マイクロプラスチック汚染の現状、対策、国際動向

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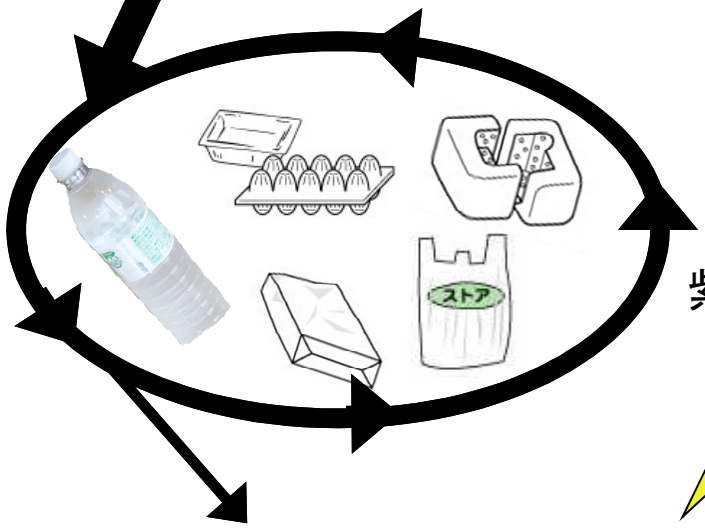
陸上の廃棄物処理からもれたプラスチックが河川を通して海へ流入

年間３億トンのプラスチックが生産されている。

石油産出量の８％がプラスチックに

そのうち半分は容器包装



紫外線

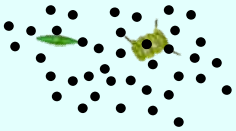
細片化

紫外線

細片化

5 mm以下の
プラスチック

マイクロプラスチック



特にことわりのない限り、本稿では「プラスチック」とは
「石油から作られたプラスチック」を指す。

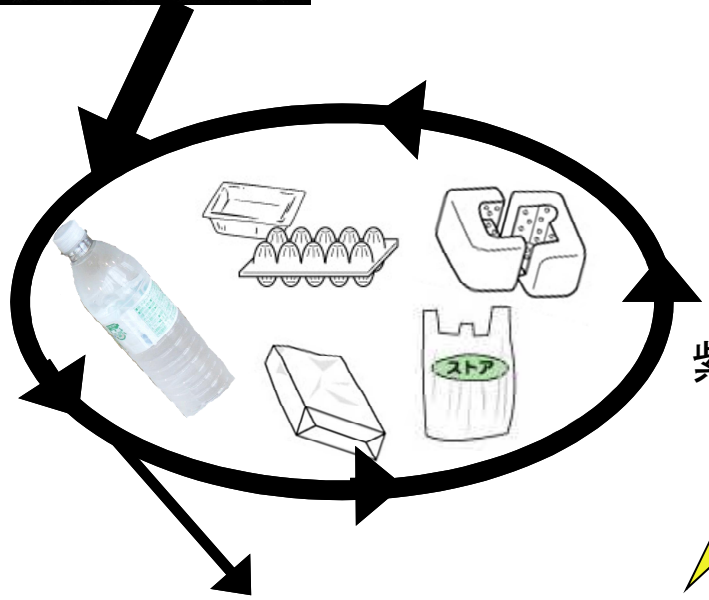
たくさん使えば、プラゴミもたくさん出る

東京、荒川

プラスチックのゴミは浮いて遠くまで運ばれる

ハワイ島、
カミロビーチ

プラスチックは紫外線、熱、波の力などにより細かな破片になっていく



紫外線

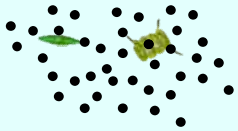
紫外線

5 mm以下の
プラスチック

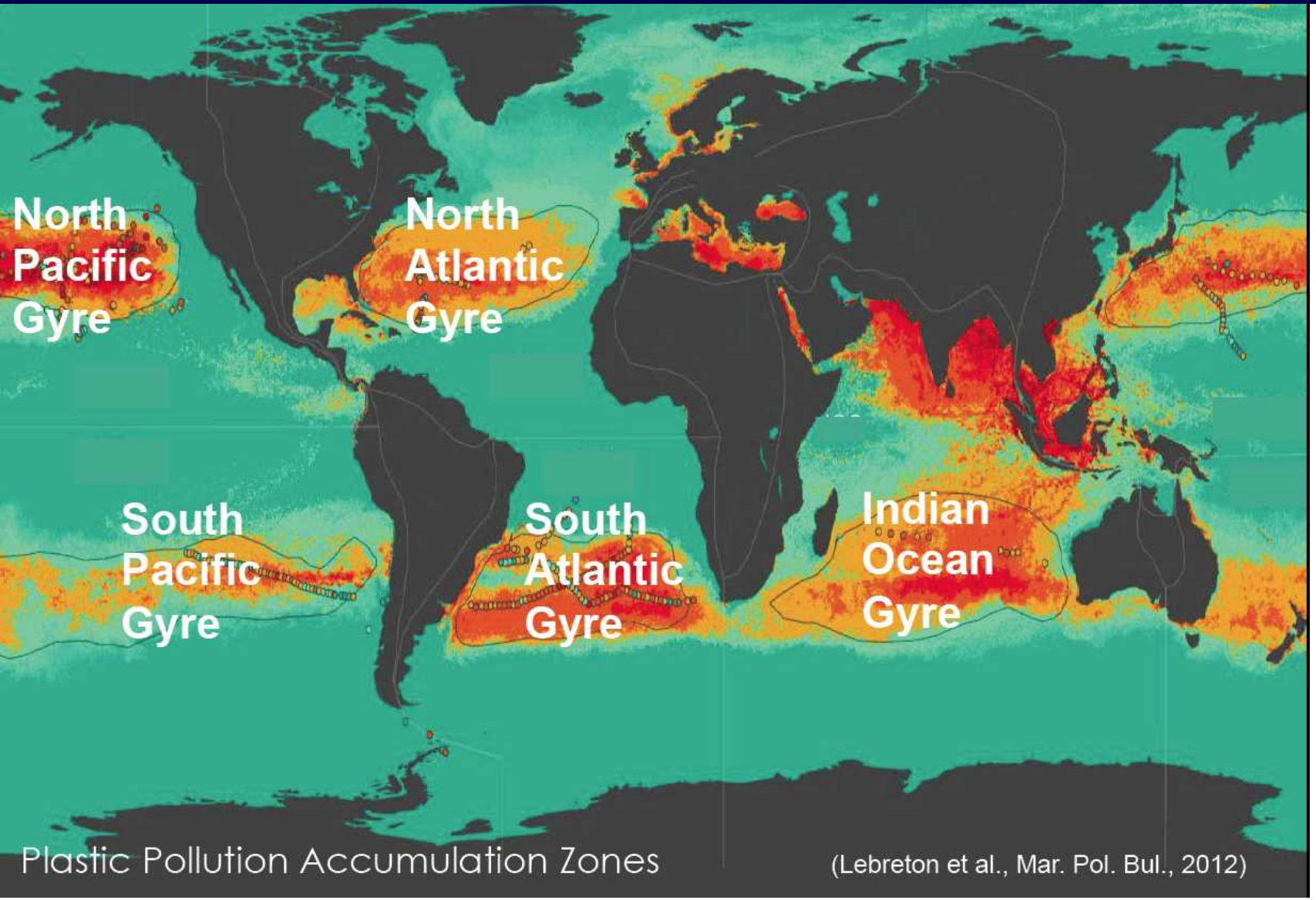
マイクロプラスチック

細片化

細片化



5兆個のプラスチックが世界の海を漂っている



(個/km^2)

