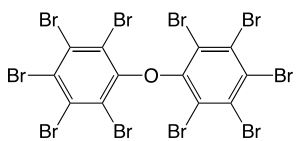
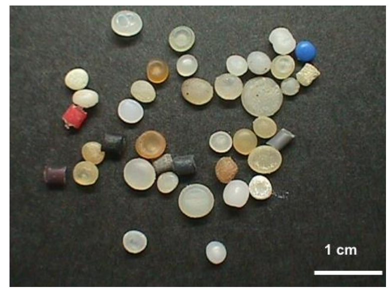
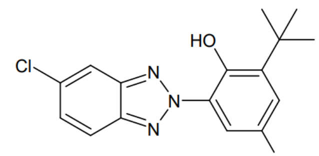
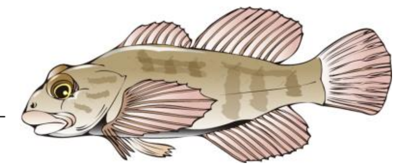
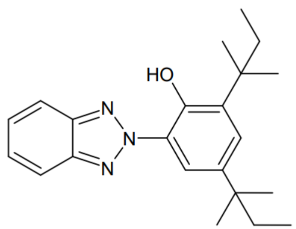
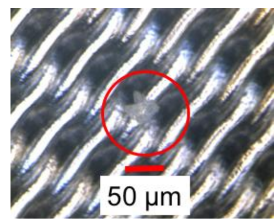
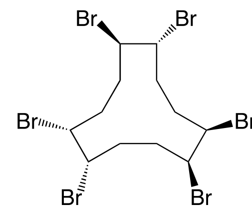
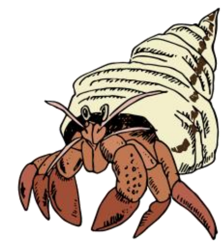
第４回環境研究シンポジウム
第２回環境化学物質３学会合同大会

海洋マイクロプラスチックによる化学物質汚染

International Pellet Watch

高田秀重

東京農工大学 農学部 環境資源科学科

Take-home message

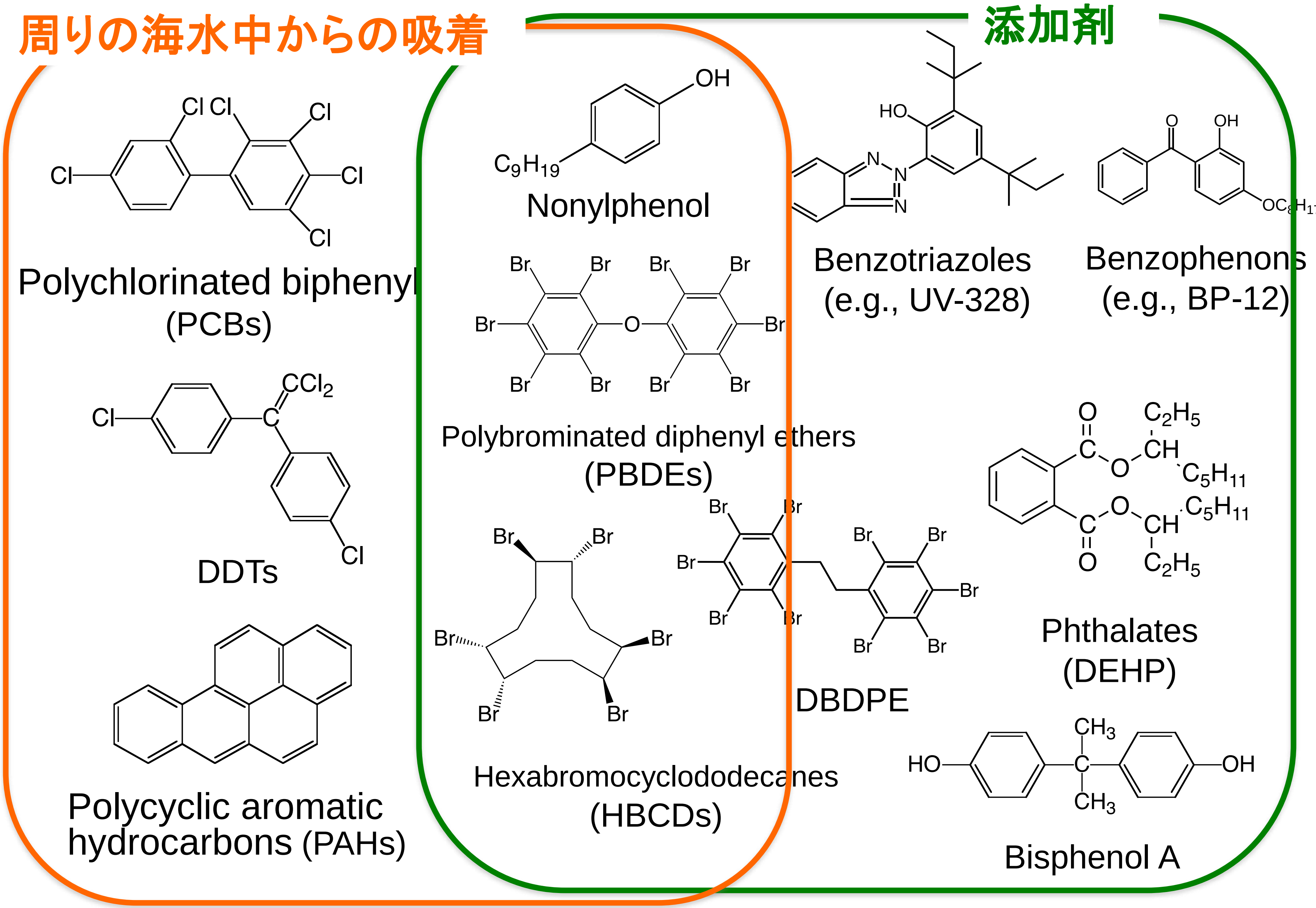
疎水性化学物質はプラスチックから生物に移行･蓄積する。

油分と界面活性剤は疎水性化学物質の移行･蓄積を促進する。

微細化は疎水性化学物質の移行･蓄積を促進する。

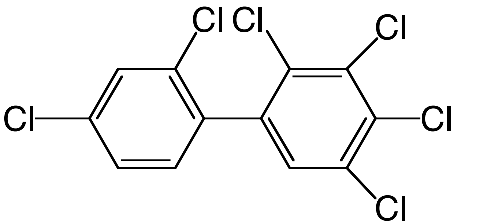
従来Biologically-inertと考えられていた添加剤とLegacy POPsをBioavailableな形にして生態系、生体システムの中にMP/NPが運び込んでいる

海洋漂流プラスチックから検出される有害化学物質

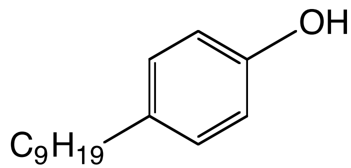


海洋漂流プラスチックから検出される有害化学物質

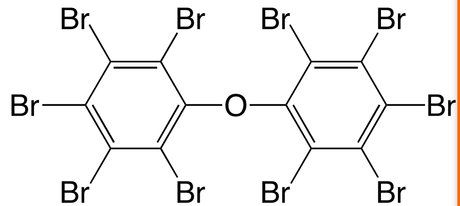
周りの海水中からの吸着



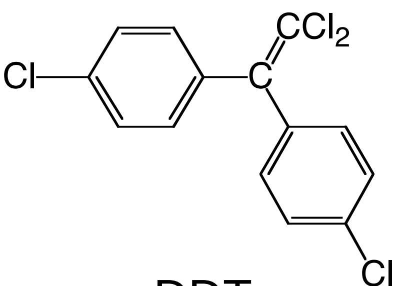
Polychlorinated biphenyl
(PCBs)



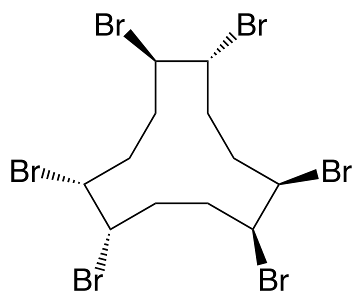
Nonylphenol



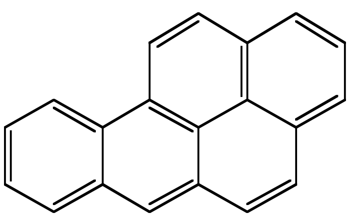
Polybrominated diphenyl ethers
(PBDEs)



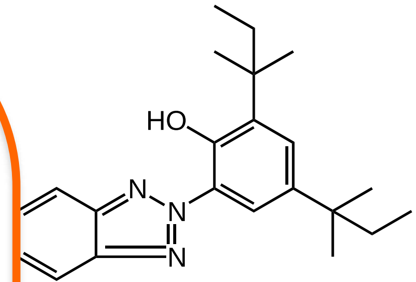
DDTs



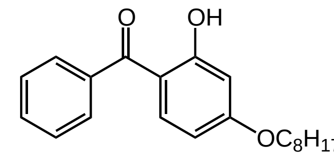
Hexabromocyclododecanes
(HBCDs)



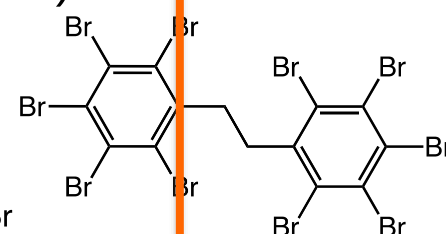
Polycyclic aromatic
hydrocarbons (PAHs)



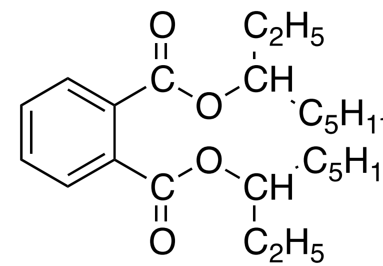
Benzotriazoles
(e.g., UV-328)



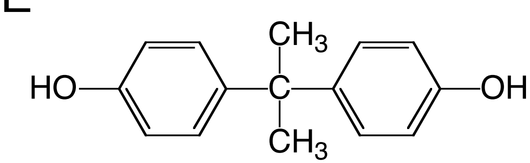
Benzophenons
(e.g., BP-12)



DBDPE



Phthalates
(DEHP)



