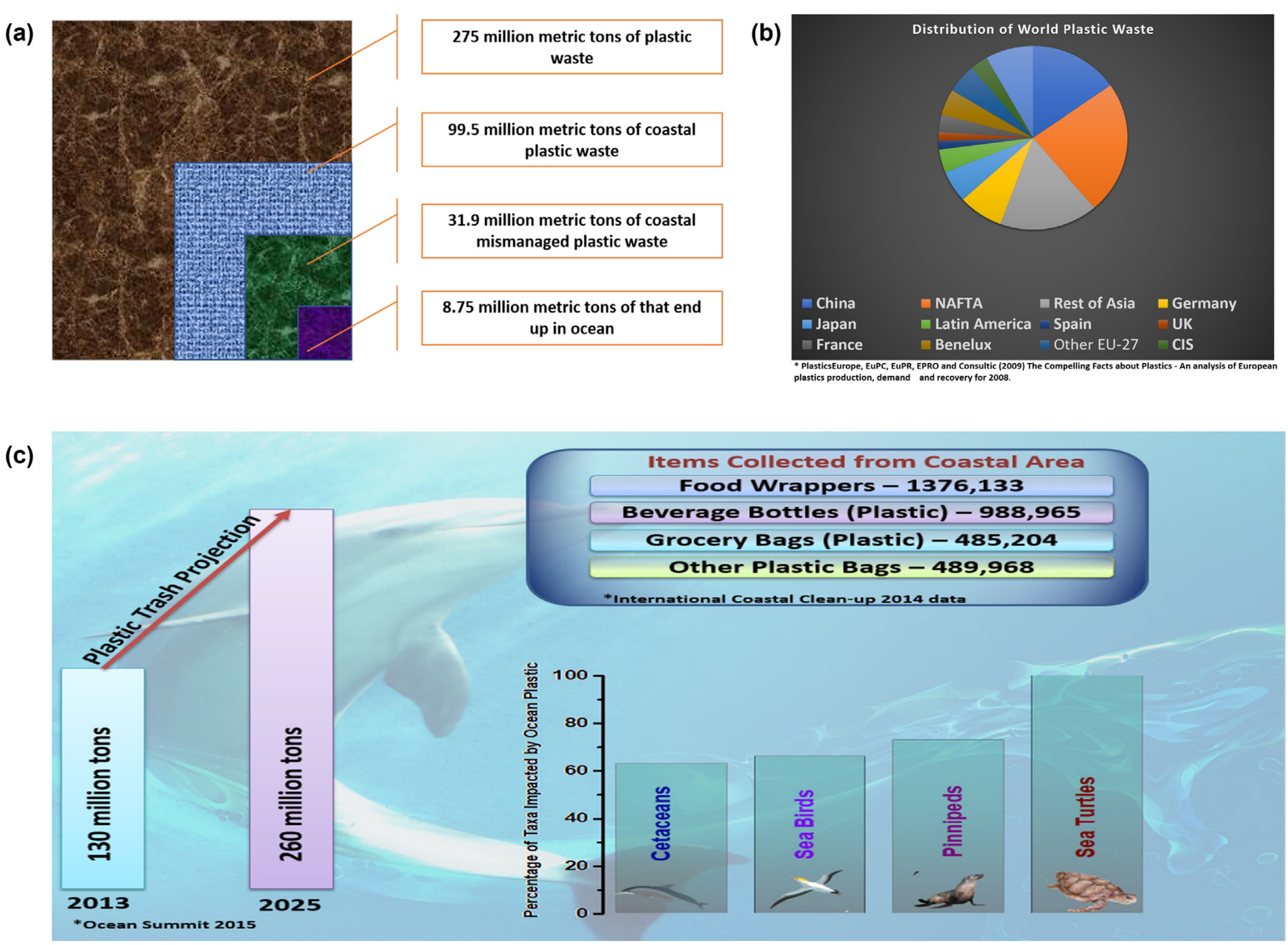

Fig. 1. Global statistics for generated plastic waste. (a) The proportion of plastic waste reaching the ocean relative to the total plastic waste produced. (b) The distribution of plastic waste in different countries according to PlasticsEurope, EuPC, EuPR, EPRO and Consultic (2009). (c) Projection of plastic waste production according to Ocean Summit 2015, plastic items collected from coastal areas according to international coastal clean-up data for 2014, and the number of taxa affected by plastic waste that reaches the ocean.