海洋プラスチックは海洋生物に摂食される

大きなプラスチックは大型海洋生物が摂食する

合成、成型

紫外線

紫外線

摂食

細片化

細片化

マイクロプラスチック

取込

摂食

摂食

海鳥の胃の中からのプラスチック検出頻度は経年的に増えてきて、1980年にはほぼ全ての個体からプラスチックが検出された。

山下ら(2016)より

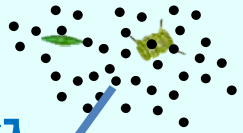
海洋プラスチックは海洋生物に摂食される

小さなプラスチックは低次栄養段階生物が取りこむ

合成、成型

細片化

細片化



マイクロプラスチック

紫外線

紫外線

摂食

摂食

摂食

取込

魚の消化管から検出

イワシの体内から検出されるプラスチックの大部分はプラスチック破片

80 %のイワシからプラスチックが検出

食の安全性への懸念

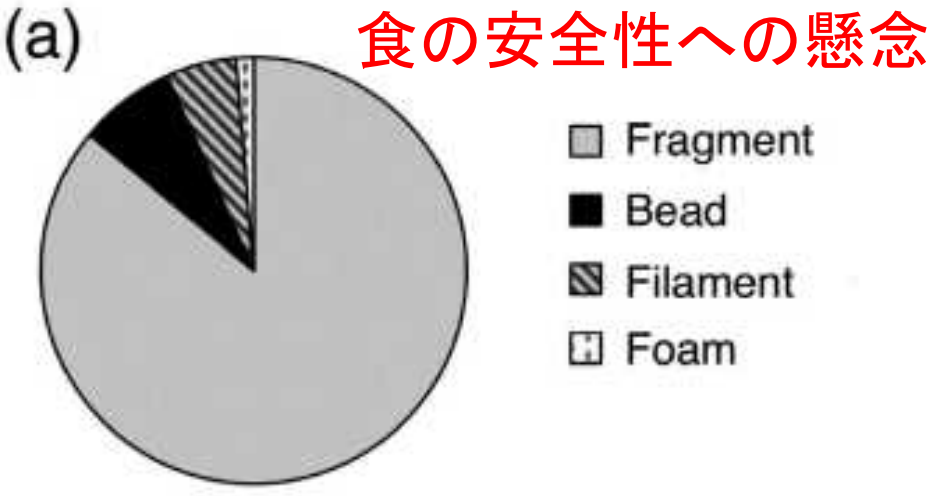
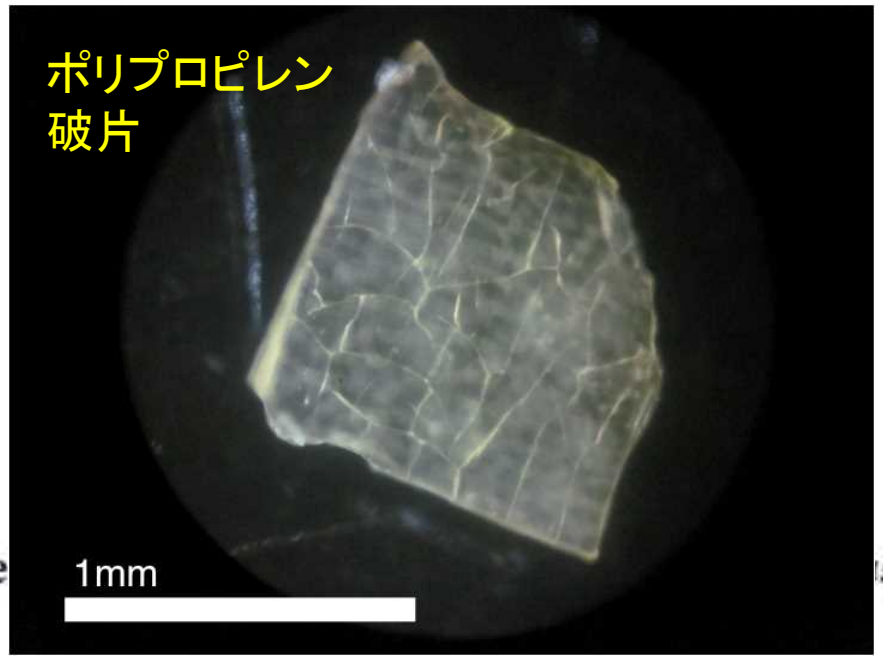
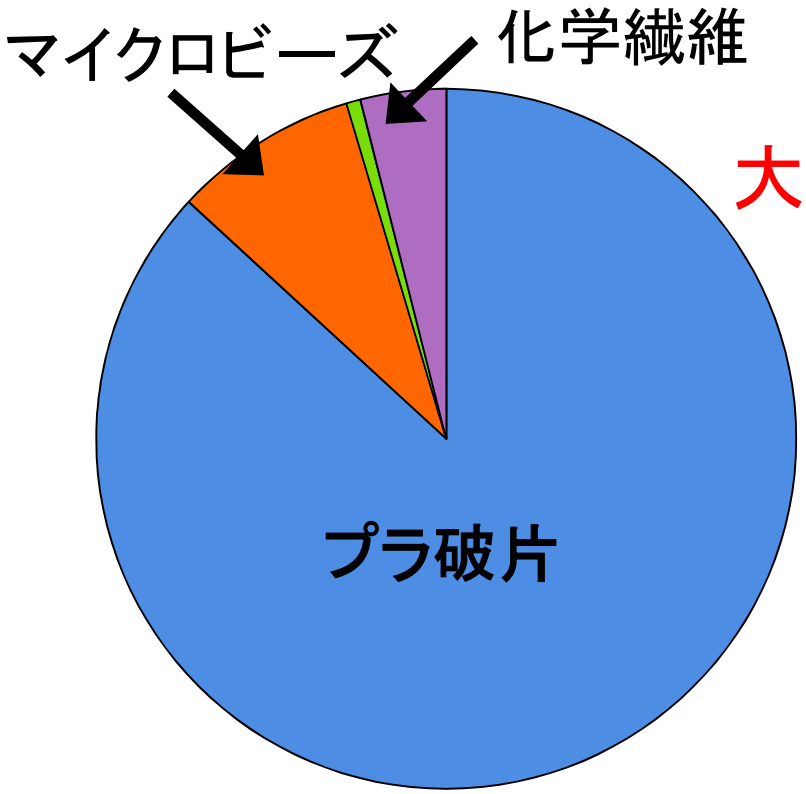


Figure 3. Types of plastics recovered from digestive
(a) Percentage by shape. (b) Percentage by polymer.



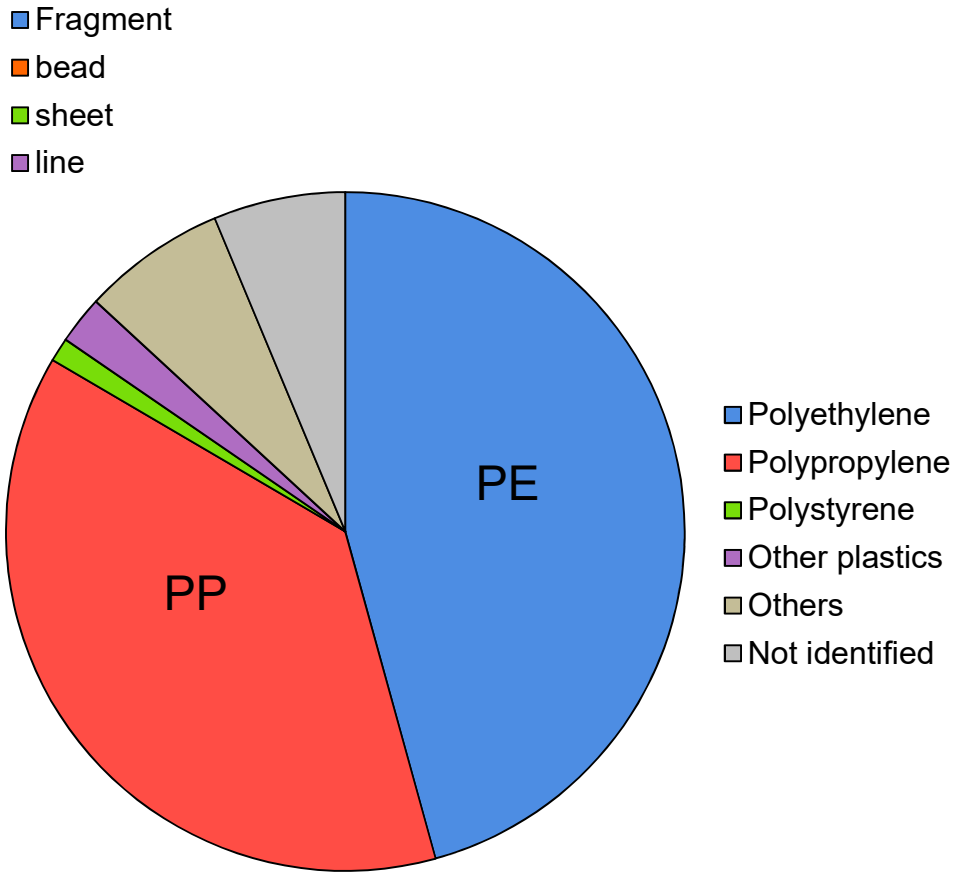
イワシから検出されたマイクロプラスチックの9割は破片



10%はマイクロビーズ
5%は化学繊維

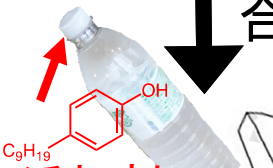
大部分は破片

→プラスチック廃棄物対策が必須

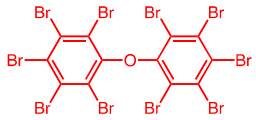


海洋プラスチックは海洋生物へ化学物質を運ぶ

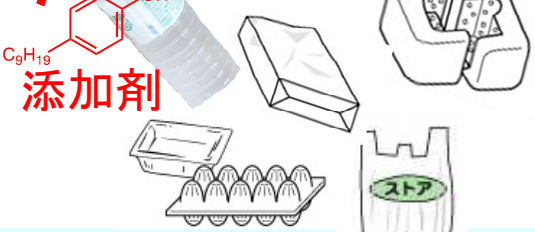
合成、成型



添加剤



添加剤



紫外線

紫外線

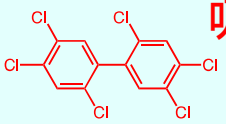
摂食

細片化

吸着

摂食

細片化

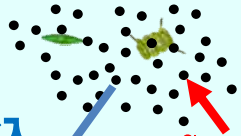


吸着

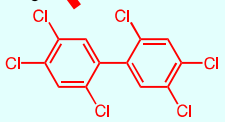
摂食

細片化

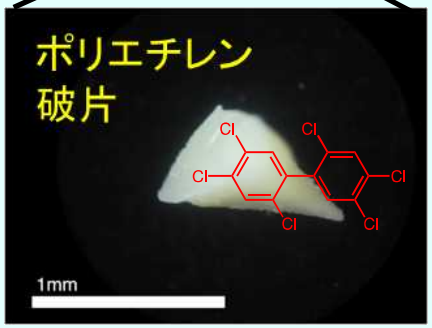
マイクロプラスチック



吸着



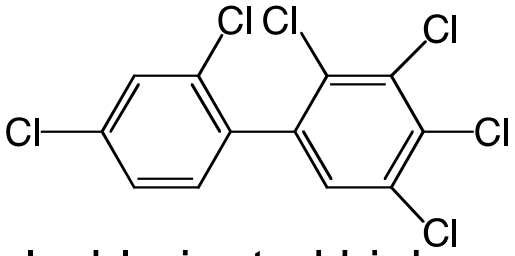
取込



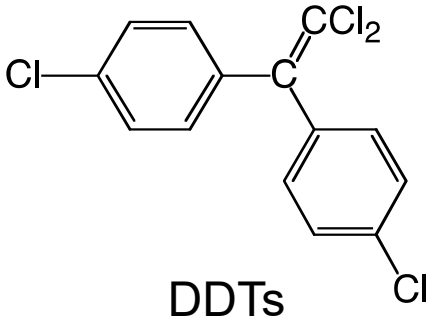
魚の消化管から検出

海洋漂流プラスチックから検出される有害化学物質

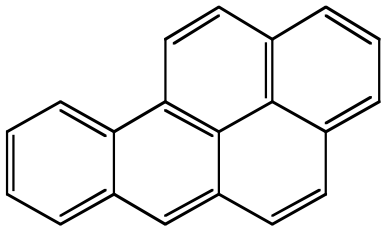
周りの海水中からの吸着



Polychlorinated biphenyl (PCBs)

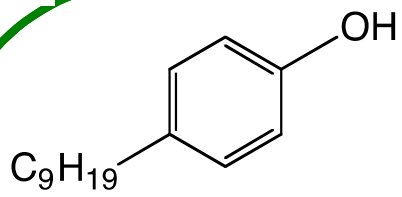


DDTs

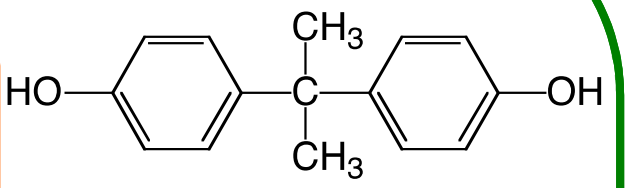


Polycyclic aromatic hydrocarbons (PAHs)

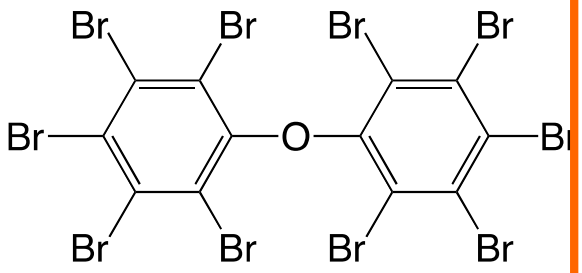
添加剤



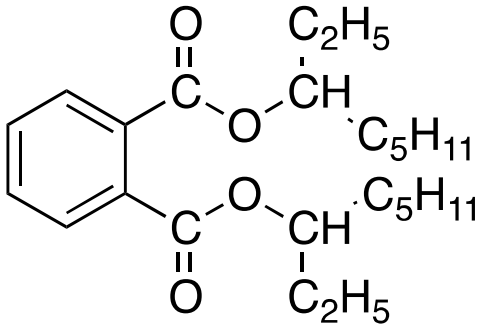
Nonylphenol



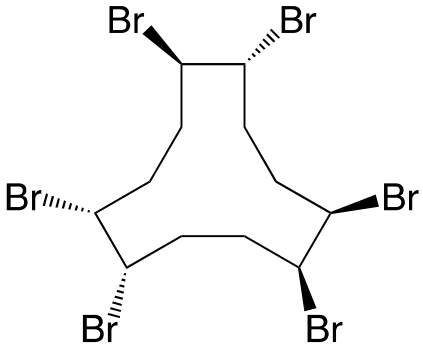
Bisphenol A



Polybrominated diphenyl ethers (PBDEs)