Bisphenol A

吸着性の化学物質の体組織への移行促進の検討

ポリエチレンビーズに海水中から取り出した有害化学物質を吸着させ、それをムラサキイガイへ曝露し、ムラサキイガイの生殖腺中の化学物質を測定した。

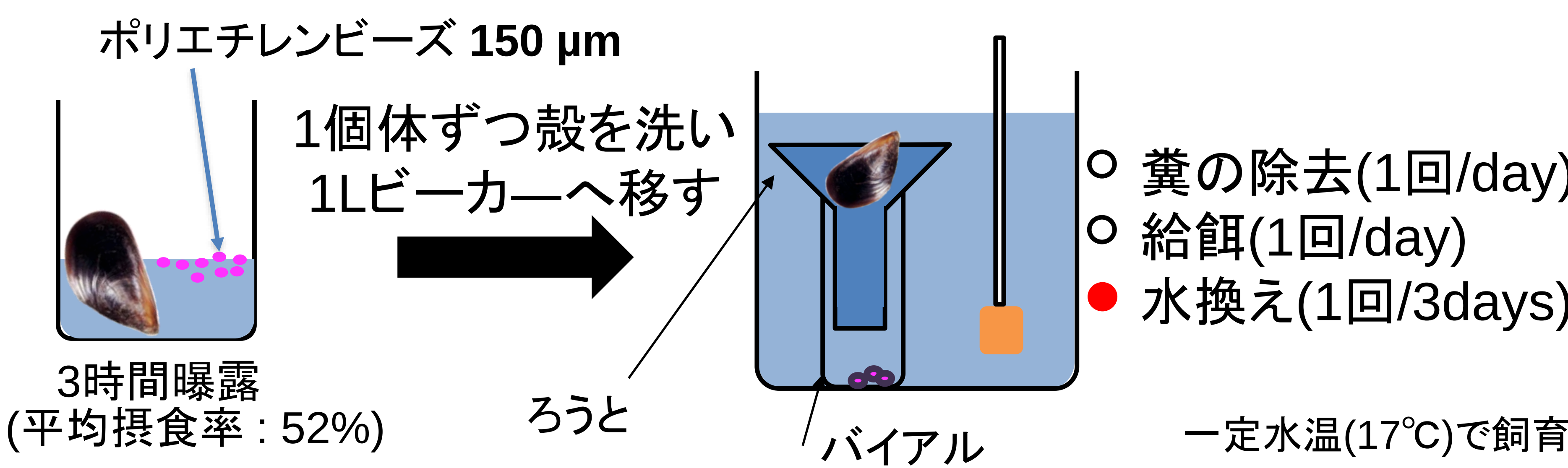
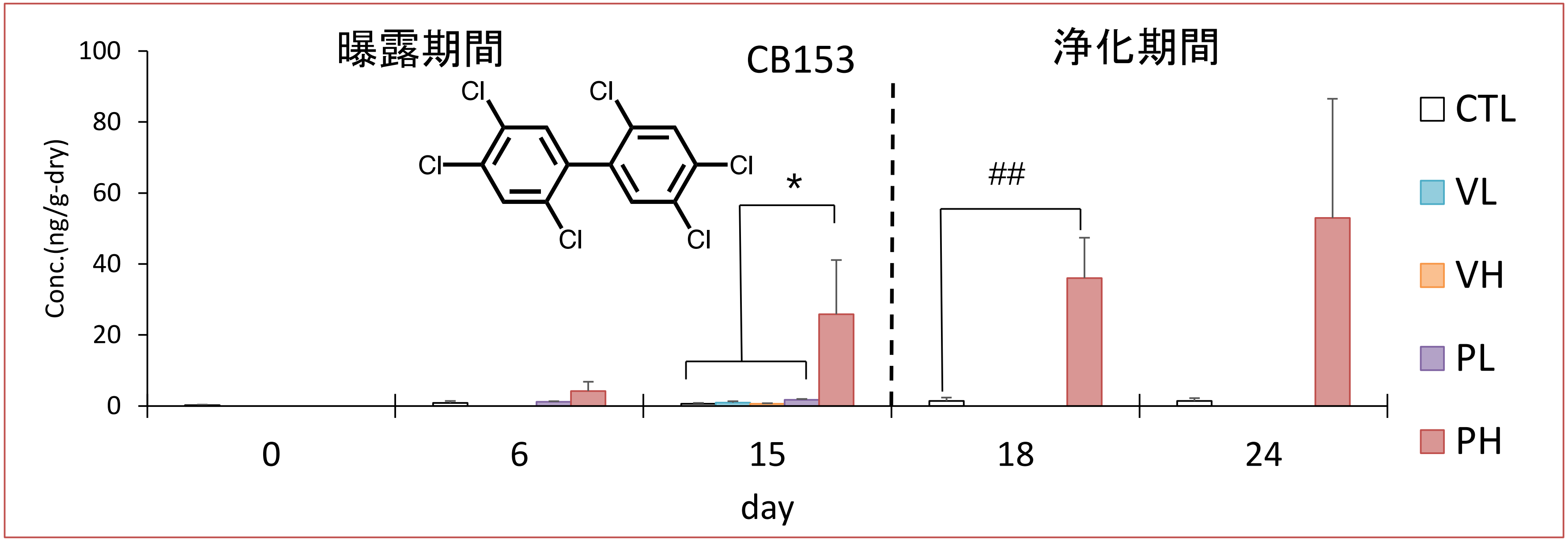


図6.　二枚貝へのPCBsのマイクロプラスチックを介した曝露実験

吸着性の化学物質の体組織への移行促進の検討



(*: p<0.05, by Tukey-Kramer test, ## : p<0.01, by *t*-test)

各処理区3-5個体分析した

day15,18：PH区のみ有意に濃度が増加

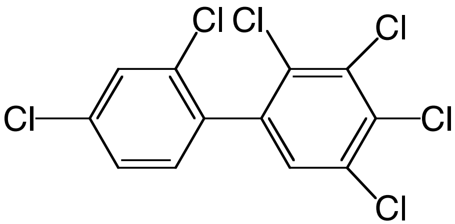
曝露を停止した後も濃度が減少しない

PCBsの移行率は0−57%、

マイクロプラスチック摂食によって
POPsが組織へ移行・蓄積することが証明

図7. 二枚貝へのPCBsのマイクロプラスチックを介した曝露実験における

海洋漂流プラスチックから検出される有害化学物質



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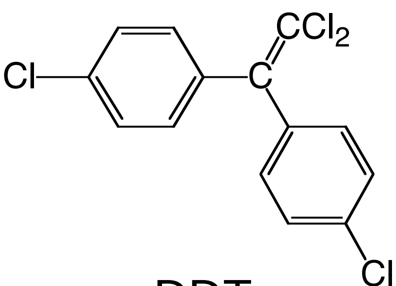
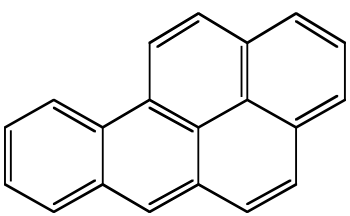
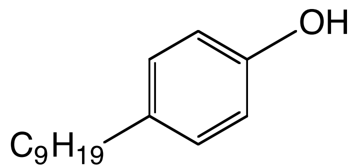


DDTs

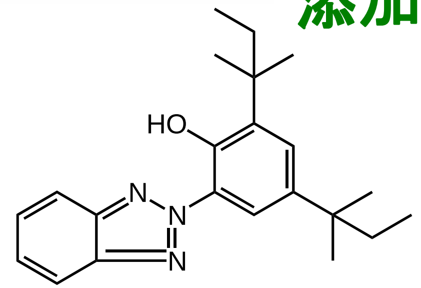


Polycyclic aromatic hydrocarbons (PAHs)

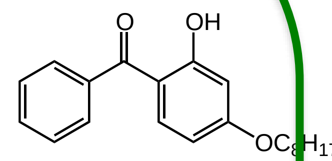
添加剤



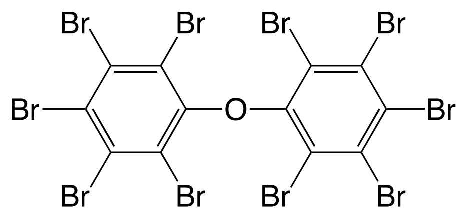
Nonylphenol



Benzotriazoles (e.g., UV-328)



Benzophenons (e.g., BP-12)



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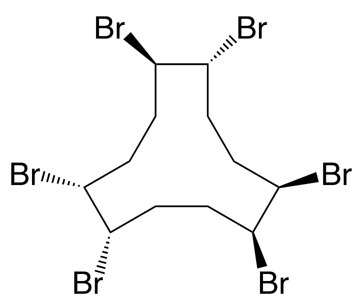

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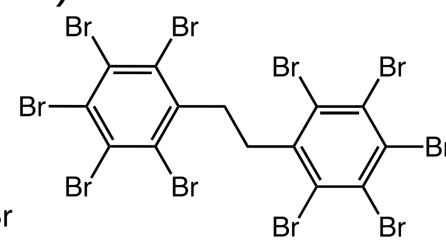
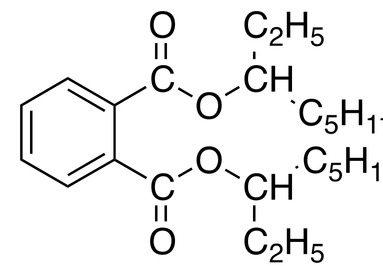


DBDPE



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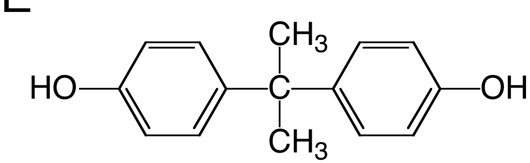


