Building Blocks of Plastic or Building Blocks for Disaster? A Case Study on Plastic Resin Pellets in Australia

L. Mallinson[1], H. Taylor[2] and O. O'Shea[3]
Tangaroa Blue Foundation PO Box 757 Port Douglas 4877

Introduction

Plastic resin pellets are the starting point for any plastic item. These pellets are the raw material that are melted, shaped and re-moulded into the products that manufacturer's desire (Derraik 2002; Ashton *et al*. 2010). Plastic resin pellets are less than 5 mm in diameter (Heskett *et al*. 2012) and are easily lost to the environment during transportation and manufacturing (Redford *et al.* 1997; Mato *et al.* 2001; Derraik 2002; Ryan 2008), creating a serious and persistent marine debris concern.
As a form of plastic marine debris, pellets are easily distributed by ocean currents due to their buoyancy and light weight. Their chemical structure also makes them environmentally resistant (Goldberg 1997; Mato *et al*. 2001; Derraik 2002) and as such they are commonly found in high quantities on beaches around the world (Redford *et al.* 1997; Mato *et al*. 2001; Derraik 2002, Ashton *et al*. 2010, Heskett *et al*. 2012). In Australia, plastic resin pellets have been recovered from beaches across broad spatial scales including sites located along rural and remote beaches where no plastic manufacturers exist, suggesting they have been transported there via oceanic currents (Smith 2010). This notion is supported by the often deteriorated condition that pellets are recovered in, for example, they can be discoloured or eroded in shape and texture, indicating weathering due to environmental exposure, contact with sand particles, oxidisation, and chemical exposure through prolonged ocean transit periods (Mato *et al.* 2001; Smith 2008; Smith 2010).

In Australia, pellets have been recovered by the Tangaroa Blue Foundation within the river systems of five cities (Brisbane, Sydney, Melbourne, Perth and Adelaide) supporting the belief that domestic sources are contributing to spill-over. These rogue pellets are washed through stormwater drains via surface run-off which lead to the river systems that link to our oceans (Mato *et al.* 2001; Heskett *et al.* 2012). Identifying the sources of pellets e.g. international or domestic is often impossible due to the properties of pellets. The one consistent variable among samples so far has been their condition. While pellets are durable and persistent, they are affected by environmental conditions, such as UV exposure, which can roughly indicate duration i.e. short or long periods in the environment, but it cannot offer an insight as to their origin. For this reason, assessing points of origin for pellets can only be achieved through rigorous sampling where they are traced directly to the source. This has been demonstrated in Perth where pellets were witnessed flowing out of a manufacturing plant, into a wetland drain running directly into the Swan River (*O'Shea 2013*). While the sampling in Perth has been the most comprehensive, similar domestic spill-over has also been demonstrated in Sydney, Adelaide and Melbourne.

Background

Studies have been conducted to determine the impact that plastics in the raw form of resin pellets have had on the marine environment including ingestion by a range of taxa (e.g. Kaminuma *et al.* 2000; Kuriyama *et al.* 2002; Mato *et al.* 2002, Endo *et al.* 2005; Karapanagioti *et al.* 2007; Karapanagioti *et al*. 2010; Karapanagioti *et al.* 2011). It is clear from the literature that the main threat of plastic resin pellets to marine wildlife such as seabirds, fish and turtles is through ingestion, with animals mistaking pellets as a common food source due to their appearance (Mato *et al.* 2001; Derraik 2002; Endo *et al*. 2005; Karapanagioti *et al.* 2007; Ryan 2008; Smith 2010; Ashton *et al.* 2010) or by association whereby pellets often float attached to algal mats. Once ingested, pellets can cause

blockages in the gut and organisms will appear to feel satiated, and as such will cease foraging. In addition, perforation is common whereby a slow, inevitable death is realised.

It has been documented that animals which ingest these pellets will often die through starvation by not getting the nutrition they need to survive because they cannot dislodge the plastics from their systems (Endo *et al.* 2005; Karapanagioti *et al.* 2007; Ryan 2008; Smith 2010; Ashton *et al.* 2010).

Aside from this physical impact, pellets have also been identified as a chronic stressor. The plastic resin pellets contain chemicals and further adsorb hydrophobic toxins and pollutants such as PCBs, DDTs, HCHs and PAHs throughout exposure in the ocean environment (Mato *et al.* 2001; Endo *et al.* 2005; Karapanagioti *et al.* 2007; Teuten *et al.* 2009; Ashton *et al.* 2010; Heskitt *et al*. 2012). If ingested, an organism is at risk of chemicals being released into their systems from the pellets (Azzarello and Van Vleet 1987). Once affected, a bio-accumulatory effect may occur whereby toxins are passed up the food chain. This potentially will impact the whole food chain, including humans as consumers of possibly affected organisms at lower trophic levels, such a fish, or filter feeding mussels (Browne *et al.* 2008).

