IAHR AIRH
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6th IAHR Europe Congress
Warsaw Poland 2020

# ABSTRACT
## BOOK

International Association for Hydro-Environment Engineering and Research

Institute of Geophysics
Polish Academy of Sciences

Warsaw University of Life Sciences SGGW

PAN
Polish Academy of Sciences

IAHR2020.PL

6th IAHR Europe Congress
Warsaw Poland 2020



ISBN 978-83-66847-01-9

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# Representation of a source of plastic debris as a convolution of two functions of random variables

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ABSTRACT

Geosynthetic debris from coastal protection structures (primary sources) are spread along the shore and becomes an extended secondary sources. The method of parametrization of such a source on the basis of field screening survey is proposed using convolution of two functions of random variables.

## 1. Introduction

Hard coastal protection structures on the northern shore of the Sambian Peninsula (South-Eastern Baltic, Fig. 1a) are the sources of geosynthetic debris (Esiukova et al., 2018). Field surveys made in 2018 and 2019 showed that coastal line is polluted by fragments of plastic coating of the wire used for gabions, fragments of geo cells, geocomposites from geomats, plastic big bags. Very often there is a possibility to identify the source of the type of geosynthetic debris. These are walls, promenades, and gabions walls with a length of about several hundred meters located at different coastal segments. How to describe the sources of geosynthetic fragments in the numerical simulations of the alongshore transport?

## 2. Field data collection

The fragments of geosynthetic materials were collected at the shore during field surveys made in 2018 and 2019 along with 175 km shoreline within Kaliningrad Oblast, Russia. Their numbers were agreagted for coastal segments of a length of 500 m (Fig. 1b, bars).

## 3. The expected statistical distribution of plastic debris along the coast

The evolution of the plastic elements of shore protection structures can be imagined as follows. If the storm causes a sufficiently strong surge and the waves reach the base of the structure, some of the plastic elements in the structure are destroyed and "primary" point sources of plastic debris appear. Since the location of coastal protection structures is known, the location of the "primary" sources is quite certain. Then macro- and micro-fragments of plastic are transported by waves and currents along the shore, and at the end of the storm some of them settle down to the beach, forming "secondary" sources of plastic debris. Places of settling of pieces and, therefore, the location of "secondary" sources, are obviously random and depend on the direction of the wind, the configuration and morphology of the coast, the field of waves and currents.

In the case of coastal homogeneity, the equal probability of the direction and magnitude of storm winds and the absence of dominant coastal transport, it can be assumed that the distribution of plastic debris along the coast is normal with a maximum in the region of the "primary" source. If $x = 0$ corresponds to the location of the "primary" source, the probability density function can be written as follows (Eq. 1):

$$p_1(x,\sigma) = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}}, \qquad (1)$$

where, $x$ – alongshore coordinate [m], $\sigma$ – standard deviation [m].

If a dominant alongshore transport is present, for example, due to the different probability of storm winds from different directions, we should expect a skewed distribution of fragments of debris along the coast in the direction of the dominant transport. It can be assumed that the probability of re-deposition of plastic fragments on the beach decreases exponentially with distance from the "primary" source and can be described by the exponential distribution (Eq. 2):

$$p_2(x,\lambda) = \begin{cases} \lambda e^{-\lambda x} & \text{if} \quad x \geq 0 \\ 0 & \text{if} \quad x < 0 \end{cases}, \qquad (2)$$

where, $x$ – alongshore coordinate [m], $\lambda$ – rate parameter [$m^{-1}$].