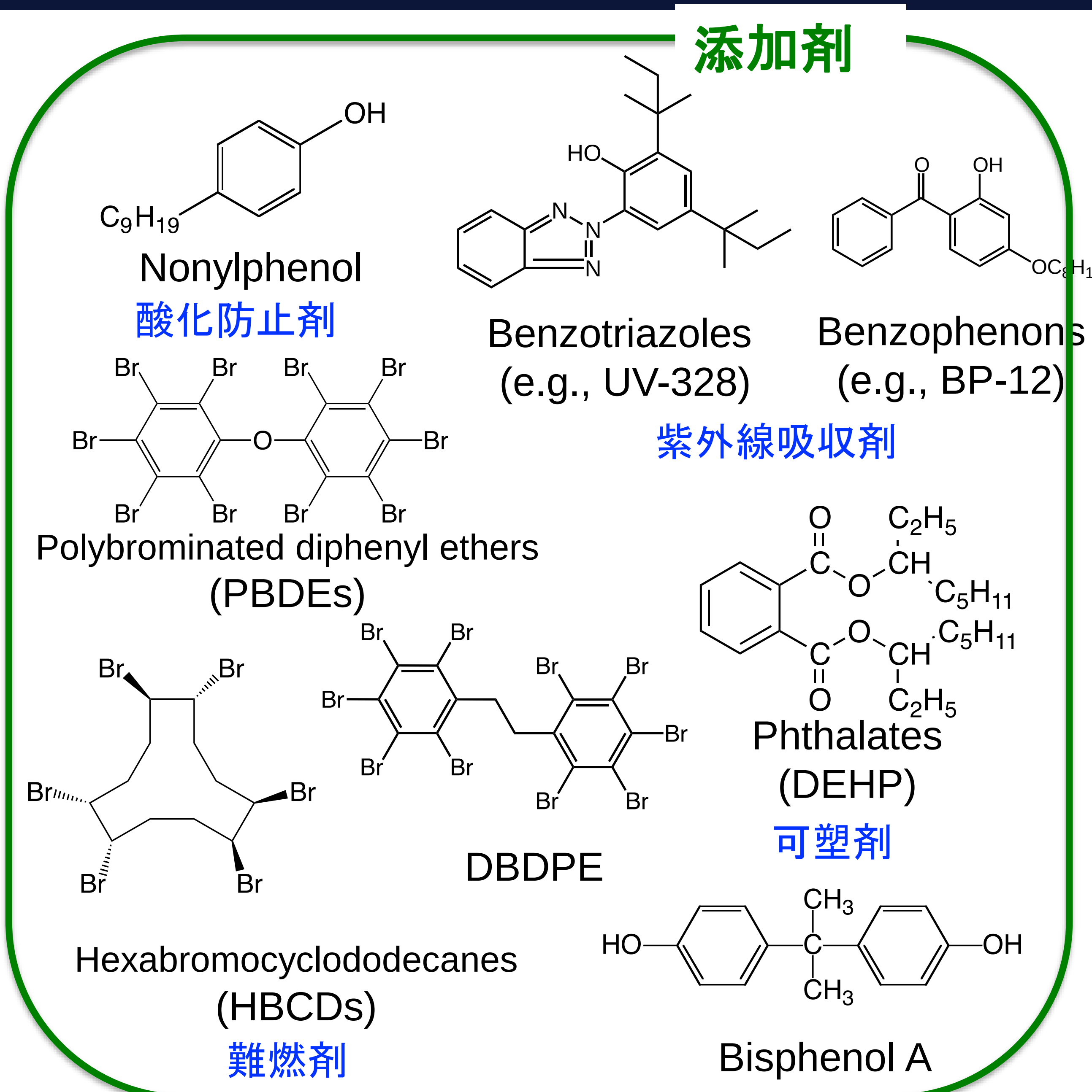
Bisphenol A

プラスチック生産量の7%が添加剤

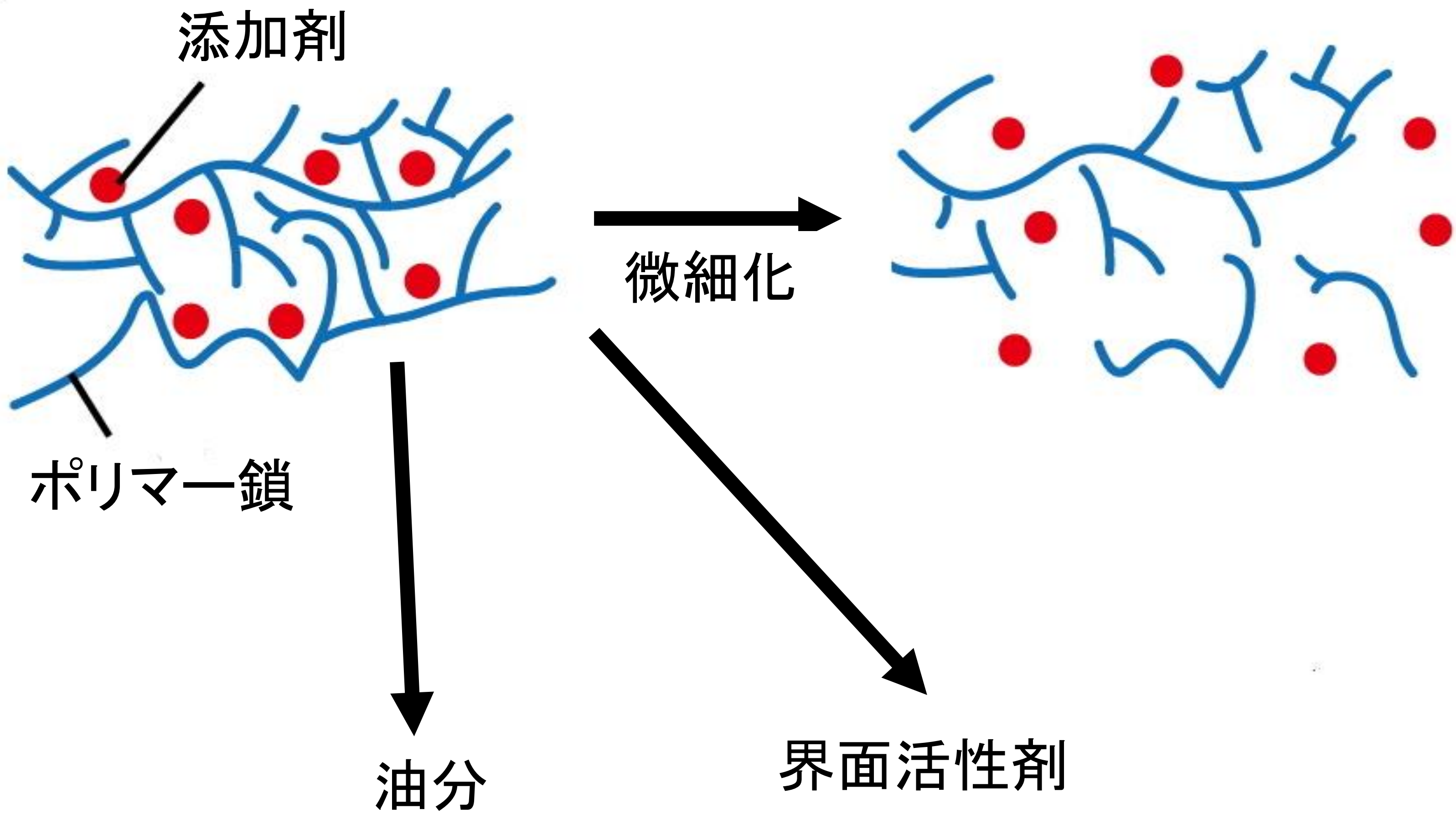
年間4億トンのプラスチックが生産される
→2800万トンの添加剤が生産されている。

可塑剤、難燃剤が75%

Geyer et al., 2017



添加剤はポリマー鎖に取り込まれているので溶出・生物濃縮されないと考えられてきた



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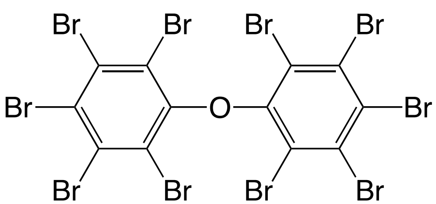
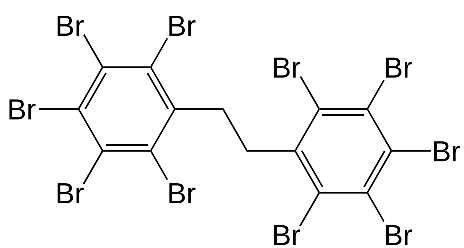
本講演で例示する化学物質の構造と疎水性

臭素系難燃剤



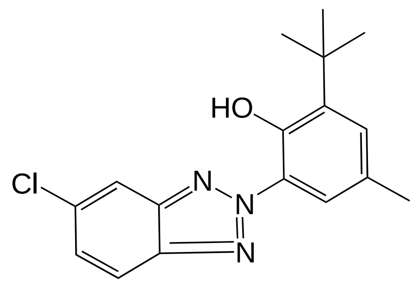
BDE209 (log K_{ow} : 12.11)



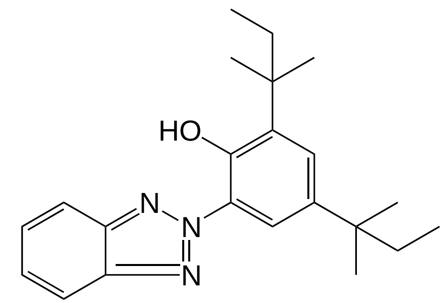
DBDPE (log K_{ow} : 13.64)

超疎水性

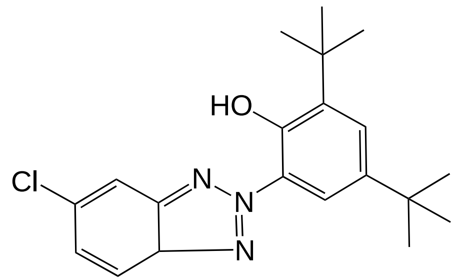
ベンゾトリアゾール系紫外線吸収剤



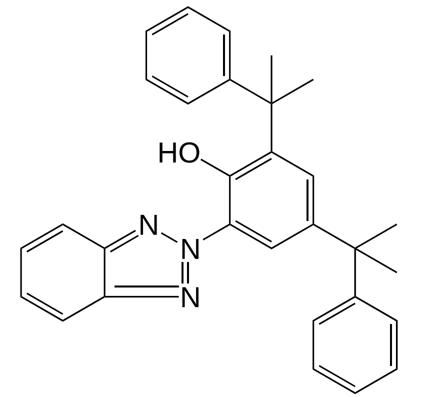
UV326 (log K_{ow} : 5.55)



UV328 (log K_{ow} : 7.25)



UV327 (log K_{ow} : 6.91)



UV234 (log K_{ow} : 7.67)

疎水性

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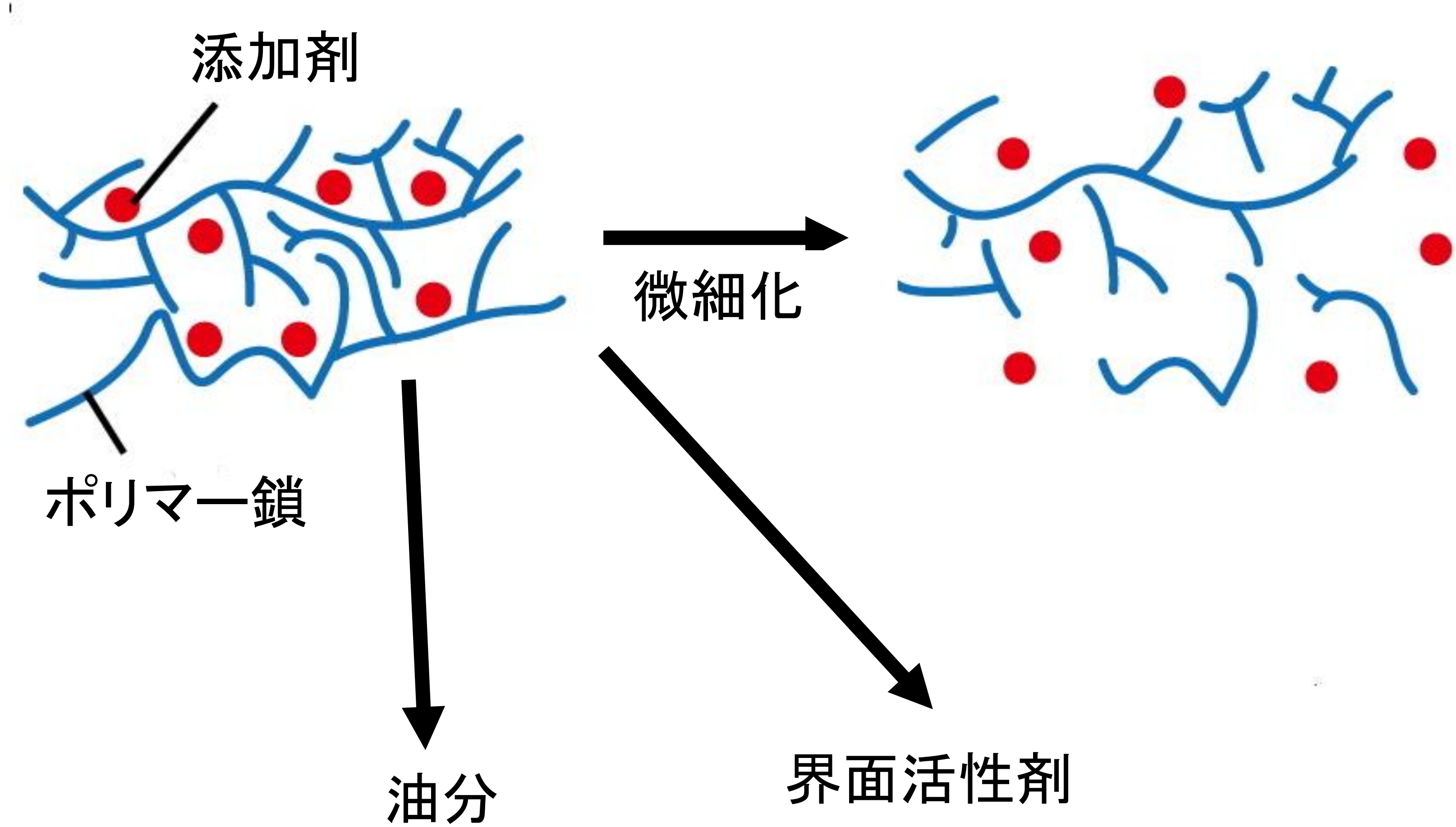
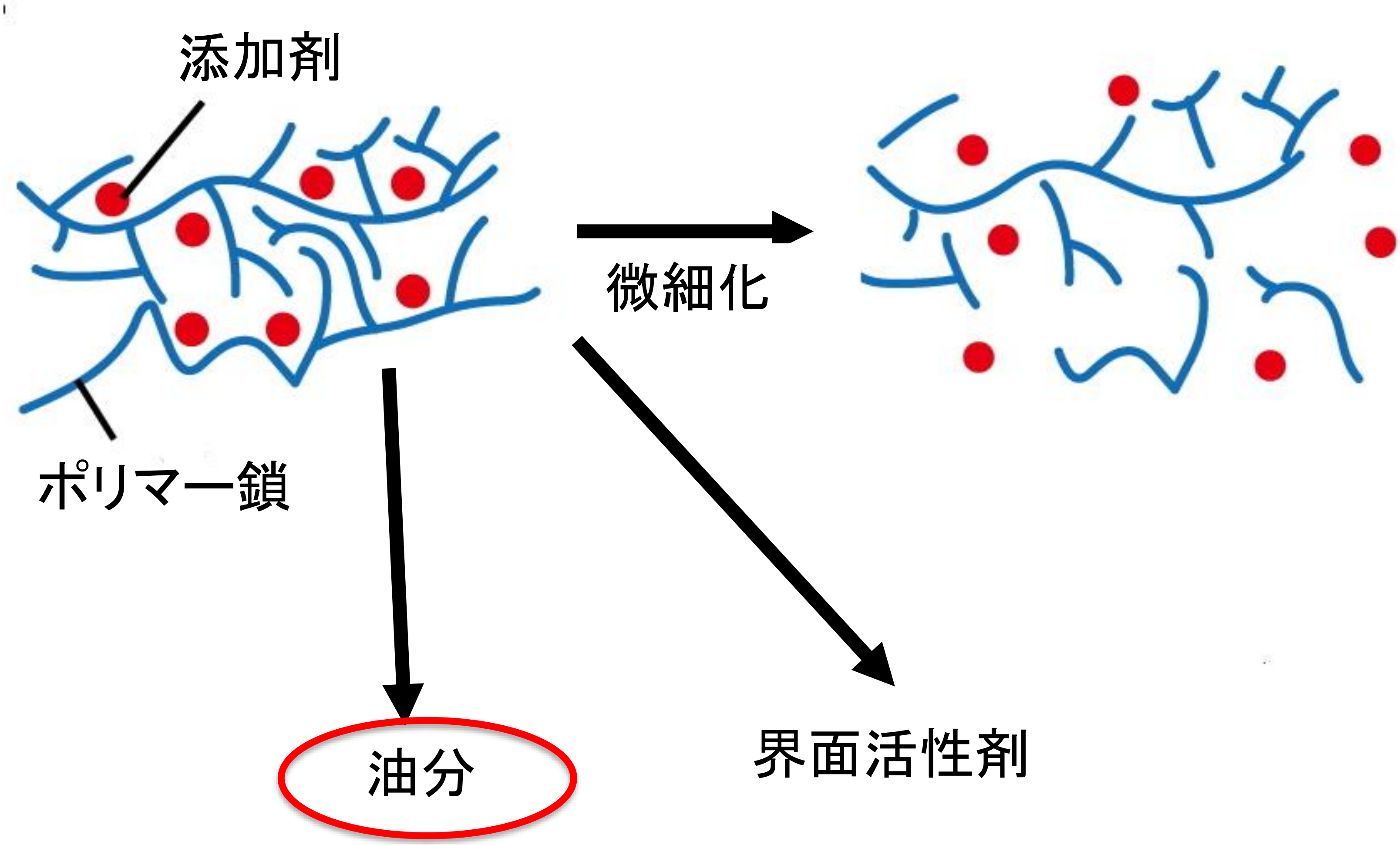
溶出・生物濃縮されないと考えられてきた