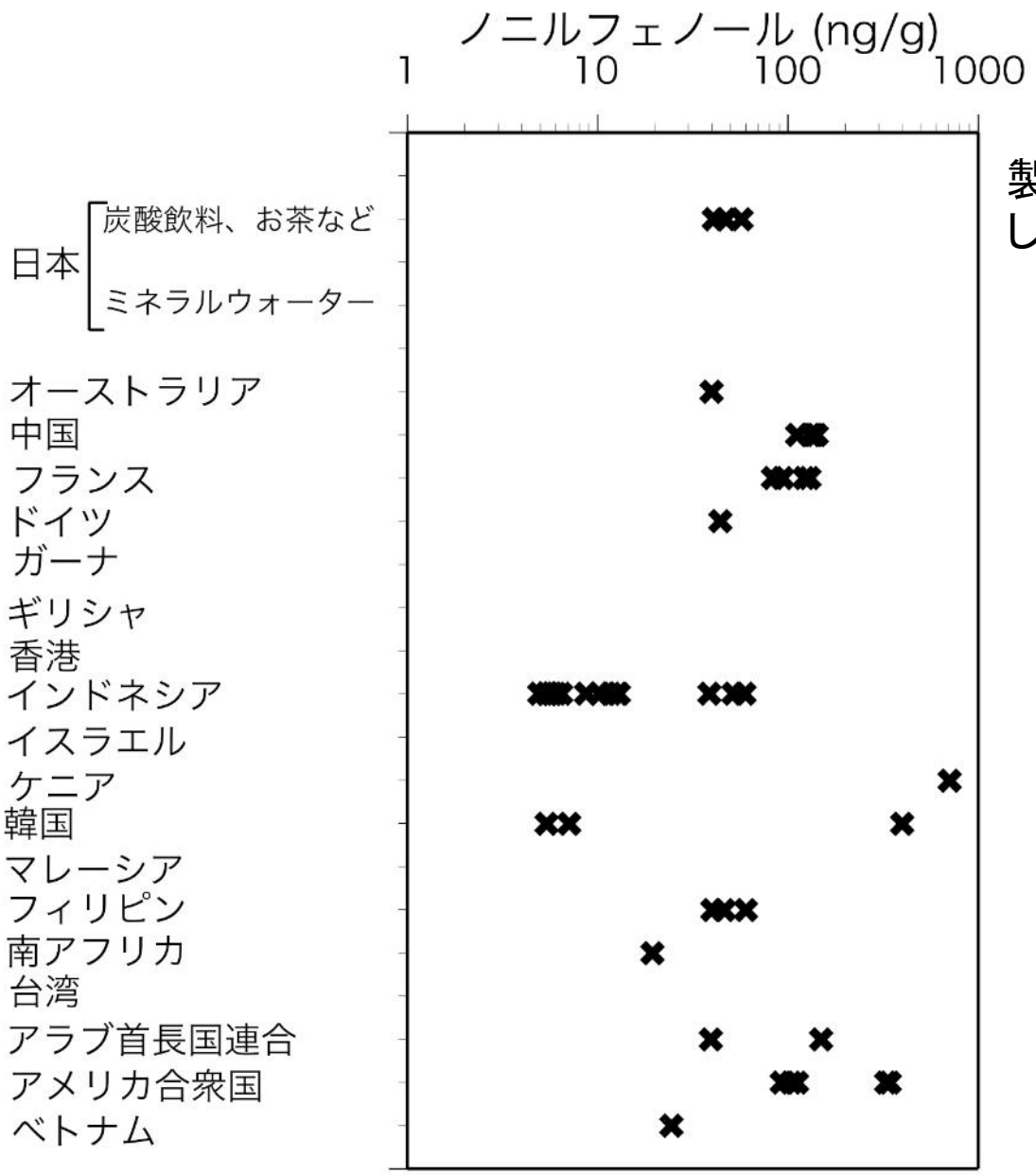


Phthalates (DEHP)



Hexabromocyclododecanes (HBCDs)

ペットボトルの蓋中の環境ホルモン



製品にもともと添加剤として含まれている

Organic micropollutants in marine plastics debris from the open ocean and remote and urban beaches

Hisashi Hirai [a], Hideshige Takada [a,*], Yuko Ogata [a], Rei Yamashita [a], Kaoruko Charita Kwan [b], Charles Moore [c], Holly Gray [c], Duane Laursen [c], Erik R. Zettle Christopher M. Reddy [e], Emily E. Peacock [e], Marc W. Ward [f]

ノニルフェノール(NP)等の
有害な添加剤は
海を漂うプラスチックにも
残留している。

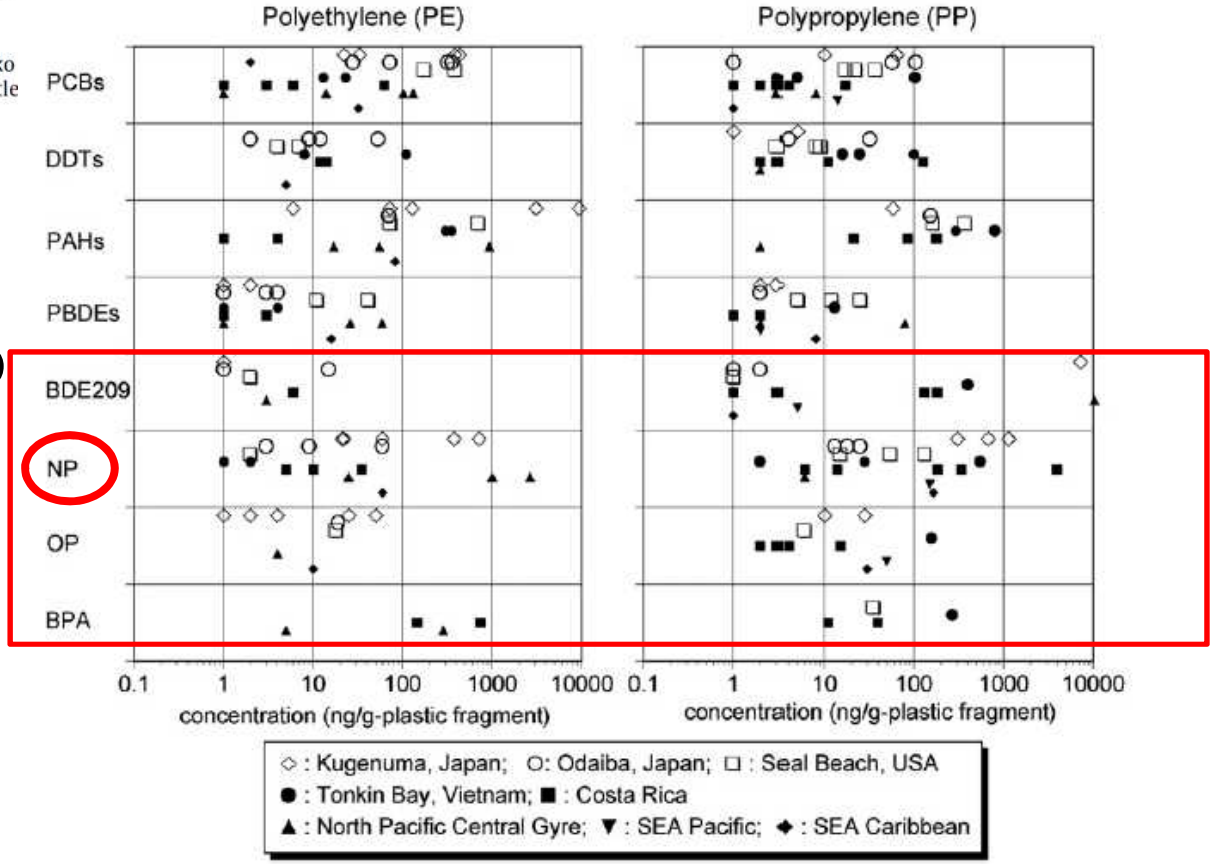


Fig. 2. Concentrations of organic micropollutants in marine plastic fragments.

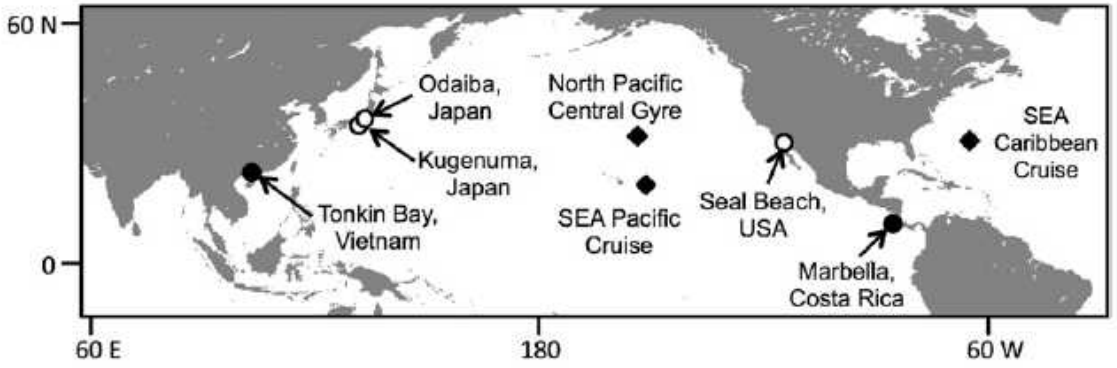
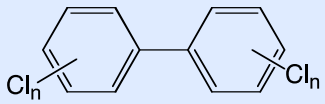


Fig. 1. Sampling locations. Closed diamond: open ocean sample; closed circle: remote beach sample; open circle: urban beach sample

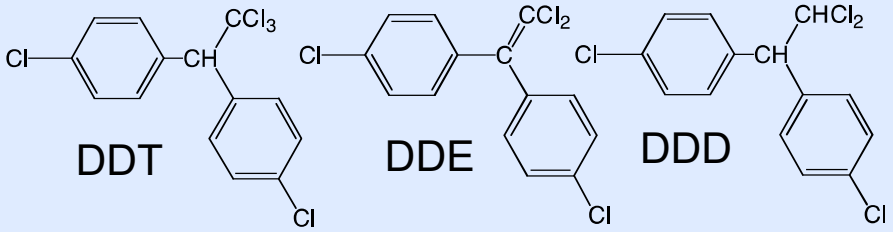
プラスチックは周辺海水中から残留性有機汚染物質(POPs)を吸着する

PCBs



- Industrial products for a variety of uses including dielectric fluid, heat medium, and lubricants.
- Endocrine disrupting chemicals