Initiatives: International Pellet Watch and Tangaroa Blue Foundation

International Pellet Watch is a volunteer-based global monitoring program located in Fuchu, Tokyo, Japan. Samples are received from around the world and sent to the laboratory in Japan for analysis on the concentrations of hydrophobic organic pollutants adsorbed by plastic resin pellets. High concentrations of pollutants on pellets indicate areas that need to be investigated further to mitigate the issue.

Tangaroa Blue Foundation is a not-for-profit organisation that coordinates the Australian Marine Debris Initiative (AMDI), a national program focusing on the removal and mitigation of marine debris from coastal locations. Through the AMDI program, Tangaroa Blue Foundation has taken baseline studies of pellet distribution since 2007. These studies have been aimed at documenting the locations where pellets have been found and the physical condition of the pellets at the time they were collected (e.g. stained, texture and size). Samples of pellets collected throughout this study have also been sent to the International Pellet Watch.

The overall aim of this report is to expose plastic resin pellet pollution and to consider effective, proactive ways to prevent their incursion to the environment. More specifically, this report will outline the severity of pellet abundance across multiple locations throughout Australia to highlight the need to implement a Source Reduction Plan to curb their discharge.

Methods

Pellets were collected from beach cleaning events or are from samples that volunteers collected and reported after specifically looking for them. Pellets are collected using clean tweezers and then placed into a paper envelope or aluminium foil to minimise contamination of chemicals in the pellet. The amount sampled at each site varied between 25-100; however, a sample size of n = 50 is ideal for robust analysis.

Results

Plastic resin pellets were recovered from 41 sites in Australia including remote and isolated coastal areas of northern Australia, such as the Cape York Peninsula and Torres Strait Islands. In addition to beaches and island ecosystems, pellets were also recovered from five

capital cities highlighting the scale of this issue in spatial terms and further highlighting domestic sources of spill (Figure 1).

.

Figure 1: Sites around Australia where the samples of plastic pellets were collected.

In Brisbane, samples were collected along the tidal reaches of the Brisbane River within the city, 16 km upstream of the Pacific Ocean. This was also the case for Sydney, where pellets were found at Manly Cove, Botany Bay and the upper reaches of the Parramatta River. In Melbourne, pellets were recovered from Queenscliff at the mouth of Port Phillip Bay, which is very narrow relative to the bay itself (< 3 km). Despite this, further sampling upstream over 50 km away in St. Kilda, further revealed pellets recovered from beaches. In Perth, pellets were found at multiple sites within the Swan River, with some over 35 km from the ocean in the upper reaches near Guildford (O'Shea 2012). In Adelaide, samples were collected from an enclosed lake (West Lakes) with no open access to the ocean. The other locations in Adelaide were connected to the ocean; however stormwater drains were also present in the area.

It is likely that pellets are present at many more sites around Australia. The results are based on limited sampling due to volunteer capacity and the remote nature of some of the Australian coastline.

Discussion

Pellets have been documented in high abundances from all over the world and while this report addresses these issues in regard to Australia's environment, a troubling trend is emerging where plastic resin pellets are also impacting freshwater ecosystems, often many kilometres inland. Results presented here detailing recoveries from five major Australian cities are a clear indication of domestic release points. Furthermore, environmental and physical restrictions in current flow along these major river systems further suggest it unlikely that these pellets are being washed upstream from an ocean source.

Pellets located within the Brisbane River were almost 20 km from Moreton Bay and were recovered well within the city limits. These sites are both up and downstream from Brisbane's main industrial and manufacturing areas highlighting the strong possibility of domestic release. Manly Cove is on the inside of Sydney National Park land which stretches out as a cape for 3 km. This appears to be sheltering the cove from direct wave action and current flow, which may make it unlikely for pellets to be deposited here from outside sources; however, it is possible that the pellets could also be washed in from Sydney Heads into the harbour. This is currently being further investigated through a comprehensive and spatially extensive sampling program.

In Melbourne, samples in Port Phillip Bay collected from St. Kilda beach are extremely unlikely to have travelled northward from the mouth of the bay. A more likely scenario is that either deposits from industry further upstream of the Yarra River or Port Phillip catchments are contributing to their abundances considering the geographic relationship between the Yarra river mouth, major stormwater drain outlets and St. Kilda beach. In Perth, similarly to Brisbane, the pellets were found upstream of a winding riverine system (up to 35 kms) from the Indian Ocean near the suburb of Guildford. Furthermore, the Swan River is actually a convergence of two rivers including the Canning River and on account of the industry located along both these river systems, domestic sources seem the most plausible point of origin for most, if not all of the samples found at these sites.