消化液中の油分により溶出が促進されるのでは？



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消化液の中の油分は疎水性添加剤の溶け出しを促進する

Environmental Science & Technology

Article

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Facilitated Leaching of Additive-Derived PBDEs from Plastic by Seabirds' Stomach Oil and Accumulation in Tissues

Kosuke Tanaka,[†] Hideshige Takada,[*,†] Rei Yamashita,[†] Kaoruko Mizukawa,[†] Masa-aki Fukuwaka,[‡] and Yutaka Watanuki[§]

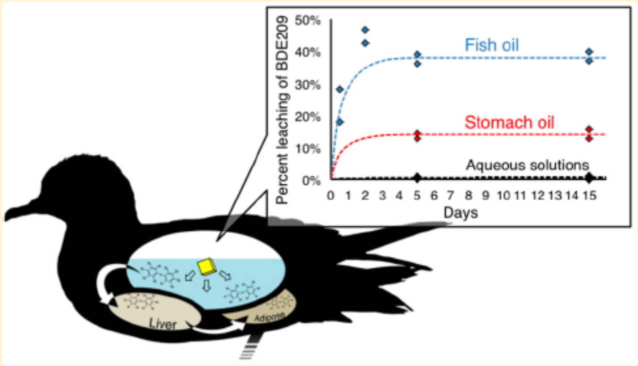
[†]Laboratory of Organic Geochemistry, Tokyo University of Agriculture and Technology, Fuchu, Tokyo 183-8509, Japan

[‡]Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Kushiro, Hokkaido 085-0802, Japan

[§]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). Analysis of abdominal adipose, liver tissue, and ingested plastics from 18 wild seabirds collected from the North Pacific Ocean showed the occurrence of deca-BDE or hexa-BDEs in both the tissues and the ingested plastics in three of the birds, suggesting transfer from the plastic to the tissues. In birds with BDE209 in their tissues, the dominance of BDE207 over other nona-BDE isomers suggested biological debromination at the meta position. Model calculation of PBDE exposure to birds based on the results of the leaching experiments combined with field observations suggested the dominance of plastic-mediated internal exposure to BDE209 over exposure via prey.



消化液の中の油分は疎水性添加剤の溶け出しを促進する

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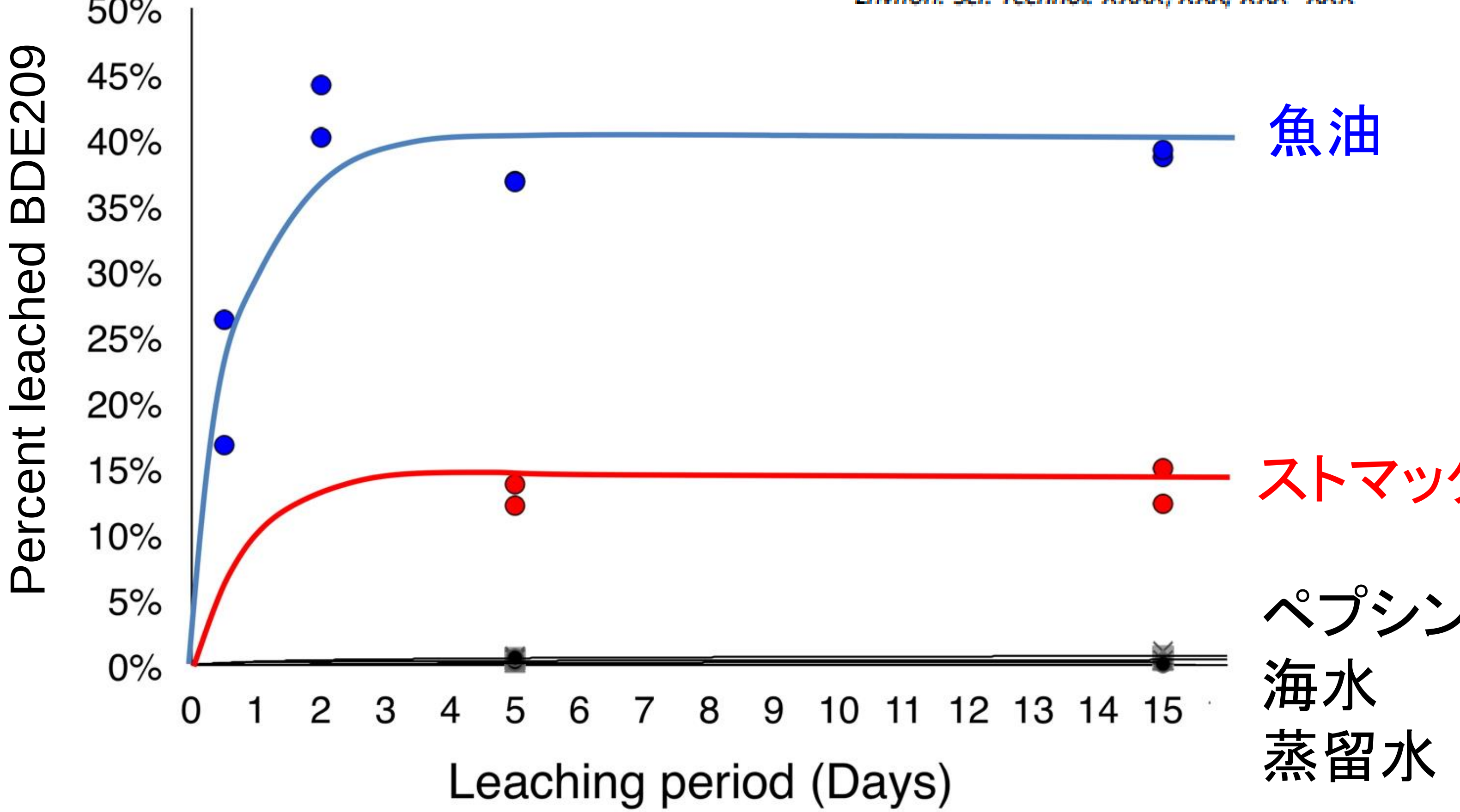
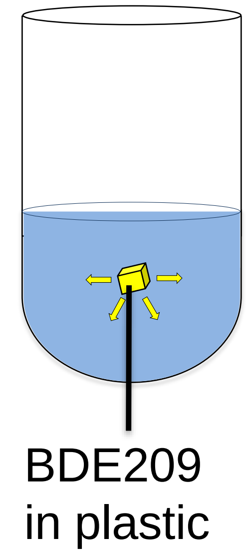
Kosuke Tanaka,[†] Hideshige Takada,[*,†] Rei Yamashita,[†] Kaoruko Mizukawa,[†] Masa-aki Fukuwaka,[‡] and Yutaka Watanuki[§]

DOI: 10.1021/acs.est.5b01376
Environ. Sci. Technol. XXXX, XXX, XXX−XXX





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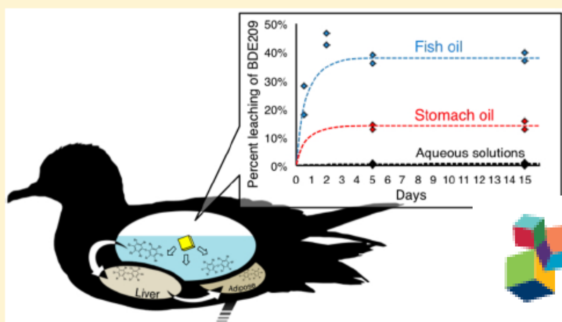

frontiers in Environmental Science

Transfer of Additive Chemicals From Marine Plastic Debris to the Stomach Oil of Northern Fulmars

Susanne Kühn[1]*, Andy M. Booth[2], Lisbet Sørensen[2], Albert van Oyen[3] and Jan A. van Franeker[1]

[1] Wageningen Marine Research, Den Helder, Netherlands, [2] Department (Ocean, Trondheim, Norway, [3] Carat GmbH, Bocholt, Germany

ORIGINAL RESEARCH
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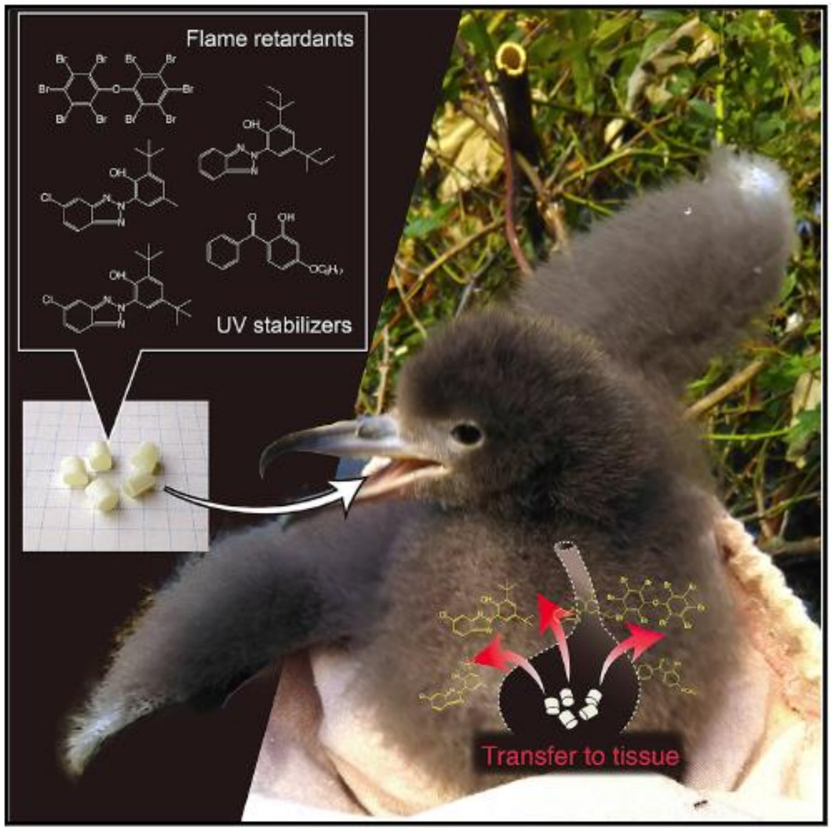
プラスチック添加剤を海鳥が吸収することが確認された