DDTs

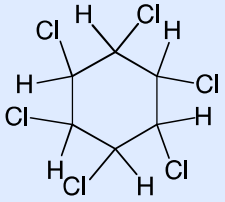


- DDT and its metabolites such as DDE and DDD.
- DDT was used as insecticides
- Endocrine disrupting chemicals

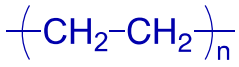
周辺海水中から吸着

プラスチック

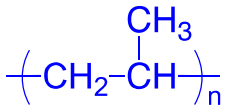
HCH



- Insecticide

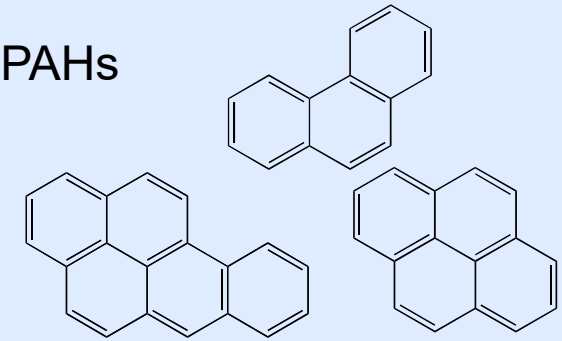


Polyethylene (PE)



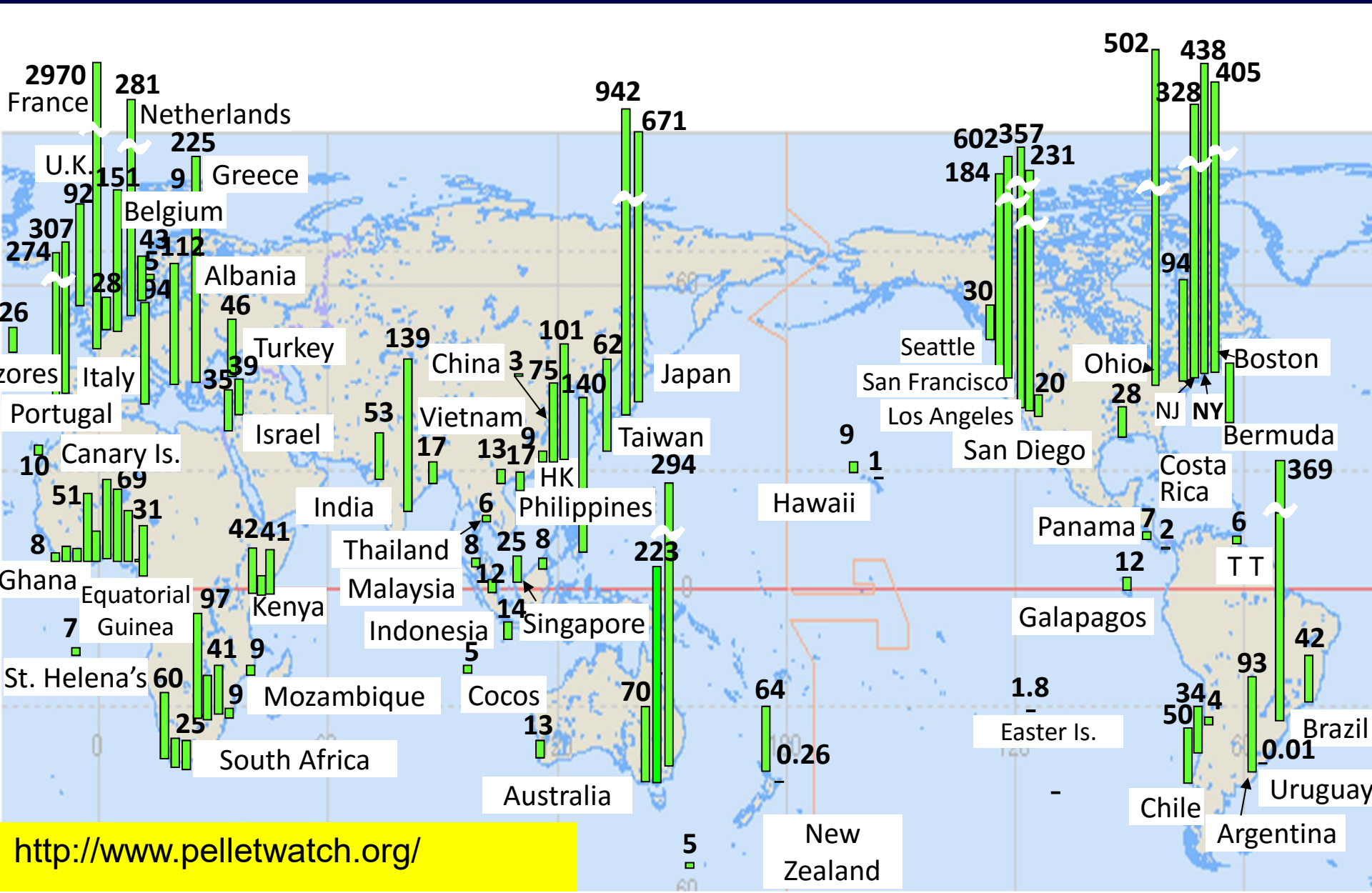
Polyprorylene (PP)

PAHs



Mato *et al*. (2001), *ES&T*

マイクロプラスチックがPOPsを吸着する



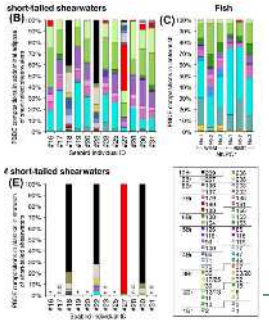
PCBs concentrations in beached plastic pellets (ng/g)

生物に取り込んだプラスチックから化学物質は生物組織に移行・蓄積する

Accumulation of plastic-derived chemicals in tissues of seabirds ingesting marine plastics

Kosuke Tanaka[a], Hideshige Takada[a,*], Rei Yamashita[a], Kaoruko Mizukawa[a], Masa-aki Fukuwaka[b], Yutaka Watanuki[c]

2013; Faculty of 1000



ENVIRONMENTAL Science & Technology

2015

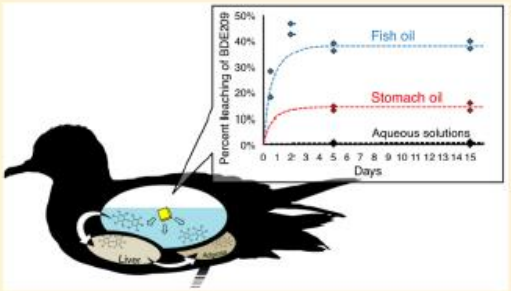
Facilitated Leaching of Additive-Derived PBI Seabirds' Stomach Oil and Accumulation in

Kosuke Tanaka,[†] Hideshige Takada,*[,†] Rei Yamashita,[†] Kaoruko M and Yutaka Watanuki[§]

[†]Laboratory of Organic Geochemistry, Tokyo University of Agriculture and Technol
[‡]Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Kushiro
[§]Faculty of Fisheries, Hokkaido University, Hakodate, Hokkaido 041-8611, Japan

Supporting Information

ABSTRACT: Our previous study suggested the transfer of polybrominated diphenyl ether (PBDE) flame retardants from ingested plastics to seabirds' tissues. To understand how the PBDEs are transferred, we studied leaching from plastics into digestive fluids. We hypothesized that stomach oil, which is present in the digestive tract of birds in the order Procellariiformes, acts as an organic solvent, facilitating the leaching of hydrophobic chemicals. Pieces of plastic compounded with deca-BDE were soaked in several leaching solutions. Trace amounts were leached into distilled water, seawater, and acidic pepsin solution. In contrast, over 20 times as much material was leached into stomach oil, and over 50 times as much into fish oil (a major component of stomach oil).



ENVIRONMENTAL Science & Technology

Article

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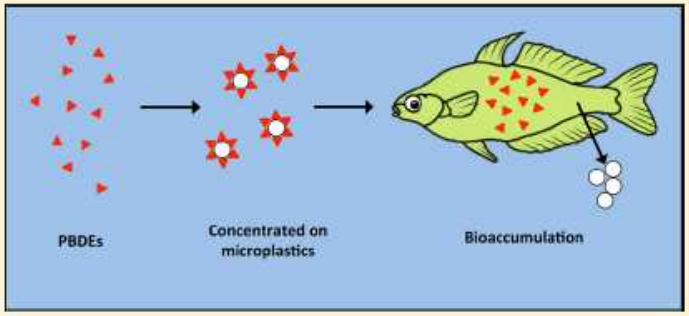
2016

Chemical Pollutants Sorbed to Ingested Microbeads from Personal Care Products Accumulate in Fish

Peter Wardrop,[†] Jeff Shimeta,[†] Dayanthi Nugegoda,[†] Paul D. Morrison,[†] Ana Miranda,[†] Min Tang,[‡] and Bradley O. Clarke*[,†]

[†]Centre for Environmental Sustainability and Remediation, RMIT University, GPO Box 2476, Melbourne, Victoria 3001, Australia
[‡]Key Laboratory of Advanced Materials of Tropical Island Resources, Ministry of Education; School of Materials and Chemical Engineering, Hainan University, Haikou, Hainan 570228, China

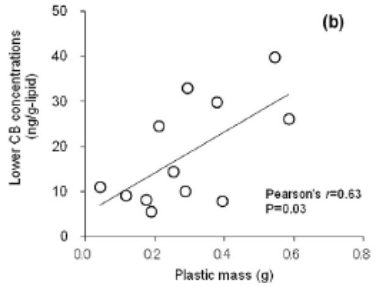
Supporting Information



Physical and chemical effects of ingested plastic debris on short-tailed shearwaters, *Puffinus tenuirostris*, in the North Pacific Ocean

Rei Yamashita[a,c,*], Hideshige Takada[a], Masa-aki Fukuwaka[b], Yutaka Watanuki[c]

2011



プラスチックに含まれる化学物質による生物への影響

室内実験ではプラスチックに吸着した化学物質により、プラスチックを摂食した生物（メダカ、ゴカイ）の肝機能の障害が観測されている。またポリスチレン微粒子の曝露により、牡蠣の再生産能力が落ちたという実験結果も報告されている。

しかし、野外の生物ではまだマイクロプラスチックが媒介した化学物質曝露による影響は観測されていない。プラスチック量や化学物質量が室内実験のレベルより低い。

Ingested plastic transfers hazardous chemicals to fish and induces hepatic stress

Chelsea M. Rochman[1], Eunha Hoh[2], Tomofumi Kurobe[1] & Swee J. Teh[1]

