Marine Pollution Bulletin 129 (2018) 52–60

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

The unaccountability case of plastic pellet pollution

Therese M. Karlsson[a], Lars Arneborg[b,c], Göran Broström[c], Bethanie Carney Almroth[d], Lena Gipperth[e], Martin Hassellöv[a,*]

[a] University of Gothenburg, Department of Marine Sciences, Kristineberg Marine Research Station, 45178 Fiskebäckskil, Sweden
[b] Swedish Meteorological and Hydrological Institute, Department of Research and Development, Sven Källfelts gata 15, 42671 Västra Frölunda, Sweden
[c] University of Gothenburg, Department of Marine Sciences, Box 461, 40530 Göteborg, Sweden
[d] University of Gothenburg, Department of Biological and Environmental Sciences, Medicinaregatan 18A, 41390 Göteborg, Sweden
[e] University of Gothenburg, Department of Law, Box 650, 405 30 Göteborg, Sweden

ARTICLE INFO

Keywords:
Microplastics
Pellets
Plastic pollution
Policy recommendations
Pellet distribution

ABSTRACT

Plastic preproduction pellets are found in environmental samples all over the world and their presence is often linked to spills during production and transportation. To better understand how these pellets end up in the environment we assessed the release of plastic pellets from a polyethylene production site in a case study area on the Swedish west coast. The case study encompasses; field measurements to evaluate the level of pollution and pathways, models and drifters to investigate the potential spread and a revision of the legal framework and the company permits. This case study show that millions of pellets are released from the production site annually but also that there are national and international legal frameworks that if implemented could help prevent these spills. Bearing in mind the negative effects observed by plastic pollution there is an urgent need to increase the responsibility and accountability of these spills.

1. Introduction

Plastic material is an integral part of our daily lives and the annual production is today > 300 million tons (PlasticsEurope, 2014). Most thermoplastic articles and materials originate from virgin plastic pellets, also called preproduction pellets, beads, or nurdles. These are produced in polymeric production industries, or to some extent in recycling facilities. The pellets typically have a diameter of 2–5 mm and are regular in shape. Smaller powders, often referred to as fluff, are also produced and have more irregular shapes and sizes. The produced pellets are subsequently transported from the production site, with train, truck and/or ship to the facility where the final product is being molded or extruded from the virgin material. This material can however be lost in all steps during the production chain, from preproduction, to the final item production.

The first scientific reports to document the occurrence of plastic pellets in the environment were published during the 1970's (Carpenter and Smith, 1972; Carpenter et al., 1972). Since then plastic pellets have been found in surface water samples and on beaches all over the world (Colton et al., 1974; Gregory, 1977; Morris and Hamilton, 1974; Fernandino et al., 2015; Eriksen et al., 2013). Plastic pellets are also found on beaches that are not directly in contact with petrochemical or polymer industries. Although they can be in minority in comparison to other plastic litter (do Sul et al., 2009; Fok and Cheung, 2015) they are commonly found, showing the possibility for large scale transport.

Several species of fish and birds have shown to ingest plastic pellets (Carpenter et al., 1972; Kartar et al., 1973; Baltz and Morejohn, 1977) and although the potential risks of microplastic ingestion to marine organisms are hard to quantify, the list of species known to ingest plastic in the marine environment is currently in the hundreds (Kühn et al., 2015), and includes species from all trophic levels (Eriksson and Burton, 2003). The effects of ingestion of macroplastic debris are well documented (Browne et al., 2015; Kershaw et al., 2015). Few studies conclusively address the effects of pellets ingestion and the types and amounts of microplastics used in laboratory studies are rarely consistent with those found in the field (Phuong et al., 2016). But studies on the effects of microplastics show that they have the potential to be passed up through the food chain (Setälä et al., 2016), and the plastic particles can have physiological effects, including changes in reproduction (Sussarellu et al., 2016), metabolism (Cole et al., 2015; Lu et al., 2016) and behavior (Mattsson et al., 2014). Other studies that have focused on the propensity for plastics to act as vectors of environmental toxins find that levels of common POPs can be up to 10^7 times higher in plastic pellets than in sea water (Koelmans et al., 2016; Holmes et al., 2012). A number of studies indicate that microplastics can act as vectors for pollutants from the environment into organisms

* Corresponding author.
E-mail address: martin.hassellov@gu.se (M. Hassellöv).

https://doi.org/10.1016/j.marpolbul.2018.01.041
Received 1 November 2017; Received in revised form 17 January 2018; Accepted 18 January 2018

(Rochman et al., 2013; UNEP, 2014), but the importance of this factor compared to uptake via normal feed contamination or exposure to other naturally occurring particles in the environment is still uncertain (Koelmans et al., 2016). Additionally some of the additives used in plastic products have been shown to migrate from microplastics to biota (Rochman et al., 2013).

Plastic pollution can also lead to significant economic losses, for example through losses in revenue from tourism and the cost of beach cleaning (UNEP, 2014; Mouat et al., 2010; Leggett et al., 2014). Although these costs are based on the total amounts of plastic on beaches, pellets are commonly found during beach cleaning campaigns and thereby a contributing factor to the costs.