Current Biology

Report

In Vivo Accumulation of Plastic-Derived Chemicals into Seabird Tissues

Graphical Abstract



Authors

Kosuke Tanaka, Yutaka Watanuki,
Hideshige Takada, ..., Michelle Hester,
Yoshinori Ikenaka,
Shouta M.M. Nakayama

Correspondence

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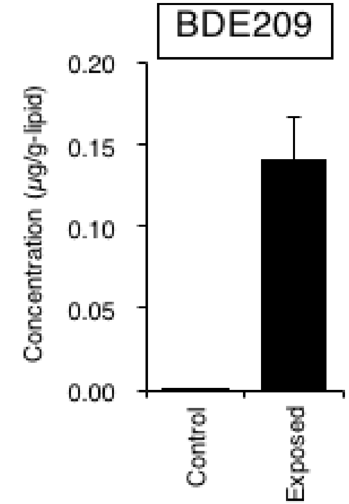
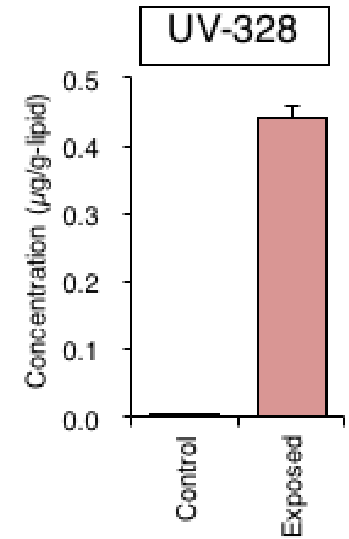
In Brief

Tanaka et al. show that feeding additive-laced plastic pellets to seabirds results in the accumulation of chemical additives in liver and adipose tissue at 10^1–10^5 times above baseline. These findings demonstrate seabird exposure to plastic additives and additives' importance as emerging pollution sources.

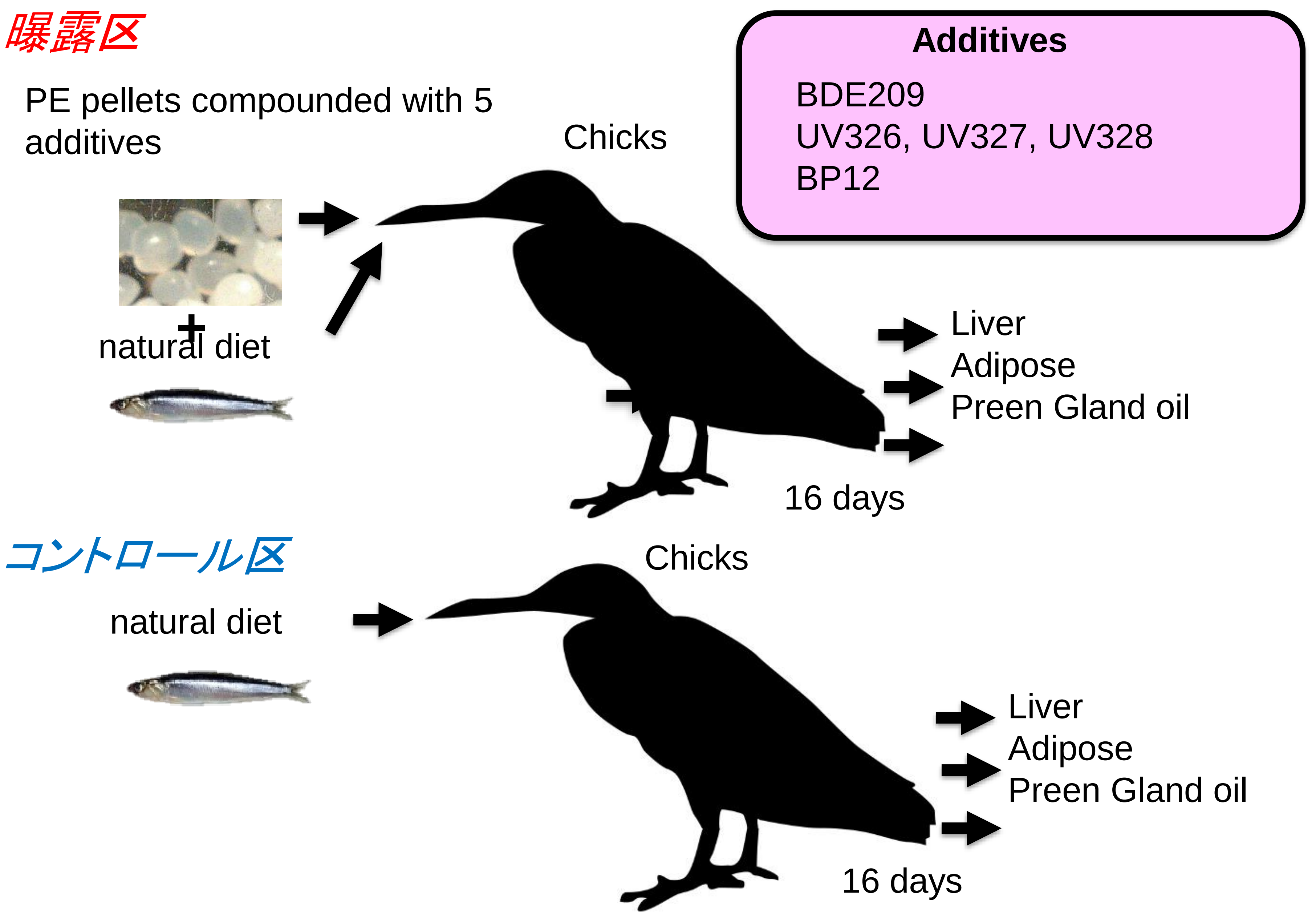




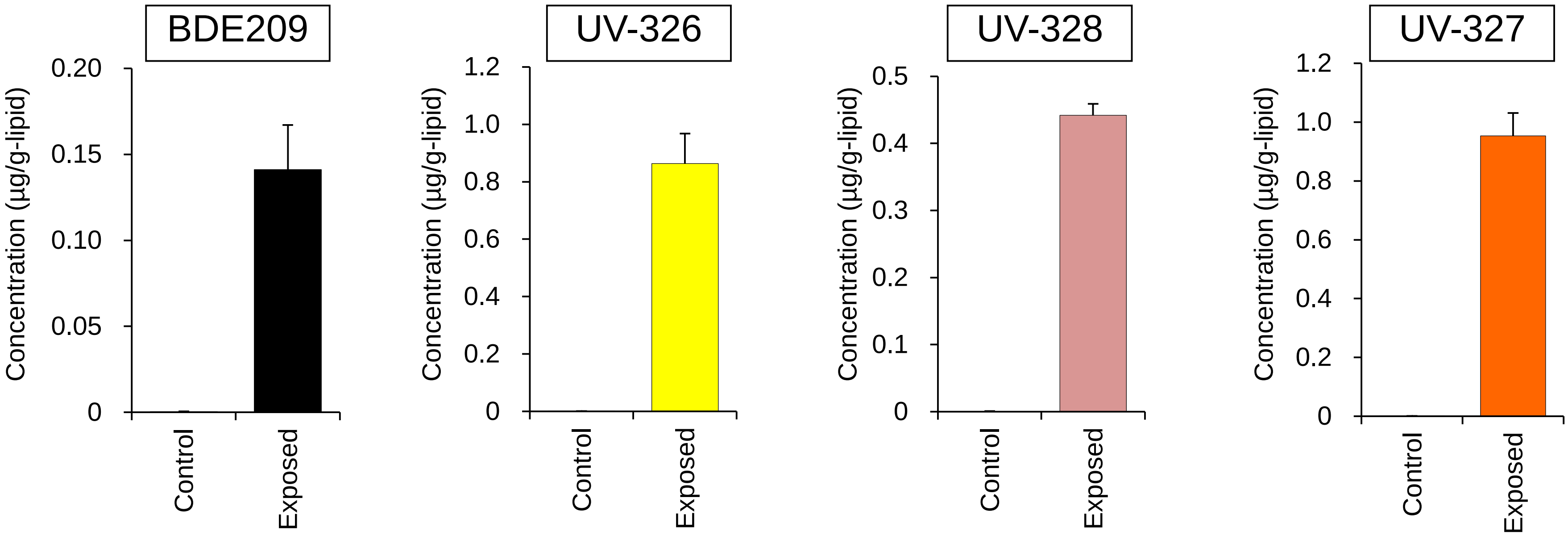
Tanaka et al., 2020, Current Biology *30*, 1–6
February 24, 2020
https://doi.org/10.1016/j.cub.2019.12.037