Thus, we can assume that the distribution of plastic debris along the coast after a sufficiently long time is determined by the sum of two random variables. One of which is distributed normally, and the other – exponentially. If it is so, the resultant probability density is their convolution (Eq. 3):

$$p(x) = \int_{-\infty}^{\infty} p_1(t) \cdot p_2(x-t)dt = \int_{-\infty}^{\infty} p_1(x-t) \cdot p_2(t)dt = (p_1 * p_2)(x). \qquad (3)$$

## 4. Comparing with field data and simulation results

The least squares method was used to find the values of the unknown parameters $\sigma$ and $\lambda$ (see Eq.1 and Eq.2). The results of field data collected in 2018 **(**Esiukova et al., 2018**)** were used as the basis for the calculations (see bars, 1 in Fig. 1b). It is known (Pakhteev and Stepanov, 2019, for ·example) that at a significant distance from the source, the exponential distribution dominates and, therefore, the final probability density is described by the Eq. 2. Thus, using only the distribution tail (we used $x \geq 1.5 \cdot 10^4$ m), the least squares method leads to $\lambda \approx 4 \cdot 10^{-5}$ $m^{-1}$. Further, applying the least squares method for the convolution and covering the entire available range of $x$, we obtain $\sigma \approx 4 \cdot 10^3$ m. To compare the field data and the convolution curve (3 in Fig. 1b), the last one was normalized so that the area under the curve becomes equal to the area of all bars.

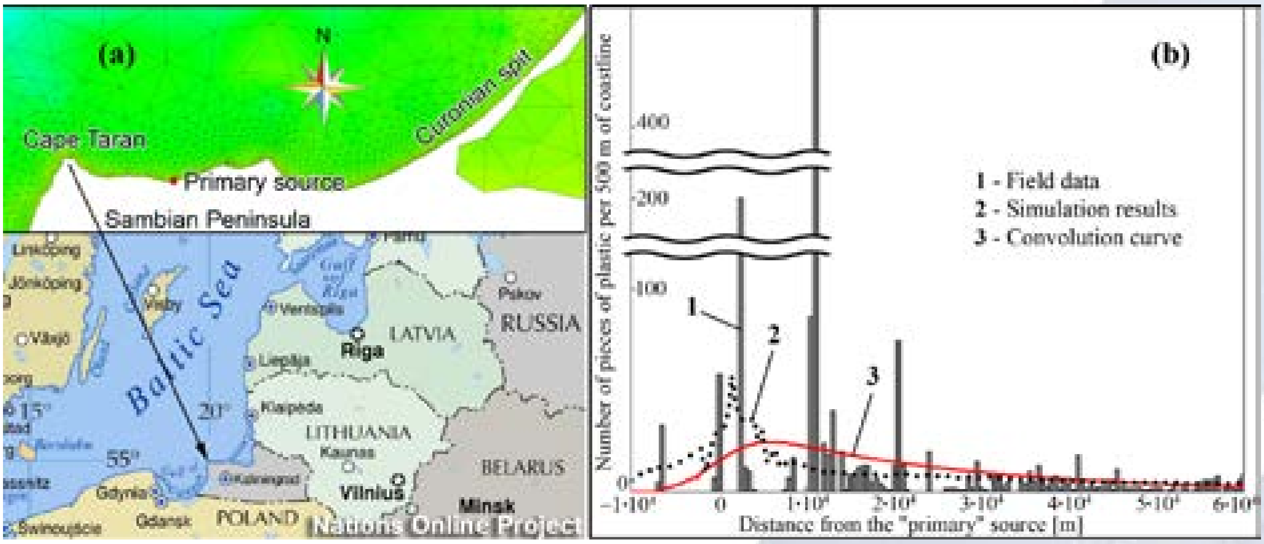


**Fig. 1**. Location of the "primary" source of geosythetic materials on the northern shore of the Sambian Peninsula (a) and example of alongshore distribution (b) of pieces of plastic coating of the wire used for the gabions and its approximation by convolution curve.

The dotted line (2 in Fig. 1b) illustrates simulation results. The following procedure was used to get them. We had a computational area covering the entire Baltic Sea and meteorological data from Era Interim reanalysis. A constant source of pollution (Primary source, Fig. 1a) was located on the northern shore of the Sambian Peninsula. The simulation of Euler concentration field of passive tracer covered 5 years (2014-2018). Then the results were averaged over space and time and normalized in the same way as for the convolution curve.

**Acknowledgements**

Investigations were supported via RFBR grant 18-55-76002 (ERANET-Rus joint project EI-Geo).

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