The occurrence of plastic pellets in the environment was linked to industrial outlets already in the 70s where researchers first started calling for precautionary measures within the industry (Hays and Cormons, 1974). Even so, a study in the river Rhine from 2015 showed that 60% of the identified plastic particles were spherules, with a possible linkage to different industries along the river (Mani et al., 2015). Similarly pellets were measured at a mean density of 693 items per 1000 m^3 in the river Danube with the highest value of 138,219 per 1000 m^3 during a heavy rainfall (Lechner et al., 2014). These were, according to a press release by a close plastic production company, at least in part due to losses at a production site (Borealis, 2014). In Austria plastic is classified as a filterable substance, and the limit for discharge is 30 mg/L. This limit, extrapolated to a year's worth of discharge amounts to 94.5 tons/year, is a threshold that researchers have questioned due to the high volumes it allows for (Lechner and Ramler, 2015). Although the actual levels that leach into the environment from the production plants are unknown a recent study in the UK indicates a national yearly loss of 5–53 billion pellets (Cole and Sherrington, 2016). The results from that study is however based on estimates on the percentage loss provided from the industry and although there are examples of studies, as mentioned above, where high concentrations of pellets have been found close to production plants there is very limited data on the actual runoff.

In order to better understand how and why plastic pellets end up in the environment a case study approach was used where we investigated the major plastic industry complex in Sweden. Although the specific volumes of pellet spills may differ from site to site there is ample evidence of their occurrence, both through present and historical studies from independent researchers and the companies themselves. As the world-wide market is dominated by a few big companies, with concentrated production facilities, although a worldwide distribution and manufacturing network, there is also reason to believe that the routines would be similar on other sites. Within the case study we therefore investigate the industries associated permits and regulations, reviewed potential environmental and economic impacts and investigated the total runoff as well as the present pellet pollution situation in the nearby area. These aspects were investigated in a multidisciplinary approach, including environmental surveillance, measurement of pellet fluxes, hydrographical mapping and modelling as well as legal studies and environmental impact assessments.

2. Case study description

In the chemical industry cluster in Stenungsund, there is a polyethylene production facility in the center, with supporting industries such as an ethylene producing cracker, and also several smaller companies involved in the handling and transport of the produced pellets. Polyethylene has been produced in Stenungsund since 1963, and the production volume has gradually increased. It is the only polyethylene production site in Sweden and the annual polyethylene production capacity in Stenungsund amounts to 0.75 Mtons (Mark- och miljödomstolen Vänersborg, 2015), which corresponds to approximately 5% of the European polyethylene demand (PlasticsEurope, 2014).

The expansion of and changes in the production has required a long row of updated and revised permits throughout the years. The current permit was approved in 2007, but the decision on some conditions was postponed because of lack of information. Since then the release of particles was not mentioned in the decisions until 2013 (Mark- och miljödomstolen Vänersborg, 2013), twenty years after the first problem formulations and legal recommendations to avoid pellet spills were provided by the US EPA (US EPA, 1992). The permit background report showed high amounts of plastic particles in the effluent and the company was assigned to investigate it further. The background material also show that the company has reported that several of the additives that are used in the plastic are classified as toxic for water living organisms (Mark- och miljödomstolen Vänersborg, 2015).

In 2014 the company issued a press release stating that "our aim is to not lose a single pellet" explaining its zero pellet loss objective (Borealis, 2014). In the company's yearly environmental report, a description of their sewage and storm water treatment was presented. The storm water drains has during recent years been led from the production site through a polyethylene separator, known as a skimmer-pit, to remove particles that float or sediment. The water is then led to Stenunge Å, a small creek running by the production site, which empties into the industrial harbor. The industrial sewage system collects water from process areas; this water is led through a density separator to separate light density liquids and polyethylene. After treatment the water is led to Askeröfjorden (Borealis, 2016) (see Supplementary material 2A for a more detailed record of the company permits).

The produced polyethylene pellets are loaded for shipping and moved from the production site by road transport but can then be further transported by boat, ferries or railroad (Mark- och miljödomstolen Vänersborg, 2015; Borealis, 2016). Records from inspections, and observations in this study, show that plastic spills have been reported in proximity to transport and storage areas as well as on sites where other companies handle waste or cleaning from the production company (Supplementary material 2B).

2.1. Description of the area

The study site is located within the Orust-Tjörn fjord system on the Swedish west coast. In close proximity, there are several important Natura 2000 areas and the shores are mainly steep and rocky interrupted by bays with beaches of protected to moderately exposed character. Along some shorelines shallow salt marsh grass meadows grazed by bird life and cattle and sheep also occur. The surface water within the fjord system has been estimated to have a residence time in the order of 40 days (Hansson et al., 2013). Organic material is transported by rivers and streams into the fjord system and although a portion of it is transported out of the area, low rates of water exchange leads to accumulations in the sub-basins (Hansson et al., 2013). The fjords inside the islands of Orust and Tjörn are not directly influenced by any larger rivers, so rather than a typical estuarine circulation the circulation in the fjords is to a large degree influenced by the stratification outside the fjords as well as local wind forcing. The main water exchanges are through the southern entrance and are caused by upwelling and downwelling of the coastal stratification (Björk et al., 2000) which is strongly related to regional wind patterns (Hansson et al., 2013). The steric pressure gradient resulting from the fresher surface waters at the southern entrance give rise to a general counterclockwise circulation (Björk et al., 2000).

Although tidal currents are relatively strong in some of the more narrow straits, the general area has weak tides (< 0.2 m amplitude). The area is however strongly influenced by the Baltic Current, which carries low-saline water from the Baltic Sea northward along the Swedish coast as well as North Sea water that joins the Baltic Current via the Jutland Current. Below and outside the Baltic Current, there also is a general cyclonic circulation of the more saline Skagerrak waters. This circulation that carries surface waters from a large part of northern