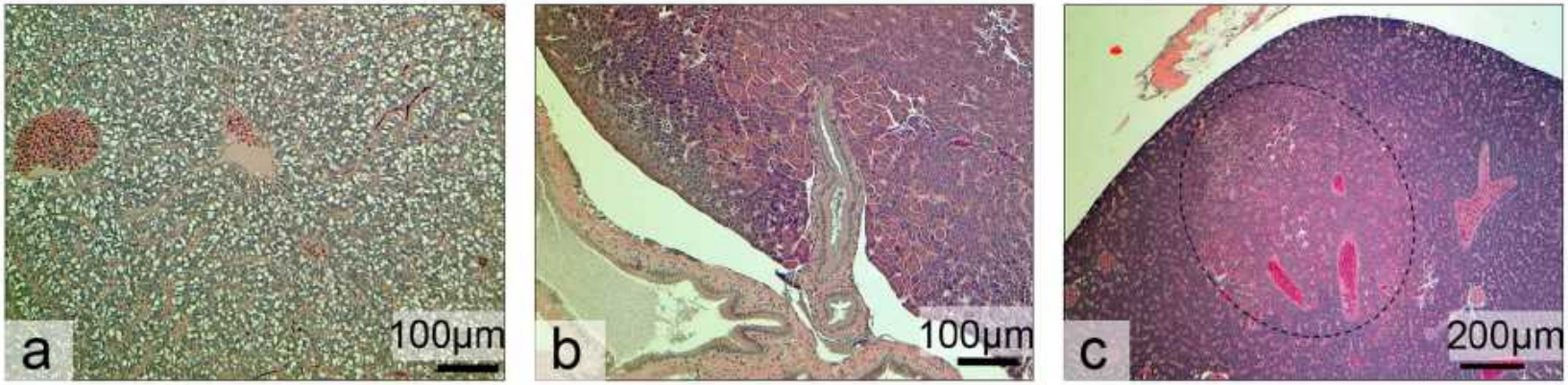
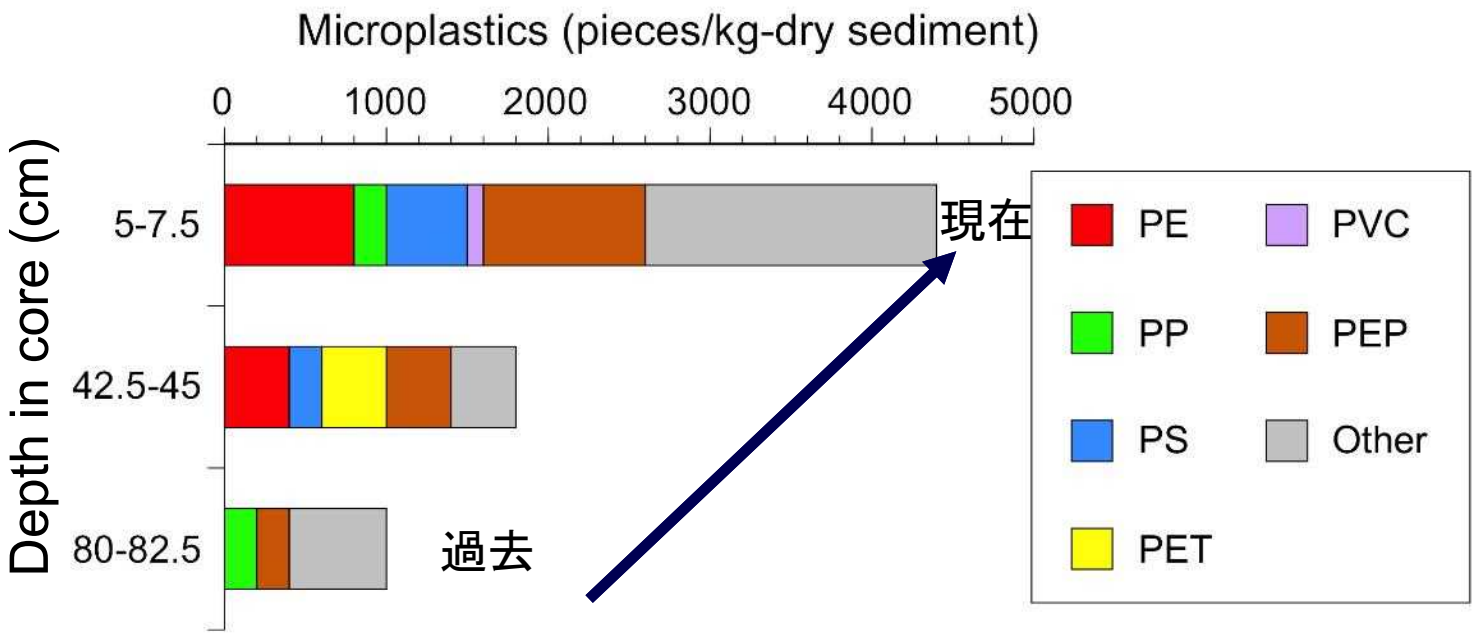


Figure 4 | Liver Histopathology in medaka sampled after 2 months. Micrographs show livers that are glycogen-rich from the control treatment (a) and glycogen-depleted from the virgin-plastic (b) and the marine-plastic treatment (c). An eosinophilic focus of cellular alteration, a precursor to a tumor, was observed in one fish from the virgin-plastic treatment (b). The circle highlights eosinophilic (pinkish coloration) hepatocytes,

