DO POPS TRANSFER FROM PLASTIC MARINE DEBRIS TO CORAL ON TROPICAL ISLANDS?

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Introduction

The study of plastic marine debris in oceans is attracting attention due to the large amounts involved and the dangers it may pose[1,2]. Floating plastics in the oceans can travel long distances[3,4]. Other chemicals that may also be facilitated by this transport are the chemicals that are inherent in the plastics (which are added during manufacture), as well as those coming from the sea itself[5-8]. This presents the potential of facilitated long-range transport of both the traditional persistent organic pollutants (POPs) and the less persistent chemicals associated with plastics themselves. The potential has been indicated by plastic debris found on remote island beaches[3,9-11].

During an expedition to the tropical St Brandon's Rock atoll (SBR; Figure 1) in the Indian Ocean we encountered large amounts of plastic debris (estimated at 3.1 million pieces) on the beaches of this remote atoll. The brand names on the debris indicate origin from the East Indies and northern Indian Ocean. For the debris to reach SBR from there they have to travel thousands of kilometres before becoming beached on SBR. It is possible that islands in or near the oceanic gyres actually scrub the circulating debris from the ocean. We predict that physical (UV and wave action) and biological action (ingestion) will cause the associated pollutants in the plastics to become available for uptake by biological systems. We collected plastics, coral rubble, and coral sand from wave-washed beaches, and coral sand from tern breeding colonies, and analysed for a variety of POPs, other pollutants and mercury.

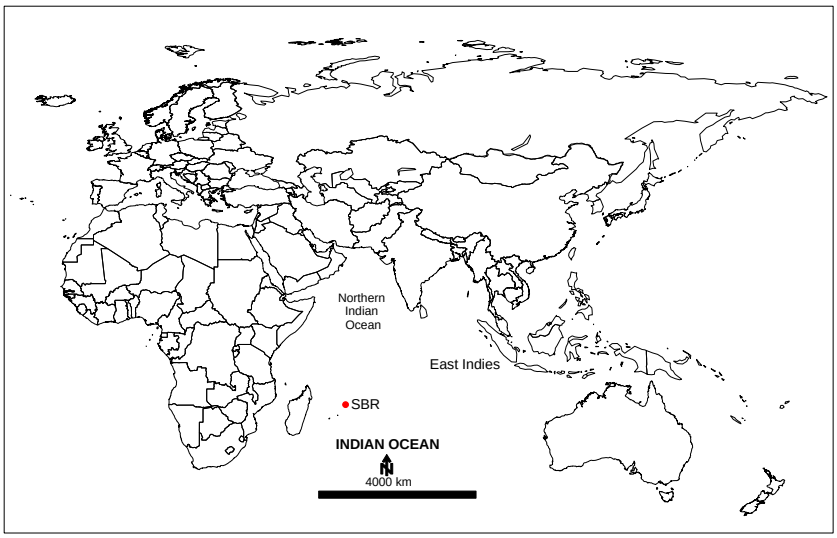

Figure 1: Location of St Brandon's Rock (SBR) in relation to suspected marine debris source areas. Surface currents in the Indian Ocean are not well understood and seem to be seasonally variable – therefore they are not indicated.

Materials and methods

We collected matrixes as indicated in Figure 2 from SBR in October 2010. SBR is an atoll consisting of 31 islands and sandbars and a large coral reef. SBR has a transient population of about 50 fishermen and government officials, with small fuel generators on two islands as only local sources.

Analyses were done at RECETOX, Brno, Czech Republic, using GC-MS/MS, GC-HRMS, and HPLC with ESI-MS/MS. Total mercury was analysed with AMA254. Compounds analysed included those shown in Figure 2, with all compounds of these classes listed in supplemental notes.

Results

The concentration and composition of the three organic pollutant classes were quite variable within and between the different matrixes. Beached plastics generally had the highest concentrations of all compound types, but for all compounds there were examples of natural matrix samples that had higher concentrations. HCHs dominated, and most were α-HCH. Of the DDTs, *p,p'*-DDT seemed to dominate, with almost no *p,p'*-DDE to speak of. Of the new BFRs, plastics were very variable in composition and concentration with decabromodiphenylethane (DBDPE) and 1,2-*bis*(2,4,6-tribromophenoxy)ethane (BTBPE) prominent, but the natural matrixes almost exclusively had *syn*-dechlorane plus and *anti*-dechlorane plus.