In Adelaide, pellets found in the enclosed system in West Lakes give a strong indication that they are coming from a local source. With this knowledge, it is acceptable to further assume that the river sampled in Adelaide, which is connected to the ocean with stormwater drains present, is likely to also be polluted due to local sources washed in from the stormwater drains.

Documented proof of domestic sources contributing to pellet spill-over in these cities exists after several site visits to industrial areas. This includes photographic evidence of pellets being discharged from factories immediately adjacent to stormwater drains and natural wetlands as well as pellets having been documented floating in and next to vegetation mats in drains within industrial areas. This documentation provides additional evidence that the pellets found in the river systems of in at least some of the Australian cities and their surrounding beaches are coming from the local factories and industries that handle plastic resin pellets.

Many reasons exist as to explain the abundance of pellets in the environment, including unsound practices within factories with regard to cleaning spill-over, but more importantly is perhaps the lack of mitigation methods that are designed to prevent such incursion to the environment from the factory floor. Some factories hose their buildings and workshop floors down at night, resulting in pellets washing into drains, which has also been documented at several major factories in these cities. There is no filter method on surrounding stormwater drains, so once they are in gutters or drainage areas, they are washed into stormwater outlets easily, resulting in loss to the river systems. Also, in transporting the resin pellets, hopper cars and trucks are not required to have lids on containers of pellets. This is likely to further contribute to loss; particularly for prolonged periods where destinations are great distances (Smith 2008; Smith and Taylor 2011).

It may be prudent to geo-reference these factories and subsequently assess pellet abundance and distribution across major cities to identify correlations between the two. This would provide further evidence as to the domestic sources of pellet abundance and indicate severity specific to certain plants. Further work may also look at oceanographic conditions responsible for moving floating debris, and how we can use this to predict areas of convergence. Continued chemical analyses could help confirm the lifetime of the pellet, how

long it may have been travelling for, and if traces are picked up in transit, it may act as environmental indicators and may be able to link it to the source.

A Solution: Operation Clean Sweep

The American Chemistry Council and Society of the Plastics Industry in the United States of America together have created 'Operation Clean Sweep', an international initiative to help prevent plastic resin pellets from entering the environment. As identified previously, spill-over can occur in various instances through process and handling, and 'Operation Clean Sweep' offers detailed mitigation methods for each possibility in the transportation of the plastic resin pellets to the factories from their manufacturers.

'Operation Clean Sweep' provides a comprehensive outline of recommendations that Australia needs to adopt to prevent spill-overs, educate their employees on containment and prevention, and manage clean-ups at each site. Ultimately, the goal is for mandatory implementation by the Australian plastics industry and manufacturers of an appropriate program based on 'Operation Clean Sweep' in Australia to mitigate pellet loss. (A.C.C and S.P. Industry 2012).

Conclusion/Take Home Messages

It is evident there is an issue with plastic resin pellets polluting the environment, and sampling in major cities shows that Australian sources are contributing to the issue.

Plastic industries in some areas have minimal mitigation methods for controlling and preventing pellet loss. The spill-over that causes domestic pollution can be prevented with proper handling methods. Tangaroa Blue Foundation has been successful in highlighting this pollution issue, and with collaboration with governments such as the Department of Environment and Conservation, Western Australia, shown that mitigation strategies are easily implemented within the industry.

This is a preliminary report regarding plastic resin pellet distribution in Australia as of March 25th, 2013, and is continually being updated as further findings of pellets are documented. Furthermore, a detailed assessment of domestic pellet release in Western Australia is available as a companion report to this one.

.

Acknowledgments

We would like to thank our volunteers for their continued dedication and support to collect, record and send samples of plastic resin pellets. Also, we thank Mark Hamann of James Cook University for his support and comments and Maybelline Yeo from the International Pellet Watch for pellet analysis and reports.

Reference

Ashton, K. Holmes, L., Turner, A. (2010). "Association of metals with plastic production pellets in the marine environment." Marine Pollution Bulletin 60: 2050-2055.

Azzarello MY, Van Vleet, E.S. (1987) Marine Birds and Plastic Pollution. Marine Ecology Progress Series 37:295-305

Browne MA, Dissanayake, A., Galloway, T.S., Lowe, D.M., Thompson, R.C. (2008) Ingested microscopic plastic translocates to the circulatory system of the mussel Mytilus edulis (L). Environmental Science and Technology 42:5026-5031

Derraik, J. G. B. (2002). "The pollution of the marine environment by plastic debris: a review." Marine Pollution Bulletin 44: 842-852.