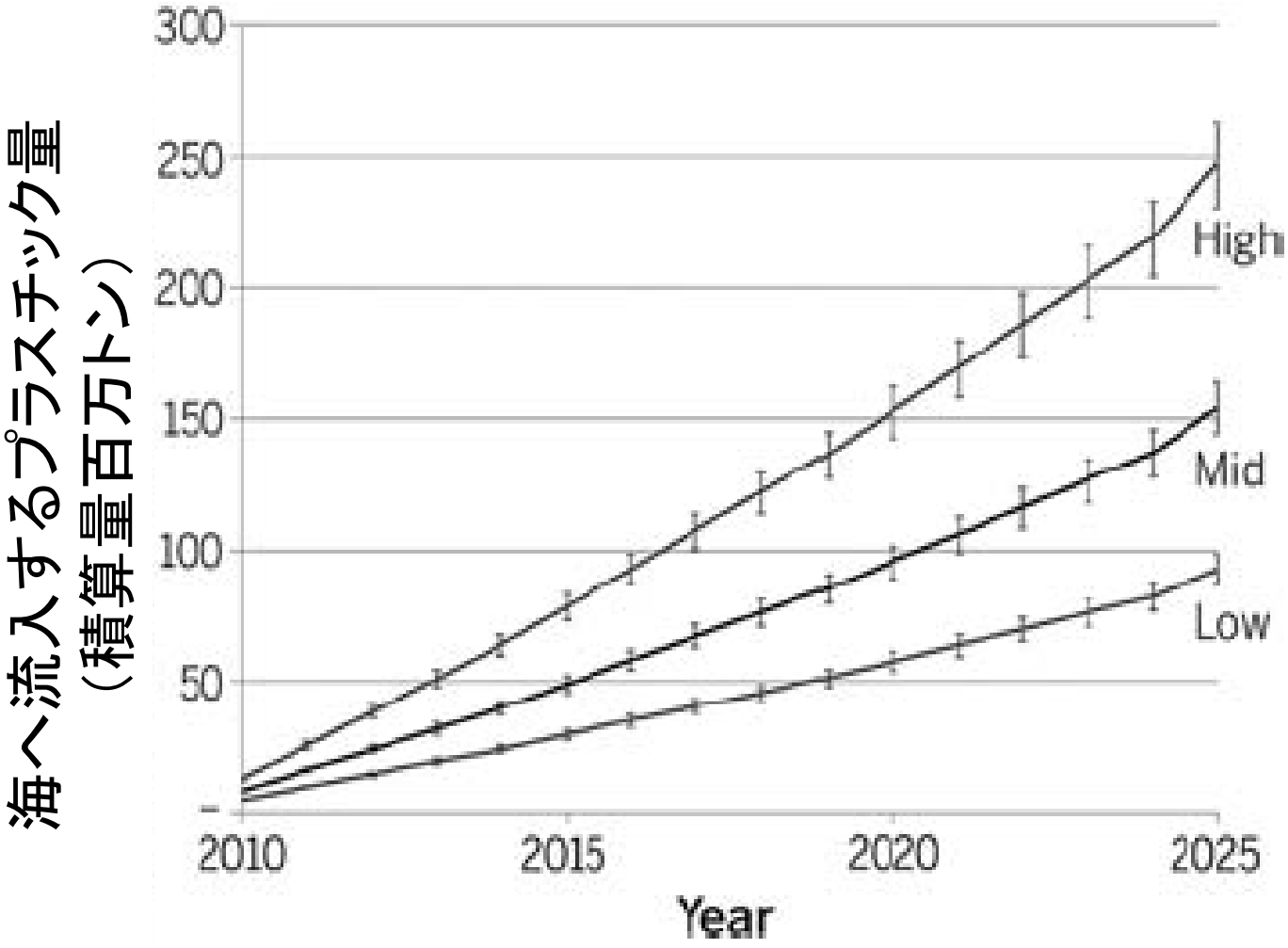
堆積物コアを利用して汚染のトレンドを解析：東京におけるコア採取

マイクロプラスチック汚染の進行が示された

泥の中のマイクロプラスチックの量



何も手を打たなければ、海に流入するプラスチックの量は20年後には10倍に増加する



Jamebeck et al. (2015), Science

国際的には予防原則に基づく対応がとられている

マイクロプラスチックのリスクについて不確かなことあるが、国際的には予防原則の立場から、対策は進められています。

←何も手を打たなければ、
　海洋プラスチック汚染は深刻化

←海洋のマイクロプラスチックは除去できない

第17回「海洋及び海洋法に関する国連総会非公式協議プロセス（ICP）」
2016年6月13日～17日

国際的には予防原則的に動いている

2015年12月　アメリカでマイクロビーズ配合禁止の
連邦法成立

2014年8月：米カリフォルニア州でレジ袋禁止の法案成立

2014年11月：EUが加盟国へレジ袋削減案策定を義務づけ
2025年までにレジ袋の消費を
１人１年40枚まで削減がEUの目標

日本では年間300億枚以上のレジ袋が使われている。
１人あたりでは年間300枚

2016年：　イギリスでレジ袋に課税

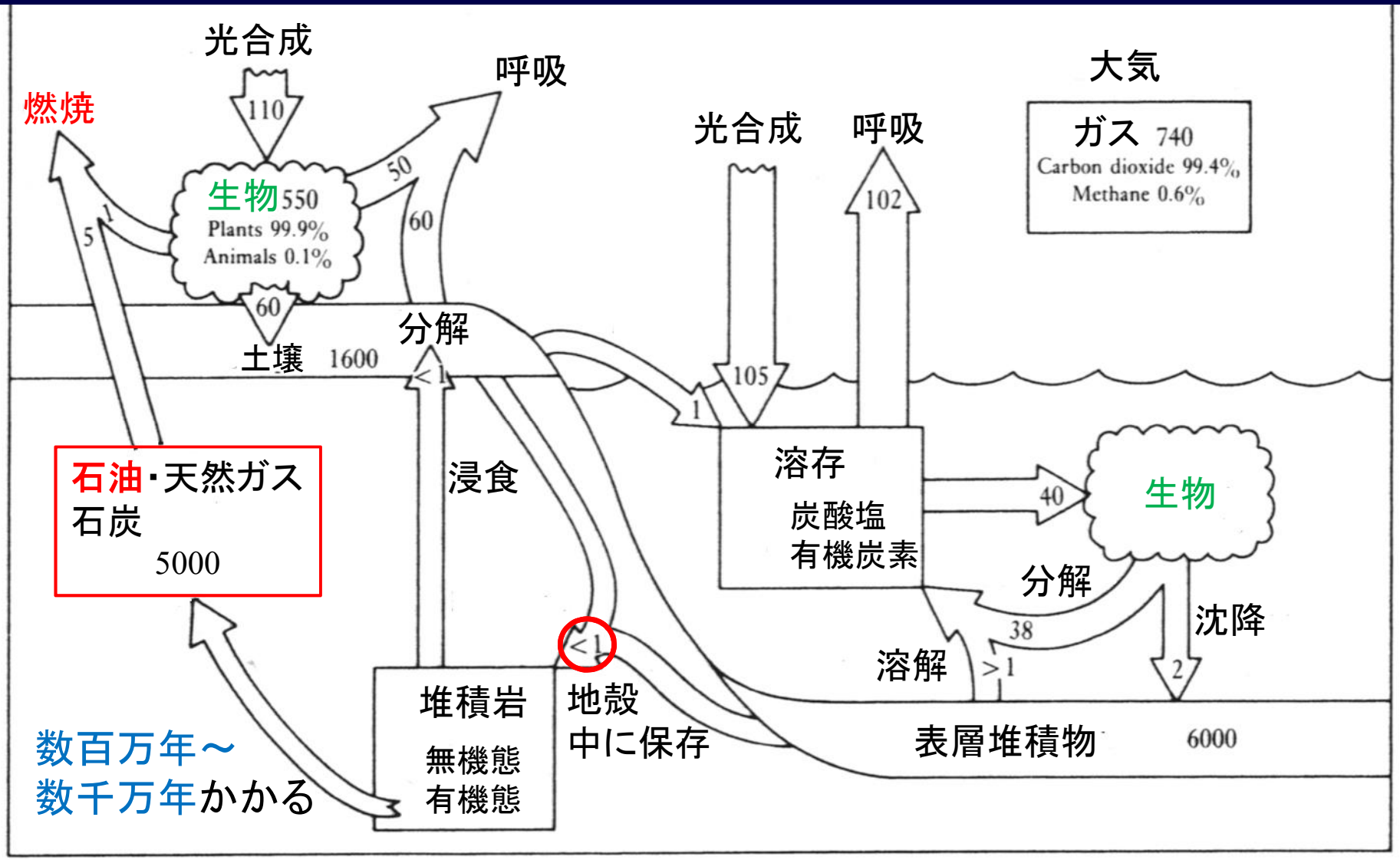
世界20ヵ国以上で
規制が行われている

国際的には予防原則的に動いている

2014年3月：米サンフランシスコ市でペットボトルでの飲料水の販売を禁止

2016年9月：フランスで「プラスチック製使い捨て容器や食器を禁止する法律」成立（2020年より）

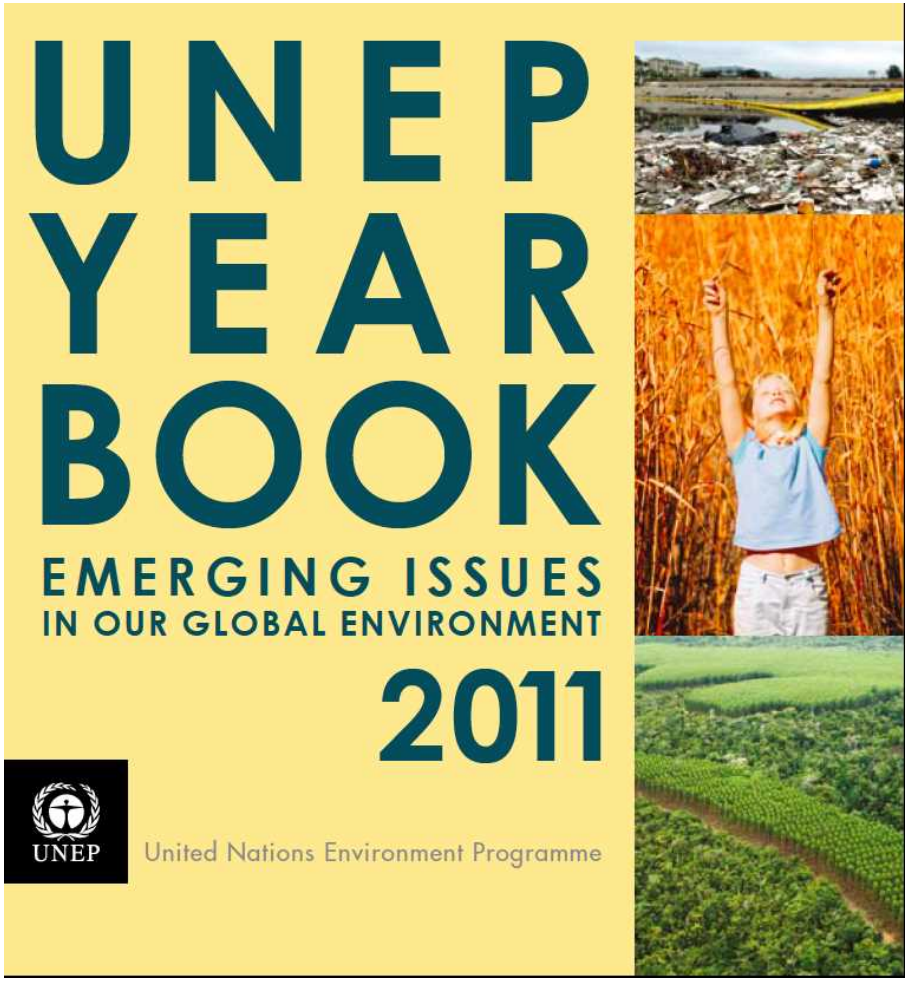
プラスチックの原料の石油は数百万年以上前の生物遺骸が地殻中で変成したもの
→石油由来のプラスチックは循環型ではない。
プラスチック削減は温暖化対策にもつながる



地球規模での炭素の循環（単位：ギガトン；矢印は年間移動量；枠内は現存量）

国際機関も海洋プラスチック汚染に注目

国連環境計画の年鑑



Plastic Debris in the Ocean

Every year large amounts of plastic debris enter the ocean, where it slowly fragments and accumulates in convergence zones. Scientists are concerned about the possible impacts of small plastic fragments—microplastics—in the environment. The role of plastics as a vector for transporting chemicals and species in the ocean is as yet poorly understood, but it is a potential threat to ecosystems and human health. Improved waste management is the key to preventing plastic and other types of litter from entering the ocean.

Box 3: Plastic pellets

Plastic resin pellets are small granules, generally in the shape of a cylinder or disc, with a diameter of a few millimetres. These particles are an industrial raw material that is remelted and moulded into final products. They enter the ocean as a result of spills or accidental releases. Like other plastic particles, they have been shown to accumulate PBTs. In the case of thin plastic films, for example those 50 micrometres or less, it may take only a few days for this process of accumulation or release to occur (Adams et al. 2007). In the case of pellets, equilibrium between the concentration of a given compound in a pellet and in the surrounding water or sediment may take many weeks or months. Older pellets consequently tend to have higher concentrations of contaminants and have been used to map the distribution of pollution in coastal waters around the world (Ogata et al. 2009, International Pellet Watch 2011) (**Figure 5**). Their consistent size makes them a useful monitoring tool.

Transport by plastic particles does not represent a significant additional flux of PBTs on a global scale compared with atmospheric or water transport (Zarfl and Matthies 2010). However, the concentration of contaminants by microplastic particles presents the possibility of increasing exposure to organisms through ingestion and entrance into the food chain—with the prospect of biomagnification in top-end predators in the food chain such as swordfish and seals. Ingestion of small particles by a wide variety of organisms has been well reported. However, the basic information needed on the biochemical and physiological response of organisms to ingested plastics contaminated with PBTs in order to quantify the scale of the problem is currently unavailable (Arthur et al. 2009, GESAMP 2010). It is conceivable that PBTs in plastic particles will be less bioavailable than those from the surrounding water or food sources (Gouin et al. 2011).

Collected from beaches around the world, plastic pellets like these have been found to accumulate persistent, bio-accumulating and toxic substances. The pellets are used in the manufacture of plastic products and have been introduced into the ocean through accidental releases. They may also be released as a result of poor handling or waste management. While there is evidence that quantities entering the marine environment have been reduced as a result of improved industrial practices, pellets already released will persist for many years. *Credit: International Pellet Watch*

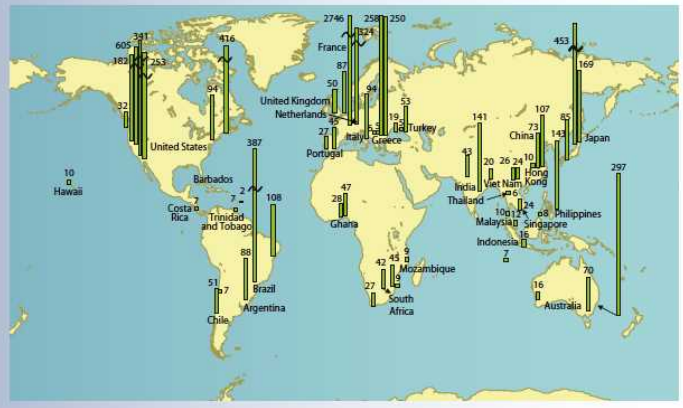


Figure 5: Concentration of PCBs in beached plastic resin pellets, in nanograms per gram of pellet. Samples of polyethylene pellets have been collected at 56 beaches in 29 countries and analyzed for concentrations of organochlorine compounds. PCB concentrations were highest in pellets collected in the United States, Western Europe and Japan. They were lowest in those collected in tropical Asia and Africa. This spatial pattern reflects regional differences in the use of PCBs. *Source: Ogata et al. (2009) with additional data provided by International Pellet Watch in 2010*