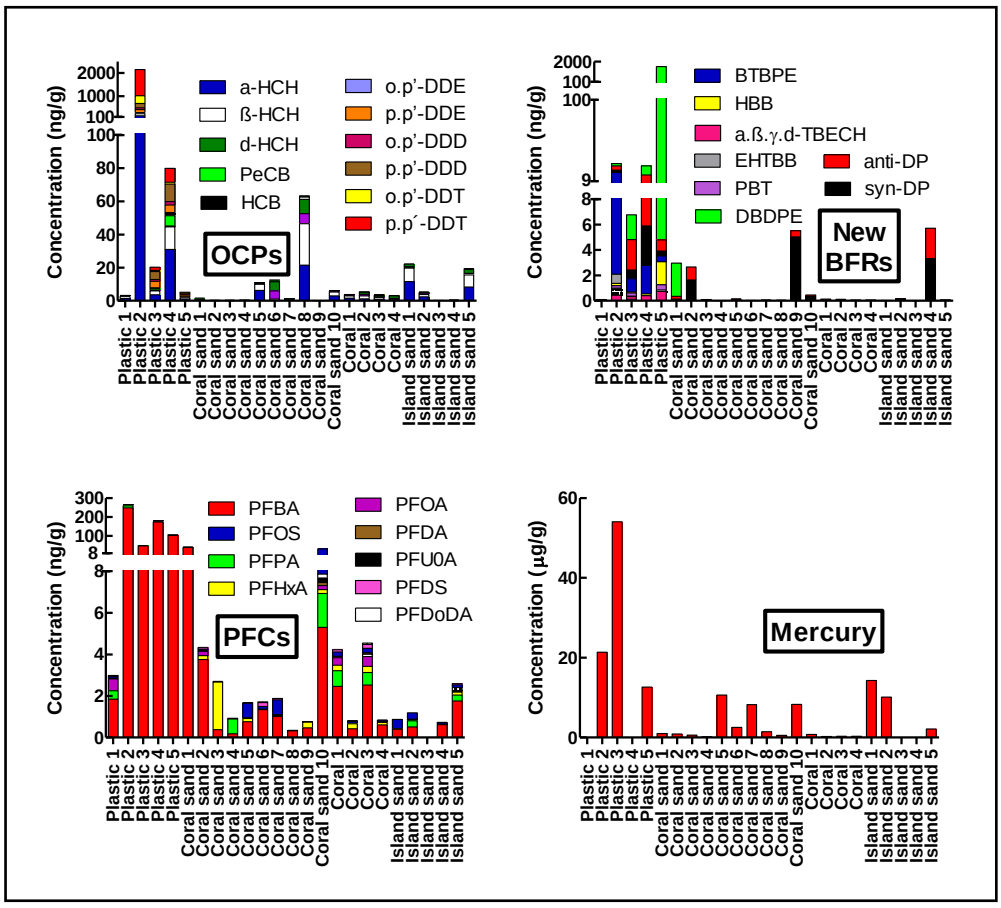

Figure 2: Concentrations of pollutants in beached plastics and coralline matrixes from SBR.

Perfluorobutanoic acid (PFBA) and perfluoropentanoic acid (PFPA) dominated the PFAS compound class in all matrixes and occurred in highest concentrations in plastics. PFOS and PFOA occurred in relatively small amounts. Mercury was higher in plastics than in coralline matrixes, but levels were quite variable within each matrix.

A non-metric multidimensional scaling (NMS) of relativised data (Figure 3) shows consecutive overlaps from plastics to coral sand and coral rubble, to colony sand. Axis 1 is dominated by BDEs and new BFRs in plastics, and HCHs in colony sand. Axis 2 is dominated *syn*- and *anti*-DP for coral sand and colony sand, and PFPA, TBECH, HCB and mercury in coral sand.

