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Review

Message in a bottle – The story of floating plastic in the eastern Mediterranean sea

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ABSTRACT

The Mediterranean Sea is a closed basin with limited water exchange through the Strait of Gibraltar, and sites along its shores show the greatest densities of marine debris in the world. Plastic bottles, which are a growing concern due to high consumption of soft drinks and bottled water, constitute most of the floating marine debris. In this paper we present the transport mechanisms of floating marine debris to and from the Israeli coast using an experimental offshore release and recovery of plastic bottles, with the participation of citizens. Many bottles released near the beach in the south part of Israel, returned to the beach at a short distance and time from the release point. Some release locations had no bottle returns. Ten bottles, released from three locations, were recovered many dozens to hundreds of kilometers from the release point. Since most of the westward water flow in the eastern Mediterranean is subsurface, it was not surprising to find our floating debris only in the east. That makes the Levant basin in the eastern Mediterranean a collection area for floating debris.

1. Introduction

According to the U.N. World Health Organization, the daily recommendation for water consumption is about three liters of water per day for men and two liters for women (Grandjean, 2004). In semi-arid countries, like Israel, people often carry with them water or beverages when going to work, school, and sport activities. Plastic bottles, mainly made of polyethylene terephthalate (PET), are convenient portable devices for these liquids, but present environmental and waste management challenges (Duis and Coors, 2016), even when doing what is considered the best solution – recycling bottles and turning them into fleece (Duis and Coors, 2016; Pirc et al., 2016). Discarded plastic bottles are also considered a problem in the marine environment, either accumulating on the bottom of the sea, floating/drifting in the water column, or as part of debris littering beaches (Galgani et al., 2015), and may turn to microplastic.

Since the 1970s, the plastic bottle industry has grown worldwide, and plastic has become one of the most commonly used packaging methods. In 2007 global demand for plastic bottles totaled 15 million metric tons, representing 8% of total demand for plastic. The extent of bottle recycling on the European continent grew to an average of 40% of all produced bottles in 2009. Coca-Cola has set itself a target to increase the collection percentage of the plastic bottles it sells in developed markets from 50% today to 75% in 2020 (Calvão and Ashkenazy, 2014), and has recently announced a pledge to recycle a used bottle or can for every one the company sells by 2030 (BBC, 2018).

Israel has two laws to address the waste management issue of beverage containers: Deposit on Beverage Containers Law and Packaging Law. The Deposit Law states that on each beverage container smaller than 1.5 L, regardless of material, the consumer will pay a deposit of about 10 cents (0.3 New Israeli Shekel), which will be refunded upon return of the empty container to a collection point. In 2012, about 700 million big beverage containers (i.e., containers larger than 1.5 L) were sold in Israel, of which, according to ELA Recycling Corporation (nonprofit organization to promote the recycling of drink containers in the state of Israel) about 48% or 335 million containers were collected through some 22,000 recycling bottle reception facilities deployed on streets. According to the

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Israel Ministry of Environmental Protection, the amount of recycled large bottles indicates that the public attaches greater weight to the convenience of recycling, given the availability of reception facilities, than returning the bottles for the deposit (Zaban et al., 2014).

Along the Israeli coast, 3% of the marine debris is plastic drinking bottles, with big bottles 6.3 times more abundant than bottles smaller than 1.5 L. (Pasternak et al., 2017). While 3% is a low proportion compared to the global scale where plastic bottles are 10% of the marine debris (Ocean Conservancy, 2016) and 14% of the Mediterranean debris (UNEP, 2015), many of the bottles found on the Israeli coast are seaborne (Pasternak et al., 2017). We have limited knowledge of how wind- and wave-induced onshore and offshore currents might move debris. To date, most current models have been developed at large scales (global, ocean, or basin), and there is a need to develop localized models to better understand near-shore transport mechanisms of marine debris at scales relevant to management, such as state or national levels (O'Shea et al., 2014). In the Mediterranean, circulation features in local coastal areas have recently been measured using drifters off Spain (Poulain et al., 2013).

The objective of the present paper is to reveal the transport patterns of floating marine debris to and from the Israeli coast using an experimental offshore release of plastic bottles. Mediterranean sites show the greatest densities of marine debris owing to the combination of a densely populated coastline, considerable marine vessels transportation in coastal waters and negligible tidal flow. Moreover, the Mediterranean is a closed basin with limited water exchange through the Strait of Gibraltar (UNEP, 2011; Galgani et al., 2015; Zaban et al., 2014). Like Ebbesmeyer et al., (2007), who used plastic bathtub toys and other cargo lost at sea to characterize ocean currents and estimate the orbital period of a large gyre, we chose plastic bottles to represent floating marine debris, which is mostly plastic (Suaria and Aliani, 2014), similar to the study of Leal (2011) in Brazil, and Israel represents the eastern Mediterranean coast. The experiment was designed as a citizen science experiment in order to gain information from remote coasts and to raise public awareness about the marine debris issue (Pattengill-Semmens and Semmens, 2003; Thiel et al., 2014; Branchini et al., 2015; Cigliano et al., 2015; Hidalgo-Ruz, and Thiel, 2015; Theobald et al., 2015; Cerrano et al. 2017). A "message in a bottle" was used to generate attention: a bottle washed ashore carrying a "mysterious" note was always an opportunity to connect with people from faraway places.