Endo, S., Takizawa, R., Okuda, K., Takada, H., Chiba, K., Kanehiro, H., Ogi, H., Yamashita, R., Date, T. (2005). "Concentration of polychlorinated biphenyls (PCBs) in beached resin pellets: Variability among individual particles and regional differences." Marine Pollution Bulletin **50**: 1103-1114.

Goldberg, E. D. (1997). "Plasticizing the seafloor: an overview." Marine Pollution Bulletin **18**: 82-84.

Heskett, M. T., H.; Yamashita, R.; Yuyama, M.; Ito, M.; Geok, Y.B.; Ogata, Y.; Kwan, C.; Heckhausen, A.; Taylor, H.; Powell, T.; Morishige, C.; Young, D.; Patterson, H.; Robertson, B.; Bailey, E.; Mermoz, J. (2012). "Measurement of persistent organic pollutants (POPs) in plastic resin pellets from remote islands: Towards establishment of background concentrations for International Pellet Watch." Marine Pollution Bulletin (64): 445-448.

Karapanagioti, H., Endo, S., Ogata, Y., Takada,H. (2011). "Diffuse pollution by persistent organic pollutants as measured in plastic pellets sampled from various beaches in Greece." Marine Pollution Bulletin **62**: 312-317.

Karapanagioti, H., Klontza, I. (2007). "Investigating the properties of plastic resin pellets found in the coastal areas of lesvos island." Global Nest Journal **9**: 71-76.

Karapanagioti, H., Ogata, Y., Takada, H. (2010). "Eroded plastic pellets as monitoring tools for polycyclic aromatic hydrocarbons (PAH): laboratory and field studies." Global Nest Journal **12**: 327-334.

Kuriyama, Y., Konishi, K., Kanehiro, H., Otake, C., Kaminuma, T., Mato, Y., Takada, H., Kojima, A. (2002). "Plastic pellets in the marine environment of Tokyo Bay and Sagami Bay." Bulletin of the Japanese Society of Scientific Fisheries **68**: 164-171.

Mato, Y., Takada, H., Zakaria, M.P., Kuriyama, Y., Kanehiro, H. (2002). "Toxic Chemicals contained in plastic resin pellets in the marine environment-spatial difference in pollutant concentrations and the effects of resin type." Environmental Science **15**: 415-423.

Mato, Y. I., T.; Takada, H.; Kanehiro, H.; Ohtake, C.; Kaminuma, T. (2001). "Plastic Resin Pellets as a Transport Medium for Toxic Chemicals in the Marine Environment." Environmental Science and Technology **35**(2): 318-324.

O'Shea, O, (2012) "Plastic resin pellets in the Perth metropolitan area and evidence of domestic release to the Swan River catchment" Tangaroa Blue Foundation: 1-11

"PACIA: Waste and Emissions." (2011) Industry Goal: An industry aiming for zero waste and emissions. 2012, from http://www.pacia.org.au/programs/wastesandemissions.

Redford, D. P. T., H.K., Trulli, W.R. (1997). Sources of plastic pellets in the aquatic environment. Marine Debris: Sources, Impacts and Solutions. J. M. R. Coe., D.B. New York, Springer-Verlag**:** 335-343.

Ryan, P. (2008). "Seabirds indicate changes in the composition of plastic litter in the Atlantic and south-western Indian Oceans." Marine Pollution Bulletin 56: 1406-1409.

Smith, W. (2008). "Fremantle Port and the Swan River as Sources of Plastic Resin Pellets." Tangaroa Blue Ocean Care Society: 1-5.

Smith, W. (2010). "Plastic Resin Pellets on the Western South Coast of West Australia." Tangaroa Blue Ocean Care Society: 1-18.

Smith, W., Taylor, H. (2011). "Plastic Resin Pellets in Port Phillip Bay, Victoria." Marine Micro Plastic Pollution Newsletter (2): 1-4.

Teuten, E., Saquing, J., Knappe, D.R.U., Barlaz, M.A., Jonsson, S., Björn, A., Rowland, S.J., Thompson, R.C., Galloway, T.S., Yamashita, R.,Ochi, D., Watanuki, Y., Moore, C., Viet, P.H., Tana, T.S., Prudente, M., Boonyatumanond, R., Zakaria, M.,

Akkhavong, K., Ogata, Y.,Hirai, H., Iwasa, S., Mizukawa, K., Hagino, Y., Imamura, A., Saha, M., Takada, H. (2009). "Transport and release of chemicals from plastics to the environment and to wildlife." Philosophical Transactions of The Royal Society **364**: 2027-2045.