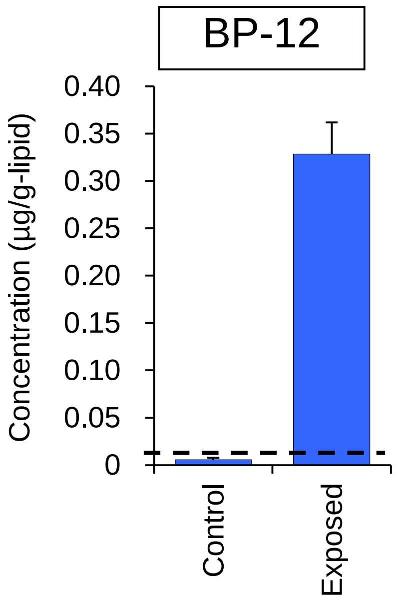
腎機能に関連する遺伝子が発現

現場の条件で海鳥への添加剤を練り込んだプラスチックの摂食実験



曝露16日後の個体の腹腔内脂肪、肝臓、尾腺ワックスから添加剤が検出された

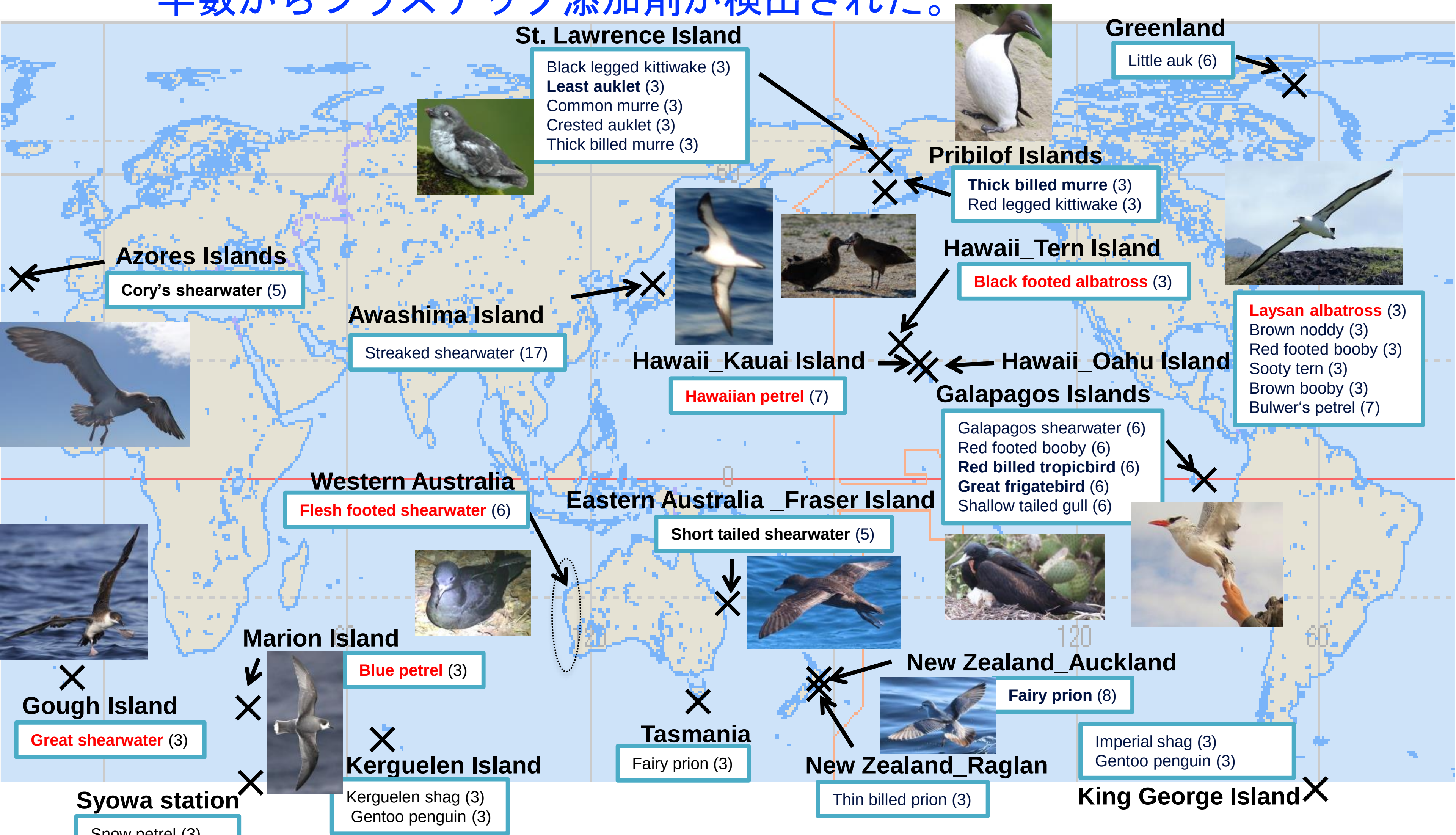




◆BDE209, UV-326, UV328, UV327, BP-12
→detected in all of the bird exposed to plastics.

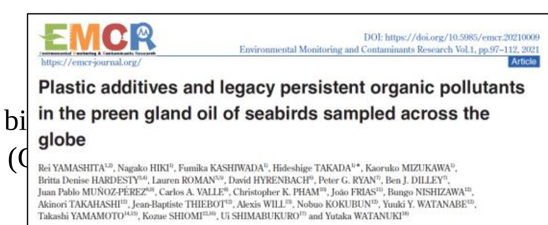
Broken line: limit of quantification (LOQ)
Error bar：SE

世界16地域32種145個体の海鳥の尾腺ワックスの分析の結果、半数からプラスチック添加剤が検出された。



特に、ハワイのシロハラミズナギドリ、西オーストラリアのアカアシミズナギドリ、ハワイのアホウドリ、亜南極海のアオミズナギドリやズクロミズナギドリなどで高い濃度の添加剤が検出され、摂食したプラスチックからの蓄積であると考えられました。

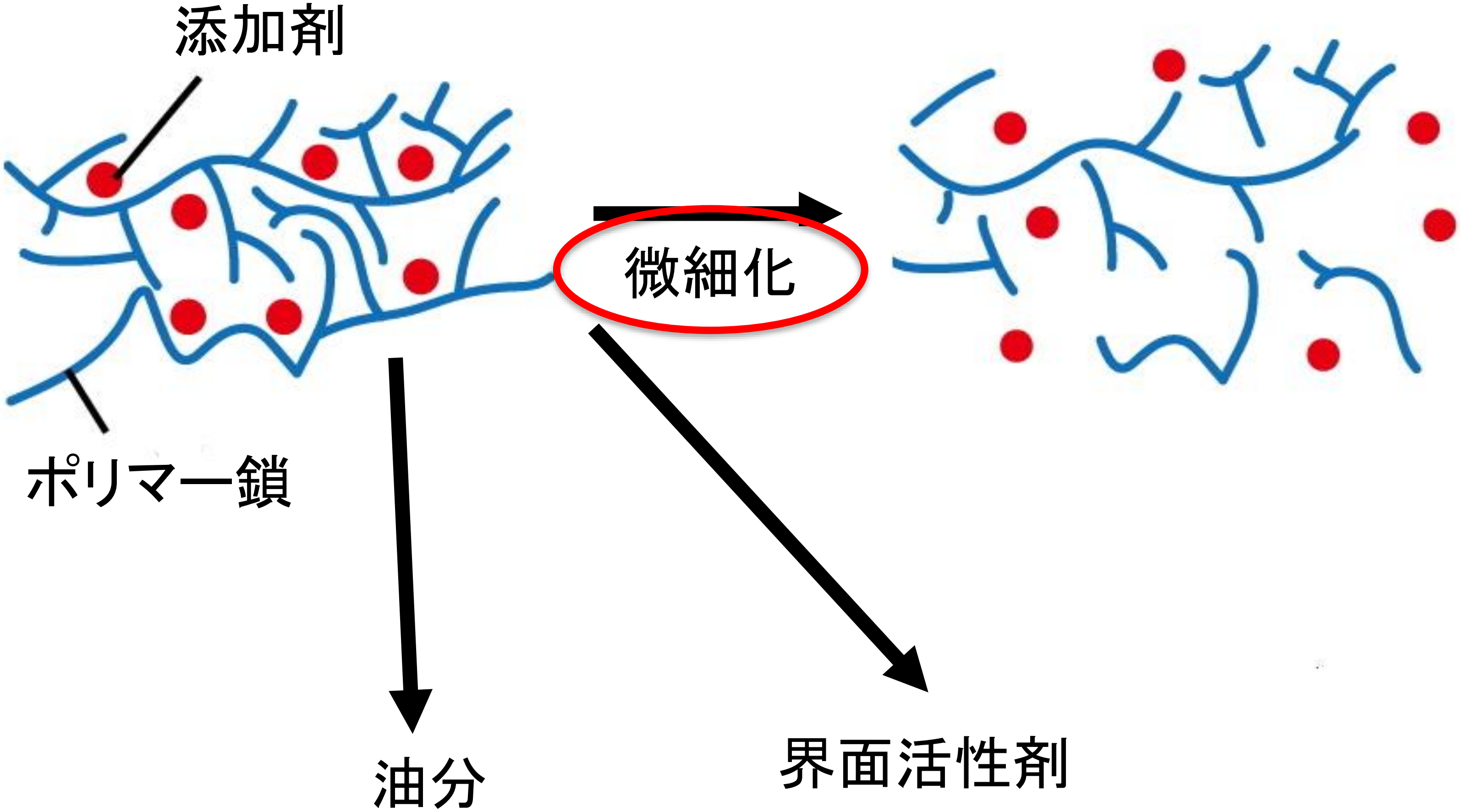
Photos by
David Hyrenbach (Haw… …d bi…
(Cory's shearwater), Lauren Roman (Flesh footed shearwater, Short tailed shearwater, Fairy prion), Peter G. Ryan (C…
Takahashi (Least Auklet), Carlos A. Valle (Great frigate bird), Takashi Yamamoto (Thick-billed murre).


EMCR
DOI: https://doi.org/10.5985/emcr.20210009
Environmental Monitoring and Contaminants Research Vol.1, pp.97–112, 2021
https://emcr-journal.org/
Article

Plastic additives and legacy persistent organic pollutants in the preen gland oil of seabirds sampled across the globe

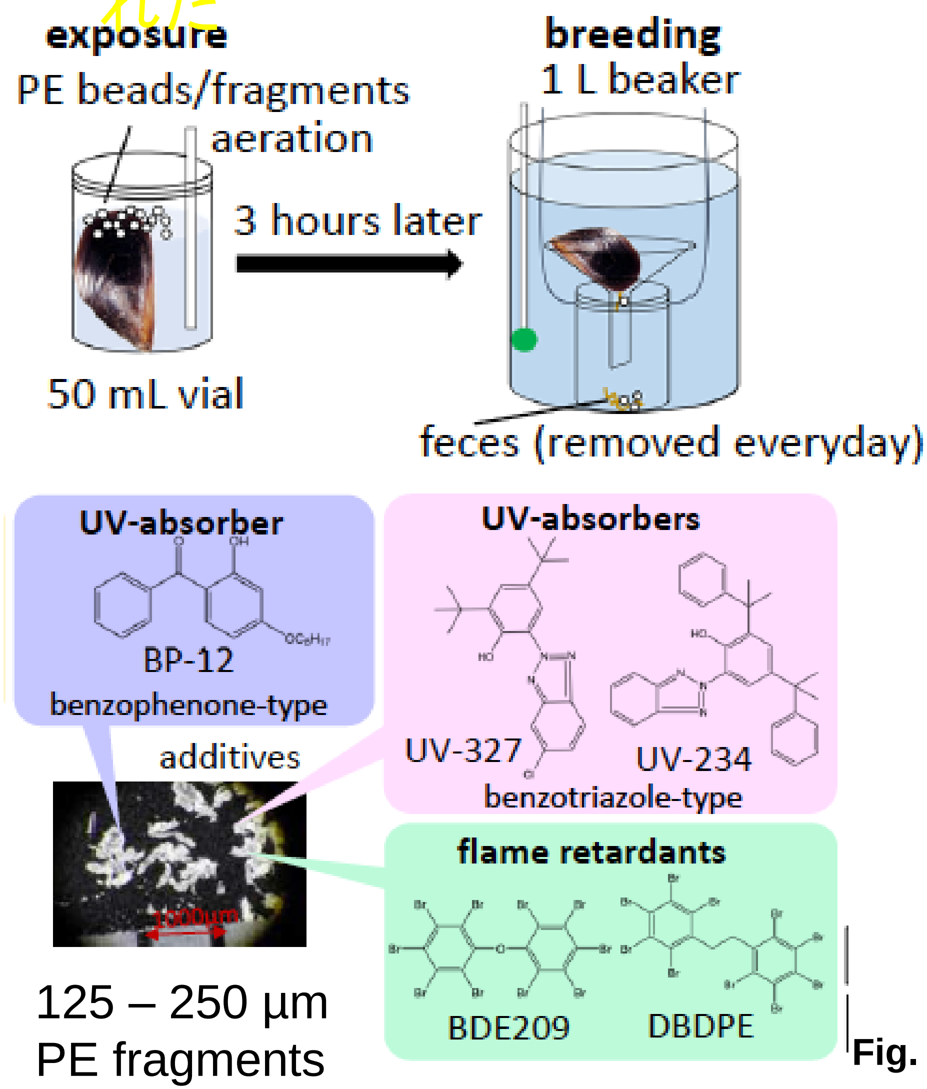
Rei YAMASHITA, Nagako HIKI, Fumika KASHIWADA, Hideshige TAKADA*, Kaoruko MIZUKAWA, Britta Denise HARDESTY, Lauren ROMAN, David HYRENBACH, Peter G. RYAN, Ben J. DILLEY, Juan Pablo MUÑOZ-PÉREZ, Carlos A. VALLE, Christopher K. PHAM, João FRIAS, Bungo NISHIZAWA, Akinori TAKAHASHI, Jean-Baptiste THIEBOT, Alexis WILL, Nobuo KOKUBUN, Yuuki Y. WATANABE, Takashi YAMAMOTO, Kozue SHIOMI, Ui SHIMABUKURO and Yutaka WATANUKI

