Marine Pollution Bulletin 133 (2018) 822–827

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Note

Questionnaire-based survey to managers of 101 wastewater treatment plants in Greece confirms their potential as plastic marine litter sources

N. Mourgkogiannis[a], I.K. Kalavrouziotis[b], H.K. Karapanagioti[a,*]

[a] Department of Chemistry, University of Patras, 26504 Patras, Greece
[b] School of Science and Technology, Hellenic Open University, Aristotelous 18, 26 335 Patras, Greece

ARTICLE INFO

Keywords:
Wastewater treatment
Effluent
Microplastics
Marine pollution source
Waste management
Cotton swab sticks

ABSTRACT

Marine pollution by plastics and microplastics (plastic particles 1 nm to 5 mm) is a recognized environmental issue. There are a few studies measuring the concentration of microplastics in the wastewater treatment plants (WWTP) effluent to the sea. Although microplastic concentrations are low in the WWTP effluent, the actual amount of microplastic ending up in the marine environment through WWTPs is quite significant. The present study is an extensive questionnaire-based survey to untrained managers of 101 WWTPs located all over Greece reporting visually-observed plastic items. 94 of the WWTPs have screens with gaps larger than 5 mm. This suggests that microplastics are passing through pretreatment to the main WWTP. In addition, 89 of the WWTP managers observed plastics in different tanks of the WWTPs. Cotton swab sticks are identified as the most common plastic found in WWTPs and the surrounding marine and coastal areas of the effluent pipes.

1. Introductions

Nowadays, plastics and microplastics (plastic particles in the size range 1 nm to 5 mm) can be found everywhere in the coastal and marine environment (GESAMP, 2015). They should be classified as hazardous once they are in the environment since they can both physically and chemically harm wildlife (Rochman et al., 2013). Some are known to contain chemicals that are added during manufacture (Manoli and Voutsa, 2017), to sorb and concentrate pollutants such as pesticides or polycyclic aromatic hydrocarbons from the surrounding seawater (Ogata et al., 2009; Karapanagioti and Klontza, 2008), and to host potential allochthonous pathogens (Eckert et al., 2018).

UNEP in its (2009) assessment on the marine environment listed “sewage treatment and combined sewer overflows” as one of the eight main land-based sources for marine debris (IOC-UNESCO/UNEP, 2009). Along with rivers, wastewater discharge is an important point source and estimating the contribution of these systems could be the key to quantify inputs of marine debris (GESAMP, 2010). In the developed countries, 80% of wastewater is discharged to WWTPs and ocean disposal of sewage sludge is prohibited (Duis and Coors, 2016). However, worldwide only about 15–20% of wastewater is treated and sewage sludge is still disposed at sea (Duis and Coors, 2016). This way, plastic debris directly reach the aquatic environment.

There are two possible ways for the introduction of microplastics in a WWTP (Karapanagioti, 2017). The direct one is when people are intentionally or non-intentionally throwing solid wastes down the toilet or the sinks. The indirect introduction of plastics can happen in combined sewer systems when the sewer system is carrying both wastewater and stormwater runoff.

Although the plastic debris route through WWTPs is known, not many studies have specifically measured the microplastics in the WWTP effluents. Table 1 summarizes the findings of most of them. Browne et al. (2011) were the first to point to WWTP effluents as source for microplastic and especially synthetic fibers and measure them at the WWTP effluents. Similar results were found by most researchers. Microplastics were found in sludge, grit, and grease and in most of them in the effluent. The removal efficiencies were high from 83 to > 99.9%. However, despite the large reduction, it was calculated that million of microplastics are released from each WWTP into the receiving water every day. This shows that despite the efficient removal rates of microplastics achieved by WWTPs when dealing with such a large volume of effluent even a modest amount of microplastics being released per litter of effluent could result in significant amounts of microplastics entering the environment.

The aim of the present study is to identify the potential of WWTPs to act as a source for microplastics into the sea and to explore if the WWTP managers are aware of this issue. The specific objectives of this study are a) to collect data on the pretreatment screen gaps of WWTPs and determine if microplastics could potentially pass through these gaps, b) to determine if WWTPs are potential sources for plastic pollution in the

* Corresponding author.
E-mail address: Karapanagioti@upatras.gr (H.K. Karapanagioti).

https://doi.org/10.1016/j.marpolbul.2018.06.044
Received 18 April 2018; Received in revised form 12 June 2018; Accepted 15 June 2018
0025-326X/

Table 1
Summary of the studies found in literature dealing with microplastics measured in WWTPs.