国連でも議論され、海のプラスチック汚染が国際的に共通した懸念に

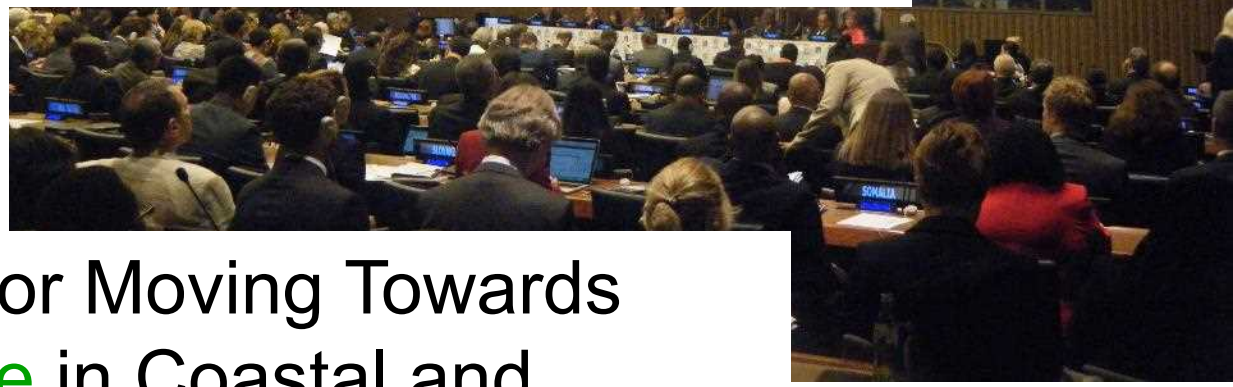
第17回「海洋及び海洋法に関する国連総会非公式協議プロセス（ICP）」
2016年6月13日～17日

ニューヨーク 国連本部

マイクロプラスチック国際条約についても議論が始まる

THE OCEAN CONFERENCE

UNITED NATIONS, NEW YORK, 5-9 JUNE 2017



Side event

3 R as the Basis for Moving Towards Zero Plastic Waste in Coastal and Marine Environment

“Issue of microplastics in the coastal and marine environment and 3R solutions” Hideshige Takada (Japan)

持続可能な開発目標


1 貧困をなくそう
2 飢餓をゼロに
3 すべての人に健康と福祉を
4 質の高い教育をみんなに
5 ジェンダー平等を実現しよう
6 安全な水とトイレを世界中に
7 エネルギーをみんなにそしてクリーンに
8 働きがいも経済成長も
9 産業と技術革新の基盤をつくろう
10 人や国の不平等をなくそう
11 住み続けられるまちづくりを
12 つくる責任つかう責任
13 気候変動に具体的な対策を
14 海の豊かさを守ろう
15 陸の豊かさも守ろう
16 平和と公正をすべての人に
17 パートナーシップで目標を達成しよう
SUSTAINABLE DEVELOPMENT GOALS
2030年に向けて
世界が合意した
「持続可能な開発目標」です

14.1
By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including **marine debris** and nutrient pollution

14.1.1
Index of coastal eutrophication and floating **plastic debris** density

United Nations

General Assembly

United Nations Conference to Support the Implementation of Sustainable Development Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development
New York, 5-9 June 2017
Item 11 of the provisional agenda*
Outcome of the Conference

Draft call for action

4. We are particularly alarmed by the adverse impacts of climate change on the ocean, including the rise in ocean temperatures, ocean and coastal acidification, deoxygenation, sea-level rise, the decrease in polar ice coverage, coastal erosion and extreme weather events. We acknowledge the need to address the adverse impacts that impair the crucial ability of the ocean to act as climate regulator, source of marine biodiversity and as key provider of food and nutrition, tourism and ecosystem services and as an engine for sustainable economic development and growth. We recognize, in this regard, the particular importance of the Paris Agreement, adopted under the United Nations Framework Convention on Climate Change.

(g) Accelerate actions to prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities, including marine debris, plastics and microplastics, nutrient pollution, untreated wastewater, solid waste discharges, hazardous substances, pollution from ships and abandoned, lost or otherwise discarded fishing gear, as well as to address, as appropriate, the adverse impacts of other human-related activities on the ocean and on marine life, such as ship strikes, underwater noise and invasive alien species;

(h) Promote waste prevention and minimization; develop sustainable consumption and production patterns; adopt the 3Rs — reduce, reuse and recycle — including through incentivizing market-based solutions to reduce waste and its generation, improving mechanisms for environmentally sound waste management, disposal and recycling and developing alternatives such as reusable or recyclable products or products that are biodegradable under natural conditions;

(i) Implement long-term and robust strategies to reduce the use of plastics and microplastics, in particular plastic bags and single-use plastics, including by partnering with stakeholders at relevant levels to address their production, marketing and use;

海洋プラスチック汚染低減のための具体的対策

- 使い捨てプラスチック（特に、レジ袋）の使用規制

- 再使用・リサイクルが容易になるような商品や包装（簡易包装も含む）を生産者や流通業者がとり組むように指導、規制

- 紙や木などのバイオマスの高度利用の促進
- バイオマスベースのプラスチックの利用促進

- リサイクルを促進する社会的なシステムの開発と実装
- 生分解プラスチックの改良と陸上での処理装置での分解促進
- 食品包装へのバイオマスベース生分解性プラスチックの適用とコンポスト化の促進

- 海岸清掃（行政、ボランティア）
- 市民の意識の3R(削減ファースト）意識の啓発

パリ協定（温暖化ガスの実質的排出ゼロ）や他の環境問題対策との整合性

ポストプラスチック社会の将来像

プラスチックの削減が最優先。紙や木の利用も促進して、リサイクルできないプラスチックは極力減らし、それでも残る食品包装等に必要なプラスチックについては石油ベースのプラスチックからバイオマスベースかつ生分解性のプラスチックに置き換え、それらを食品残渣と共にコンポスト化して、農地還元する。

(g) Accelerate actions to prevent and significantly reduce marine pollution of all kinds, particularly from land-based activities, including marine debris, plastics and microplastics, nutrient pollution, untreated wastewater, solid waste discharges, hazardous substances, pollution from ships and abandoned, lost or otherwise discarded fishing gear, as well as to address, as appropriate, the adverse impacts of other human-related activities on the ocean and on marine life, such as ship strikes, underwater noise and invasive alien species;

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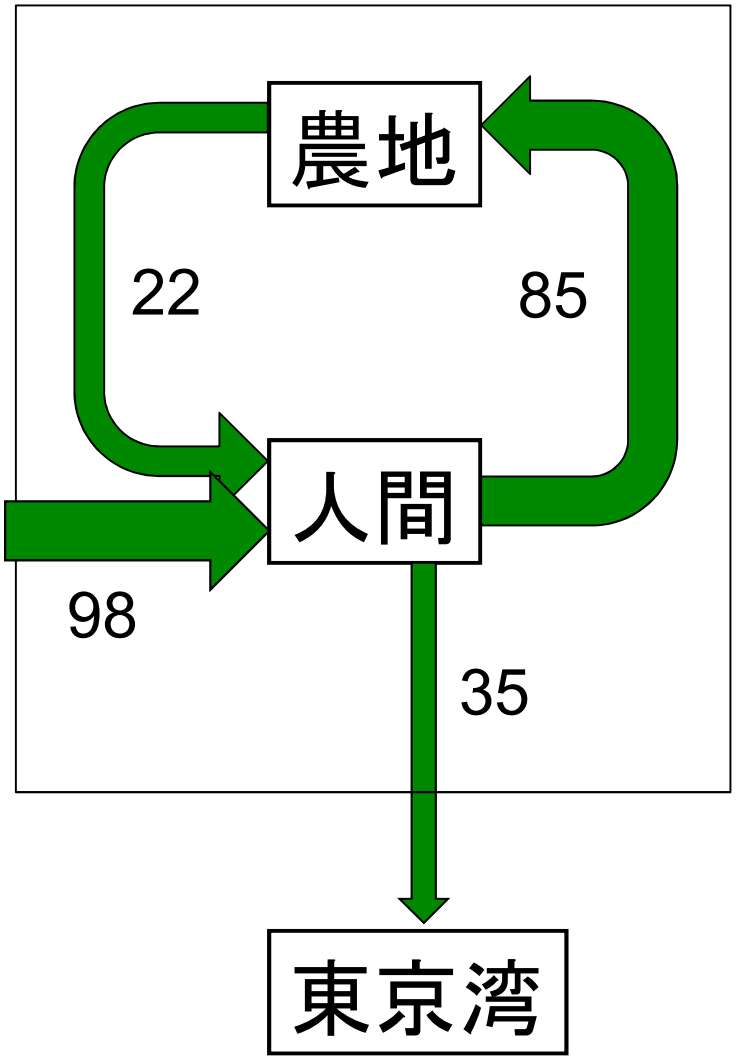
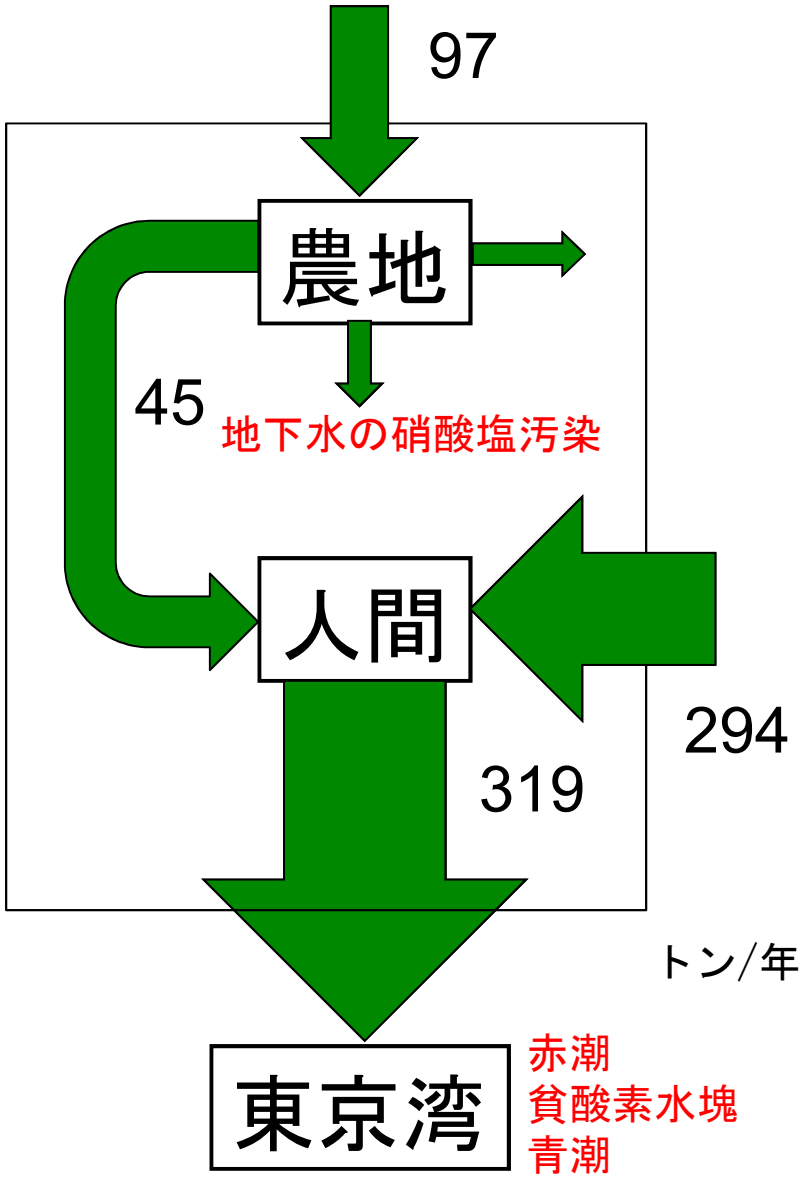
(i) Implement long-term and robust strategies to reduce the use of plastics and microplastics, in particular plastic bags and single-use plastics, including by partnering with stakeholders at relevant levels to address their production, marketing and use;