プラスチックの微細化により溶出が促進されるのでは？



videonews.com

微細なマイクロプラスチックから二枚貝生殖腺へ ベンゾトリアゾール系紫外線吸収剤が移行・蓄積することが確認された



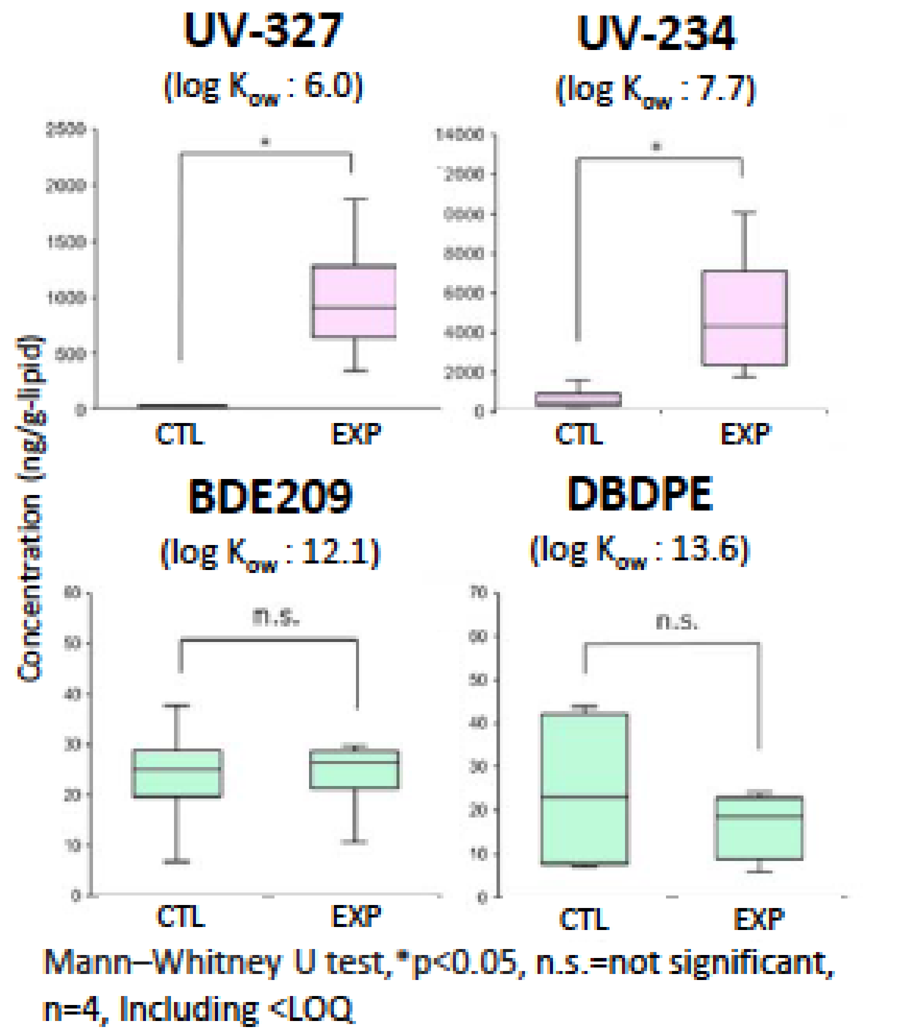
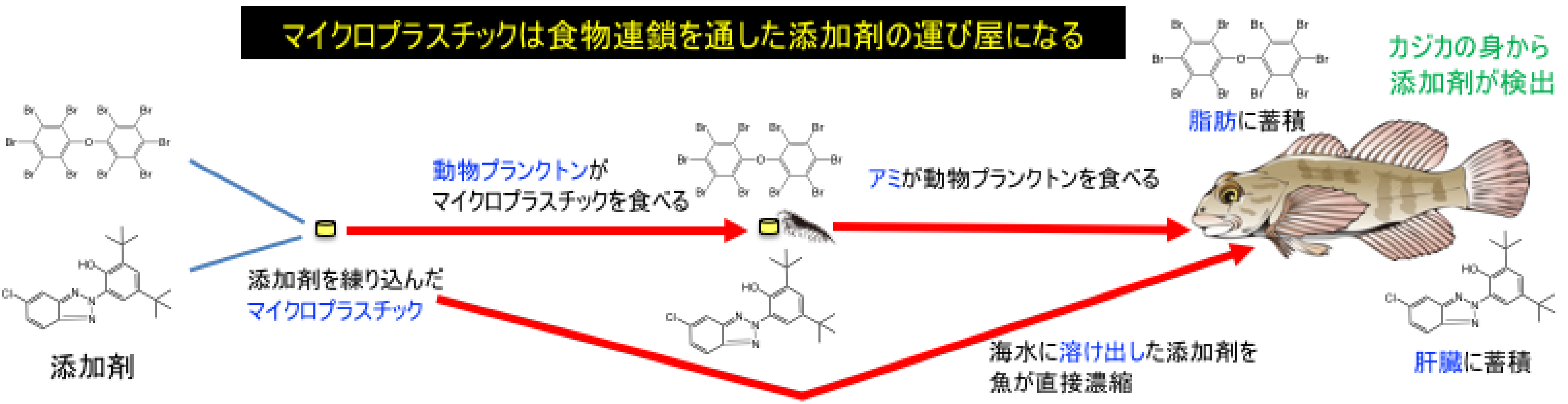


Fig. Concentrations of the additives in gonad of mussels

Mizukawa, K., Takano, T., Sakurai, R., Ota, M., Nakaoka, M., Kinjo, A., Inoue, K., Takada, H., 2022. Dietary exposure experiments on the transfer of chemical pollutants from microplastics to bivalves. In: International Online Workshop on Microplastics Issues, online.



Marine Pollution Bulletin 185 (2022) 114343

Contents lists available at ScienceDirect

Marine Pollution Bulletin

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

The significance of trophic transfer of microplastics in the accumulation of plastic additives in fish: An experimental study using brominated flame retardants and UV stabilizers

Takaaki Hasegawa [a,1], Kaoruko Mizukawa [b], Bee Geok Yeo [b], Tomonori Sekioka [c], Hideshige Takada [b], Masahiro Nakaoka [d,*]

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マイクロプラスチックは食物連鎖を通した添加剤の運び屋になる

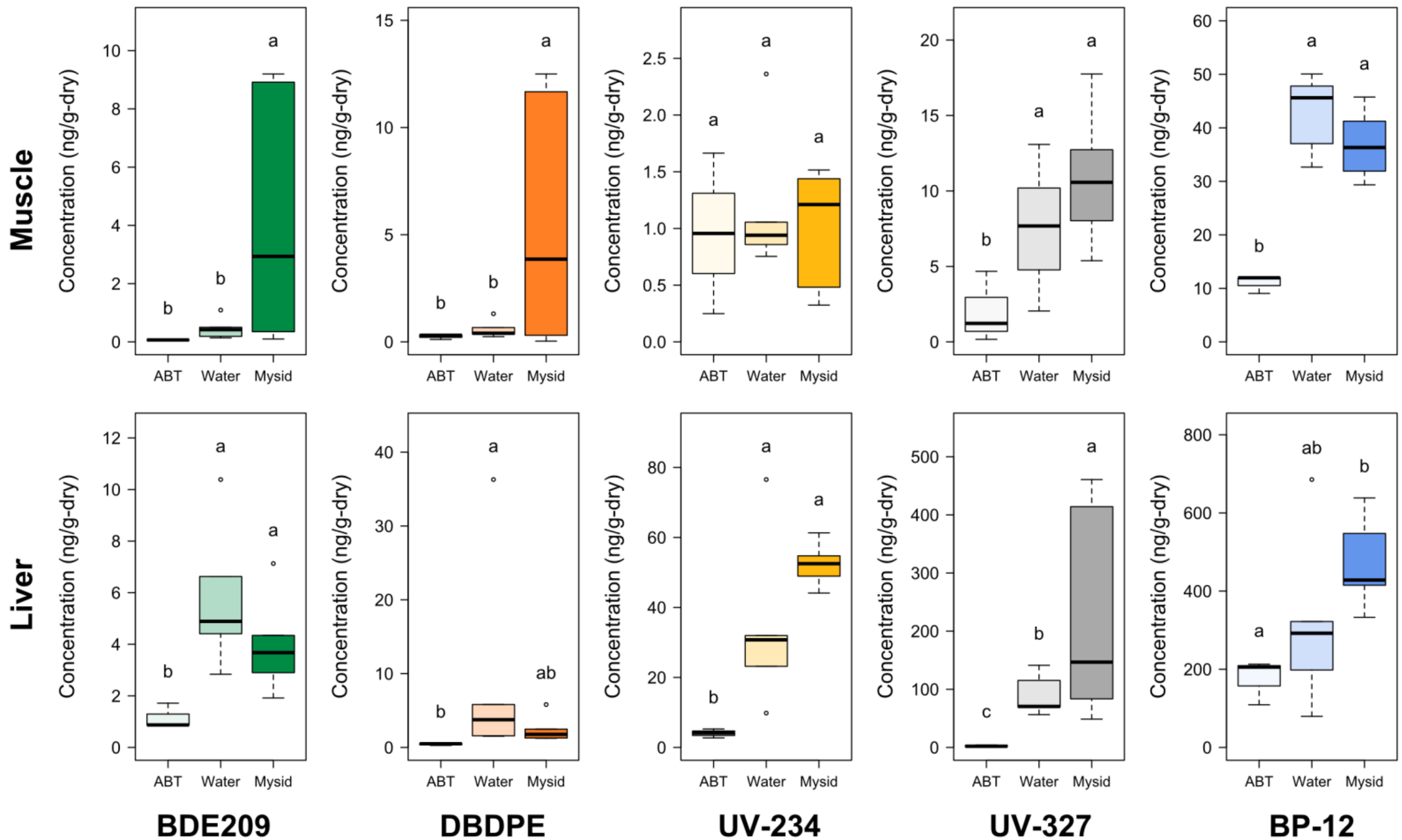
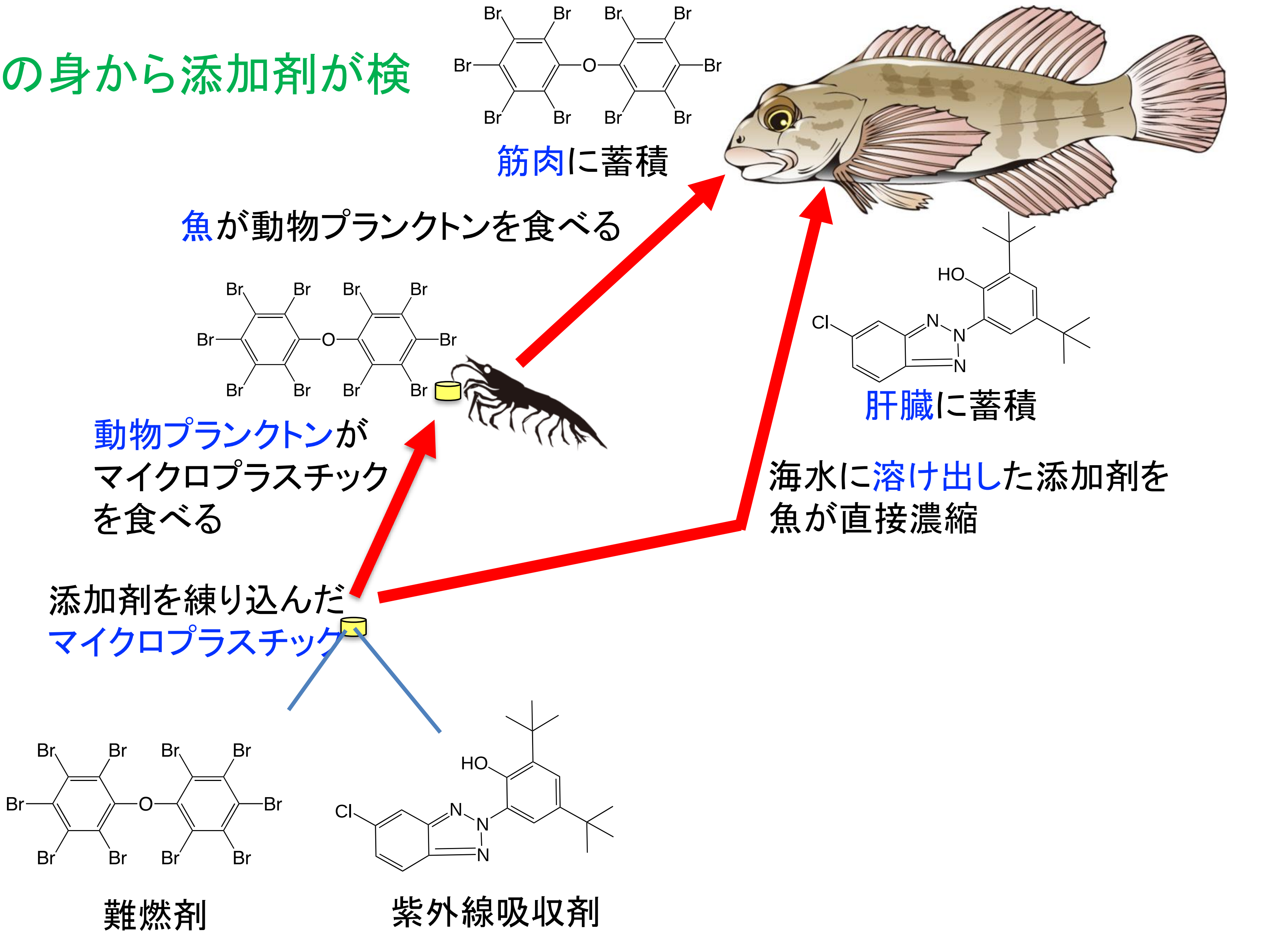