Study	Area, country	Level of treatment	Removal efficiency (%)	Number of microplastic particles/L	Number of microplastic particles released/day
Talvitie et al. (2017)	Viikinmaki, Helsinki region, Finland	Tertiary	99	0.7–3.5 after tertiary treatment	1.7×10^6 to 1.4×10^8 microplastics
Ziagahromi et al. (2017)	Sydney, Australia	One primary, one secondary, and one tertiary	–	0.28 for tertiary 0.48 for secondary 1.54 for primary	3.6×10^6 for tertiary 8.16×10^6 for secondary 460×10^6 for primary
Carr et al. (2016)	Southern California, USA	Seven tertiary and one secondary	99.9 for the secondary	0.88 for the secondary	100 thousands for the secondary
Mason et al. (2016)	17 WWTPs, USA				4 million per facility per day
Murphy et al. (2016)	River Clyde, Glasgow, UK	Secondary	98	0.25	65 million
Dris et al. (2015)	Seine-Centre WWTP, River Seine, Paris, France	Tertiary	83–95	–	–
Talvitie et al. (2015)	Helsinki archipelago, Helsinki Region, Finland	Tertiary	–	8.6 microplastics 4.9 fibers (Average 6.7)	–
Mintenig et al. (2014)	12 WWTPs in Lower Saxony, Germany	–	97 in Oldenburg WWTPs	0.08 to 8.9 for small microplastics, 0 to 0.05 for large microplastics	255 thousands to 22 million
Talvitie and Heinonen (2014)	Central WWTP of St. Petersburg, Russia	Tertiary	96	16 for textile fibers 7 for synthetic 125 for black particles (Average 49)	–
Dubaish and Liebezeit (2013)	Jade Bay, southern North Sea, Germany	–	–	33 granules 24 fragments 24 fibers (Average 27)	–
Leslie et al. (2013)	North Sea, Oude Maas River or the North Sea Canal, WWTPs of Houtrust, Amsterdam West, Heenvielt, Netherland	–	–	52	–
Leslie et al. (2012)	Heenvliet WWTP, Netherland	–	90	20	–
Browne et al. (2011)	Australia	Tertiary	–	1	–

marine environment, and c) to identify the most commonly observed by naked-eye plastics in WWTPs. This study is based on questionnaires that are based on visual observations of untrained WWTP managers.

2. Methodology

Currently, in Greece, there are > 300 Wastewater Treatment Plants (WWTP) in operation and some more under construction (www.ypeka.gr). Most of WWTPs are secondary treatment plants, and the rest are tertiary treatment plants (www.ypeka.gr). In the present study, the number of WWTPs that participated in the survey (101) is the 34% of the total WWTPs found in Greece. Their locations are shown in the map presented in Fig. 1. They are well-spread throughout the country including island and mainland sites. 46 WWTPs serve population equal or lower than 15,0000, 33 from 15,000 to 50,000, and 21 from 50,000 to 200,000. Psitalleia, the WWTP of Athens, is the largest WWTP in Europe and can be found in the Saronikos Gulf; it serves > 5.63 million people. 89 of the WWTPs that participated in the present research collect only municipal sewage and 12 collect both municipal and industrial sewage. 54 WWTPs discharge directly into the sea, 34 into rivers or streams, 3 into lakes, 8 into trench drainage systems and 2 onto soils. 54 WWTPs are located in touristic areas however, the managers' responses were based on the average season and did not include the touristic season. Considering that touristic activities increases the amount of waste and effluents (Ezeah et al., 2015), the situation described in this survey can be considered conservative.

To collect the most information possible in a limited time the questionnaire presented in Table S1 (Supporting information) was used as a research tool. The most questions were closed-ended type questions (e.g. in Table S1 questions No 1, 5, 9, etc.). Furthermore, the questionnaire used some open-ended type questions to take some technical information, such as the type of the screens at pretreatment tank (e.g. in Table S1 questions No 2, 15, etc.). These open-ended type questions are contingency questions that need to be answered only when the respondent provides a certain response to a question prior to them (e.g. in Table S1 questions No 3, 4, 6, etc.).

3. Results

To understand the results of the present study an analytical description and targeted interpretation of the answers to the questionnaire, will be given in the following sections. A summary of the quantitative results of the questionnaires is presented in Table 2 showing the number of managers that have observed plastic items in the different treatment tanks. Overall 99 of WWTPs managers observed solid wastes arriving to their screens and 89 observed plastics in different tanks in the WWTP.

Although the questionnaire was asking information about microplastics, the managers were not trained or aware of microplastic problem and thus, they responded for plastics that were visible with naked-eye. Since plastic debris is the precursor of microplastic and since larger plastic are easier to capture it was found necessary to analyze and present the following data even though microplastics problem was the initial aim of the questionnaire.

It is important to note that some of the wastewater treatment processes enhance floatation and others sedimentation. Frequent reports by managers in one tank do not necessarily mean higher concentrations of plastic in this tank (Table 2). Some of the plastic items are easier to identify than others. The managers can easily spot plastic that float or are left in the sludge than plastics that are present in the wastewater column.

3.1. Sewage collection

The sewer system that ends at a WWTP is either separate, carries only wastewater, or combined, carries both wastewater and