東京湾流域における窒素の動態



1930年



現在

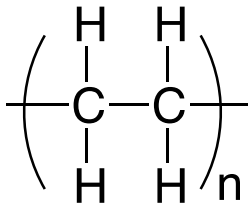
使い捨てプラスチック削減を最優先にして、多様なアイディアを取り入れた行政のイニシアティブを

以降補足スライド

5つの主要なプラスチックの生産量割合と密度

ポリエチレン (PE)

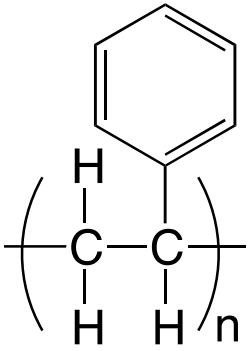
29%



密度：0.90～0.97 g/cm^3

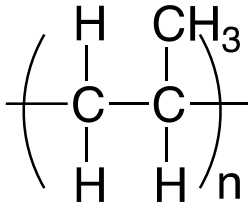
ポリスチレン (PS)

7%



1.04 g/cm^3

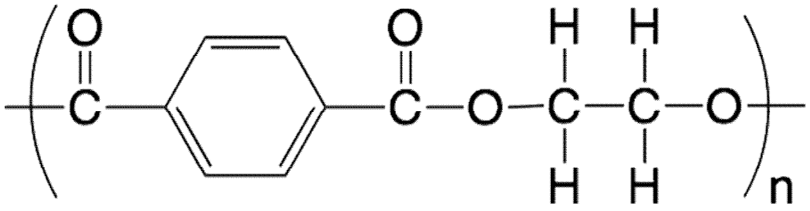
ポリプロピレン (PP)



19%

0.90 g/cm^3

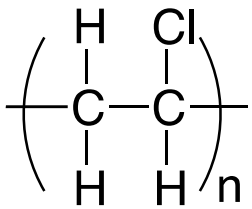
ポリエチレンテレフタラート(PET)



7%

1.34～1.37 g/cm^3

ポリ塩化ビニル (PVC)



13%

1.4 g/cm^3

マイクロ
プラスチック

5 mm以下の
プラスチック

日本列島から1000km離れた太平洋上で気象庁が採取したマイクロプラスチック。

SCIENTIFIC REPORTS

Microplastic fragments and microbeads in digestive tracts of planktivorous fish from urban coastal waters

Kosuke Tanaka & Hideshige Takada

Laboratory of Organic Geochemistry, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan. Correspondence and requests for materials should be addressed to H.T. (email: shige@cc.tuat.ac.jp)

Received: 15 March 2016

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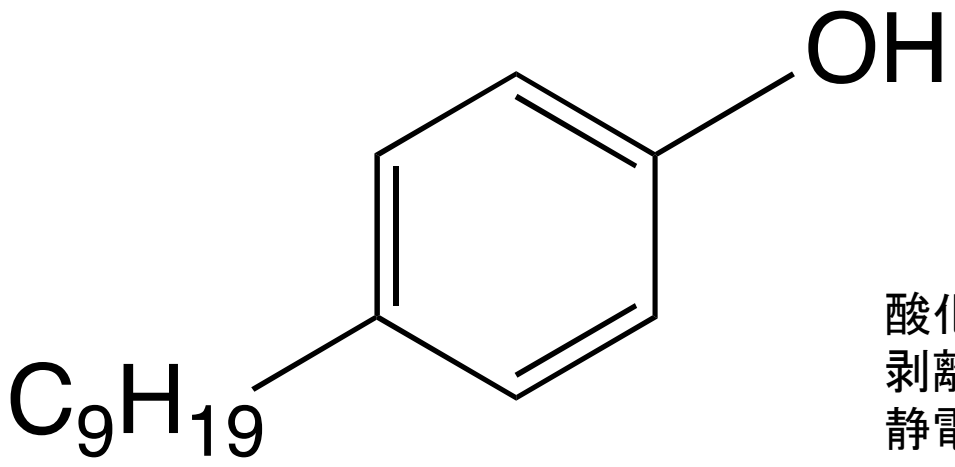
Published: 30 September 2016

マイクロプラスチックはいろいろな起源から供給される

5 mm以下のプラスチック

- プラスチック製品の破片
- 化学繊維
- レジンペレット
- マイクロビーズ（スクラブ）
- メラミンフォームスポンジ

ノニルフェノール：環境ホルモン



プラスチック添加剤

酸化防止剤
剥離剤
静電防止剤

・子宮内膜症、乳癌の増加

・メスとオスが一緒になった魚（雌雄同体）

堆積物コアを利用して汚染のトレンドを解析：東京におけるコア採取

アジア・アフリカにおけるマイクロプラスチック汚染の歴史変遷の解析

Tokyo

Gulf of Thailnad

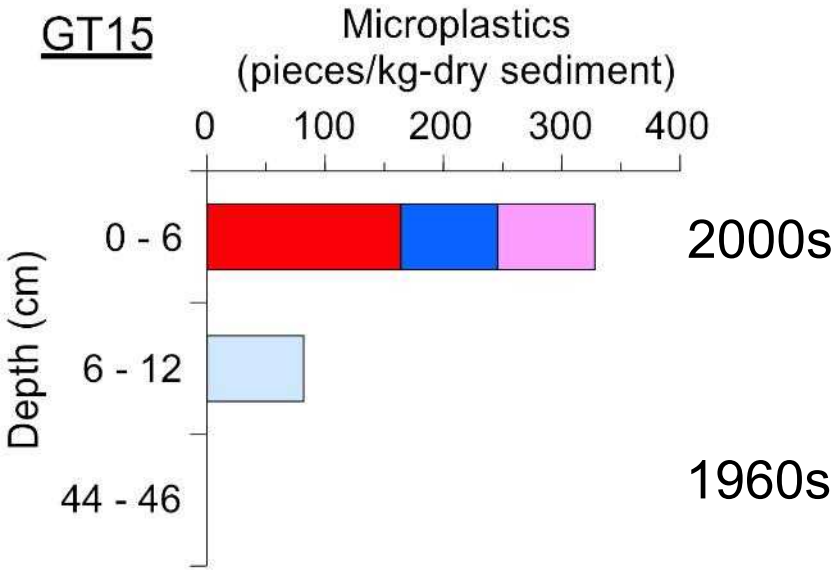
Tonkin Bay, Vietnam

Straits of
Johor, Malaysia

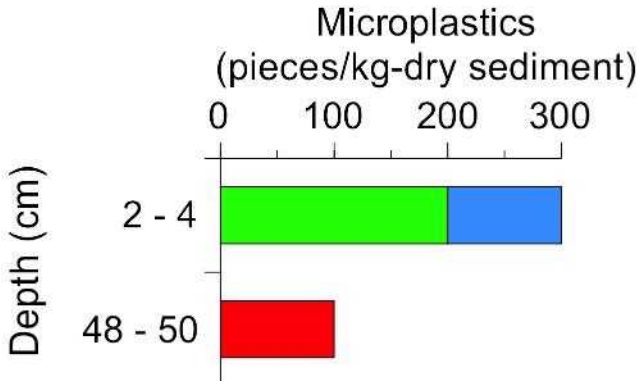
Durban, South Africa

マイクロプラスチック汚染の進行は世界的現象

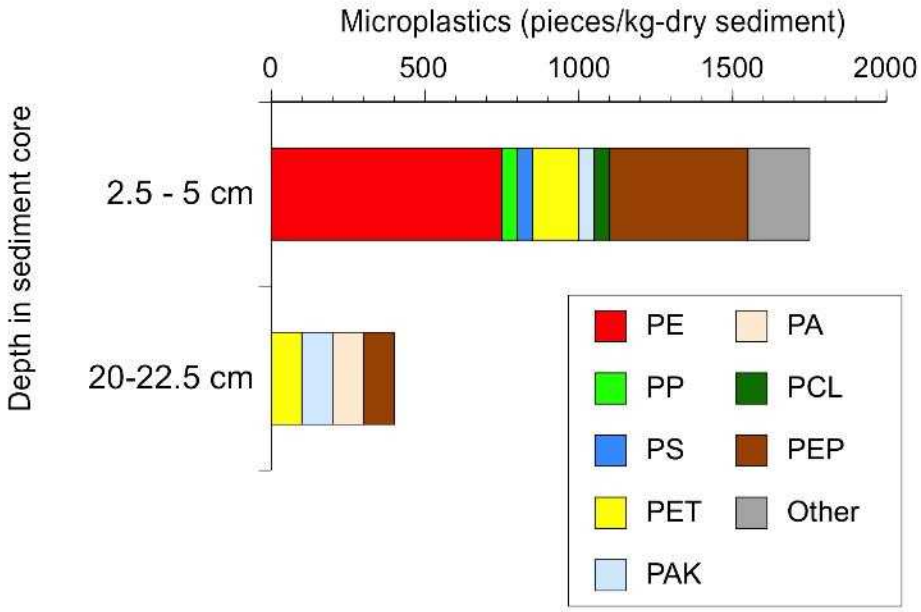
Thailand (Gulf of Thailand)



Malaysia



South Africa



Vertical profiles of microplastics in sediment cores from Asian and African waters

Regulation of plastic shopping bag : priority option

Polyethylene : high affinity with POPs

Light floating; long travel; thin

Easy to be microplastics

Table 1. Regulation on plastic shopping bags in the world

Ban	Charge	Tax
France	Sweden	Denmark
Italy	Finland	Belgium
Eritrea	The Netherlands	Luxembourg
Rwanda	Germany	Iceland
Bhutan	Australia	Ireland
Bangladesh	Spain	Kenya
Cameroon	Botswana	
	South Africa	
	Korea	
	China	
	UK	

プラスチック：　調和的な物質循環を阻害しているもの

→　削減ファースト

環境科学会誌 9(1)：27-33（1996）

わが国における食料供給と窒素循環

川島　博之*

摘　　要

わが国における食料供給システムを窒素収支概念より考察した。わが国の農耕地での空中窒素固定量は 1.5×10^5 [ton year^{-1}] 程度と推定される。これに対し 1992 年において，化学肥料として 6.1×10^5 [ton year^{-1}]，漁獲物として 2.6×10^5 [ton year^{-1}]，輸入食料・飼料として 8.3×10^5 [ton year^{-1}] の窒素が食料供給に伴いわが国に流入した。1 億 2 千万人余りの人々が多量の動物性蛋白質を摂取する豊かな食生活は，自然界の窒素循環を大きく改変することにより成立しており，内湾や湖沼の富栄養化の遠因となっている。人間活動が自然界の物質循環に大きな影響を及ぼすことのない社会を構築するためには，農耕地への化学肥料投入を人糞尿の農地還元に置き換えること，輸入飼料に依存した畜産に代わり食肉を直接輸入するなどを検討する必要がある。