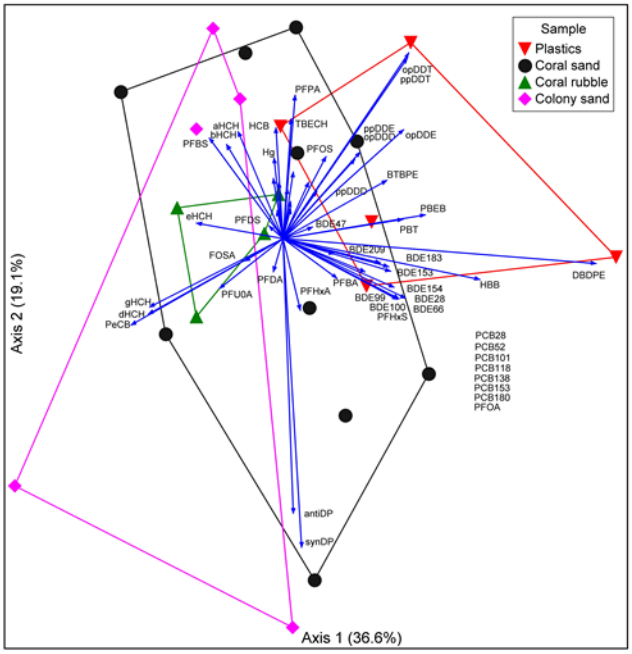

Figure 3: Non-metric multidimensional scaling (NMS) of all data (relativized). Convex hulls for sample types are indicated. Final stress = 11.9; final instability = 0.0000.

Discussion

From Figure 2 it is evident that pollutants occur in much higher levels in plastics than the coralline matrixes. It is also clear that the composition and concentrations of pollutants differ dramatically within and between sample classes. If the major source of pollutants to this almost otherwise pristine atoll would have been from seawater and air alone, one would have expected a much more homogenous composition, at least in the coralline samples. Compare for instance coral sand sample 8, 9, and 10 for all compound classes. It may be that the heterogeneity in the coralline samples is related to localised plastics loadings. As the beached plastics are broken down by wave action and sunlight, it releases the inherent pollutants to the immediate surroundings (either in solution or as microplastics), creating local pollutant hotspots. The NMS ordination (Figure 3) shows that plastics and coral sand overlap regarding pollutant profiles, and these two differ from colony sand where pollutants (such as the HCHs) could have come from bird droppings. We estimated about 1.2 million terns breeding on SBR.

Mercury, which is not added to plastics during manufacture, independently shows that the plastics could have travelled by different routes to SBR, resulting in varying concentrations in both plastics and localised releases causing hotspots. The loadings of pollutants on plastics would be governed by various factors, especially plastic types and compound interactions with plastics. It seems that certain types of compounds are retained much stronger by the plastics as they do not feature in the coralline samples, such as the DDTs,

For both organics and mercury however, the types of plastics should be controlled for (not determined in this study), but the heterogeneity of composition and concentrations of pollutants in the coralline samples indicate heterogeneous local sources rather than a homogenous background. The likely explanation for the observed patterns is that background circulation and facilitated transport by plastics are both involved, which differ for compound classes. This indicates that pollutants in plastics are released to the local environment on remote, (otherwise) pristine, coral ecosystems. More research is of course needed to confirm this effect.

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Supplemental note

Compounds analysed:

ATE	allyl 2,4,6-tribromophenyl ether
α,β,γ,δ-TBECH	*α,β,γ,δ*–tetrabromoethylcyclohexane
BATE	2-bromoallyl-2,4,6-tribromophenyl ether
TBCO	1,2,5,6-tetrabromocyklooktane
p-TBX	2,3,5,6-tetrabromo-*p*-xylene
PBEB	pentabromoethylbenzene
PBT	pentabromotoluene
DPTE	2,3-dibromopropyl-2,4,6-tribromophenyl ether
HBB	hexabromobenzene
HCDBCO	hexachlorocyclopentenyl-dibromocyclooktane
EHTBB	2-ethylhexyl-tetrabromobenzoate
BTBPE	1,2-*bis*(2,4,6-tribromophenoxy)ethane
syn-DP	*syn*-dechlorane plus
anti-DP	*anti*-dechlorane plus
BEHTBP	*bis*(2-ethylhexyl)tetrabromophtalate
DBDPE	decabromodiphenylethane

PFBA	perfluorobutanoic acid
PFPA	perfluoropentanoic acid
PFHxA	perfluorohexanoic acid
PFHpA	perfluoroheptanoic acid
PFOA	perfluorooctanoic acid
PFNA	perfluorononanoic acid
PFDA	perfluorodecanoic acid
PFUnDA	perfluoroundecanoic acid
PFDoDA	perfluorododecanoic acid
PFTrDA	perfluorotridecanoic acid
PFTeDA	perfluorotetradekanoic acid
PFBS	perfluorobutansulphonate
PFHxS	perfluorohexanesulphonate
PFOS	perfluorooctanesulphonate
PFDS	perfluorodecanesulphonate
FOSA	perfluorooctanesulphonamide
MeFOFA	N-methyl-perfluorooctanesulphonamide
EtFOSA	N-ethyl-perfluorooctanesulphonamide
MeFOSE	N-methyl perfluorooctane sulphonamidoethanol
EtFOSE	N-ethyl perfluorooctan sulphonamidoethanol

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