1.1. Hydrographical setting

1.1.1. The Levantine Sea

The Mediterranean Sea is a mid-latitude, partly closed sea, connected to the Atlantic Ocean by Gibraltar Straits, to the Black Sea by Dardanelle Straits, and to the Red Sea through the Suez Canal.

The eastern Mediterranean Sea (east of Italy) can be divided into four sub-seas or basins (from west to east): the Adriatic, the Ionian, the Aegean and the Levantine seas (El-Geziry and Bryden, 2010) (Fig. 1). The Levantine Sea is characterized by hot, dry summers with stable atmospheric conditions, cold, wet winters and relatively short transitional seasons in spring and autumn (Kit and Kroszynski, 2014). The seasonal mean winds are mainly westerly, although migratory low-pressure systems moving eastward across the Mediterranean Sea (Alpert et al., 1990) force downwelling-favorable, strong southerly to southwesterly winds along the Israeli coast (Rosentraub and Brenner, 2007). During transition seasons, the Red Sea Trough, a tongue of low pressure originates in the Sudanese-Ethiopian "low", extends northward from the southern Red Sea towards the Eastern Mediterranean and the Levant, at lower atmospheric levels (Krichak et al., 1997).

In the Levantine Sea, the water surface flow from the Atlantic Ocean loses buoyancy through heat release into the atmosphere and an evaporation / precipitation deficit and reduces the stability of the water column which becomes saltier and warmer. The denser water sinks, and at water depth of 150 m to 600 m proceeds towards Gibraltar and finally exits into the Atlantic (El-Geziry and Bryden, 2010). Several currents transport surface waters eastward, including the Mid-Ionian (MIJ) and Mid-Mediterranean Jets (MMJ), but recirculate in numerous eddies and gyres (e.g., Pelops (PG), West Cretan (WCG), Ierapetra Gyre (IG), Mersa-Matruh Eddy (MME)) before reaching the northward coastal current off Israel, Lebanon, and Syria and veering westward off Turkey as the Asia Minor Current (AMC) (Poulain et al., 2013) (Fig. 1). Other branches of the MIJ turn cyclonically southwest of Cyprus, forming the Rhodes Gyre (RG), the West Cyprus Eddy (CE) and the AMC (Menna et al., 2012).

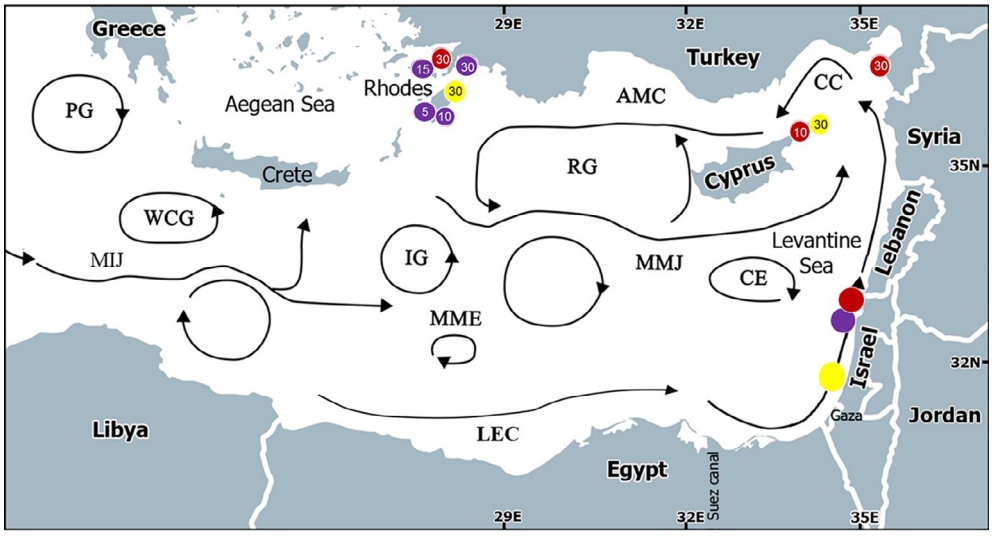

Fig. 1. Regional bottle distribution on a map of the eastern Mediterranean Sea with major circulation after Poulain et al., 2013. Colored dots represent individual bottles recovered outside of the Israeli coast by release site (red = Akko, purple = Carmel headland, yellow = Poleg). The numbers represent the water depth contour over which the bottle was dumped.