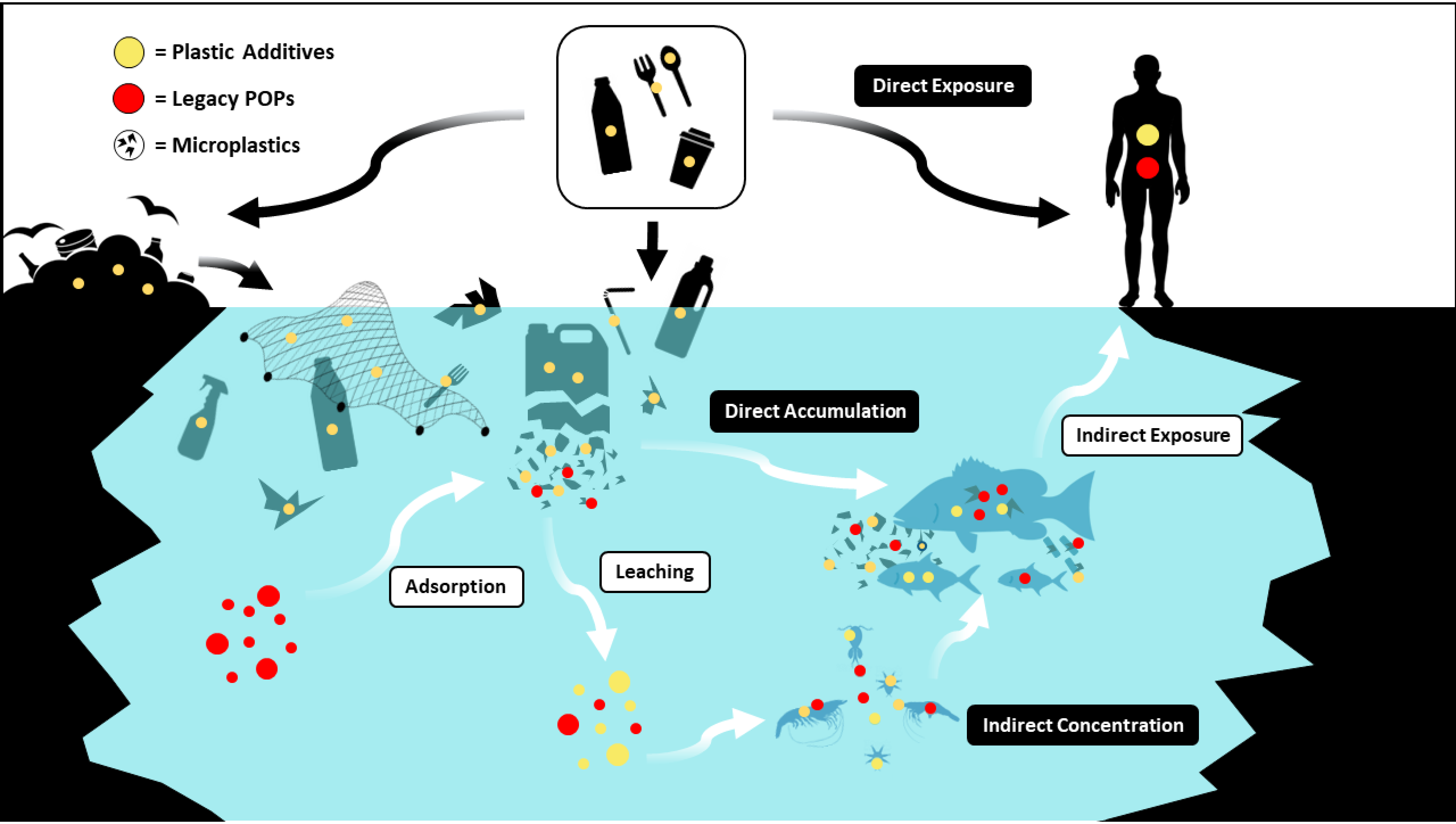
Fig. 1. Concentrations of the five additives in muscle and liver from fish immediately after collection from the ambient environment (ABT), fish exposed to microplastics suspended in the water column (Water), and fish fed mysids previously exposed to microplastics (Mysid). In each box and whisker plot, the median is shown as a solid horizontal line, the interquartile range (25th to 75th percentiles) is shown by the lower and upper ends of the box, and the 10th and 90th percentiles are shown as whiskers. Different letters indicate significant differences identified by performing post-hoc comparisons ($p < 0.01$ for a generalized linear model with post-hoc Tukey's honestly significant difference tests).

マイクロプラスチックは食物連鎖を通した添加剤の運び屋になる

魚の身から添加剤が検出



プラスチックの使用が増えると人間への環境ホルモンの曝露が増える



Credit: Shige Takada and Manuel Brunner (co-authors).

The Minderoo-Monaco Commission on Plastics and Human Health

ヒト組織・血液中の添加剤の検出

脂肪

Shi, X., et al., 2022. Associations between polybrominated diphenyl ethers (PBDEs) levels in adipose tissues and female menstrual cycle and menstrual bleeding duration in Shantou, China. Environ. Pollut. 301, 119025.

尿中

Choi, J.Y., et al., 2022. Urinary bisphenol concentrations and its association with metabolic disorders in the US and Korean populations. Environ. Pollut. 295, 118679.

Dong, J., et al., 2020. Associations of urinary di-(2-ethylhexyl) phthalate metabolites with the residential characteristics of pregnant women. Science of The Total Environment 707, 135671.

血液

Cobellis, L., et al., 2009. Measurement of bisphenol A and bisphenol B levels in human blood sera from healthy and endometriotic women. Biomedical Chromatography 23, 1186-1190.

コホート研究での添加剤と異常の関連

生殖関係の機能の異常

Shi, X., et al., 2022. Associations between polybrominated diphenyl ethers (PBDEs) levels in adipose tissues and female menstrual cycle and menstrual bleeding duration in Shantou, China. Environ. Pollut. 301, 119025.

Cobellis, L., et al., 2009. Measurement of bisphenol A and bisphenol B levels in human blood sera from healthy and endometriotic women. Biomedical Chromatography 23, 1186-1190.

肥満

Choi, J.Y., et al., 2022. Urinary bisphenol concentrations and its association with metabolic disorders in the US and Korean populations. Environ. Pollut. 295, 118679.

子宮内膜症の患者の血液からビスフェノールAが検出

Research Article
Biomedical Chromatography

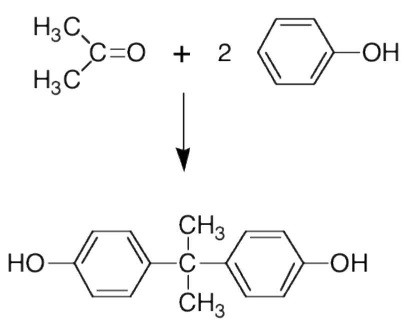
Received: 28 January 2009, Revised: 5 March 2009, Accepted: 5 March 2009 Published online in Wiley Interscience: 14 May 2009

(www.interscience.wiley.com) DOI 10.1002/bmc.1241

Measurement of bisphenol A and bisphenol B levels in human blood sera from healthy and endometriotic women

Luigi Cobellis,[a] Nicola Colacurci,[a] Elisabetta Trabucco,[a] Carmen Carpentiero[b] and Lucia Grumetto[b]*

ビスフェノールA： 内分泌攪乱物質
プラスチック由来物質



log K_{ow} = 3.40

MW = 228

Bisphenol A

ポリカーボネートやエポキシ樹脂の原材料
他のプラスチックの添加剤

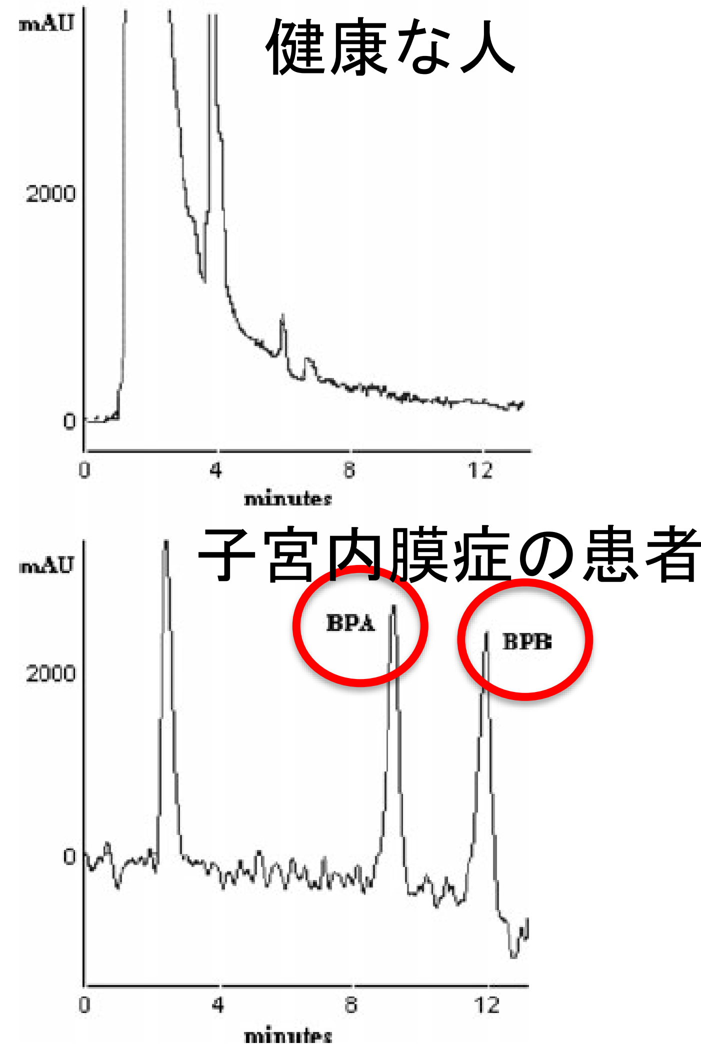


Figure 1. Chromatograms corresponding to (A) a standard solution of BPA and BPB 10.0 ng/mL; (B) blood serum of a healthy women; and (C) serum of an endometriotic woman containing both BPA and BPB. Figures on the axes are: time (min) on the abscissa, absorbance units on the ordinate.

妊婦の市販の弁当や冷凍食品の摂取と死産の関連が確認された

雑誌における論文タイトル：

Impact of ready-meal consumption during pregnancy on birth outcomes: The Japan Environment and Children's Study

和文タイトル：

妊娠中における調理済み食品の摂取頻度と妊娠帰結との関連

ユニットセンター（UC）等名： 愛知ユニットセンター

サブユニットセンター（SUC）名：

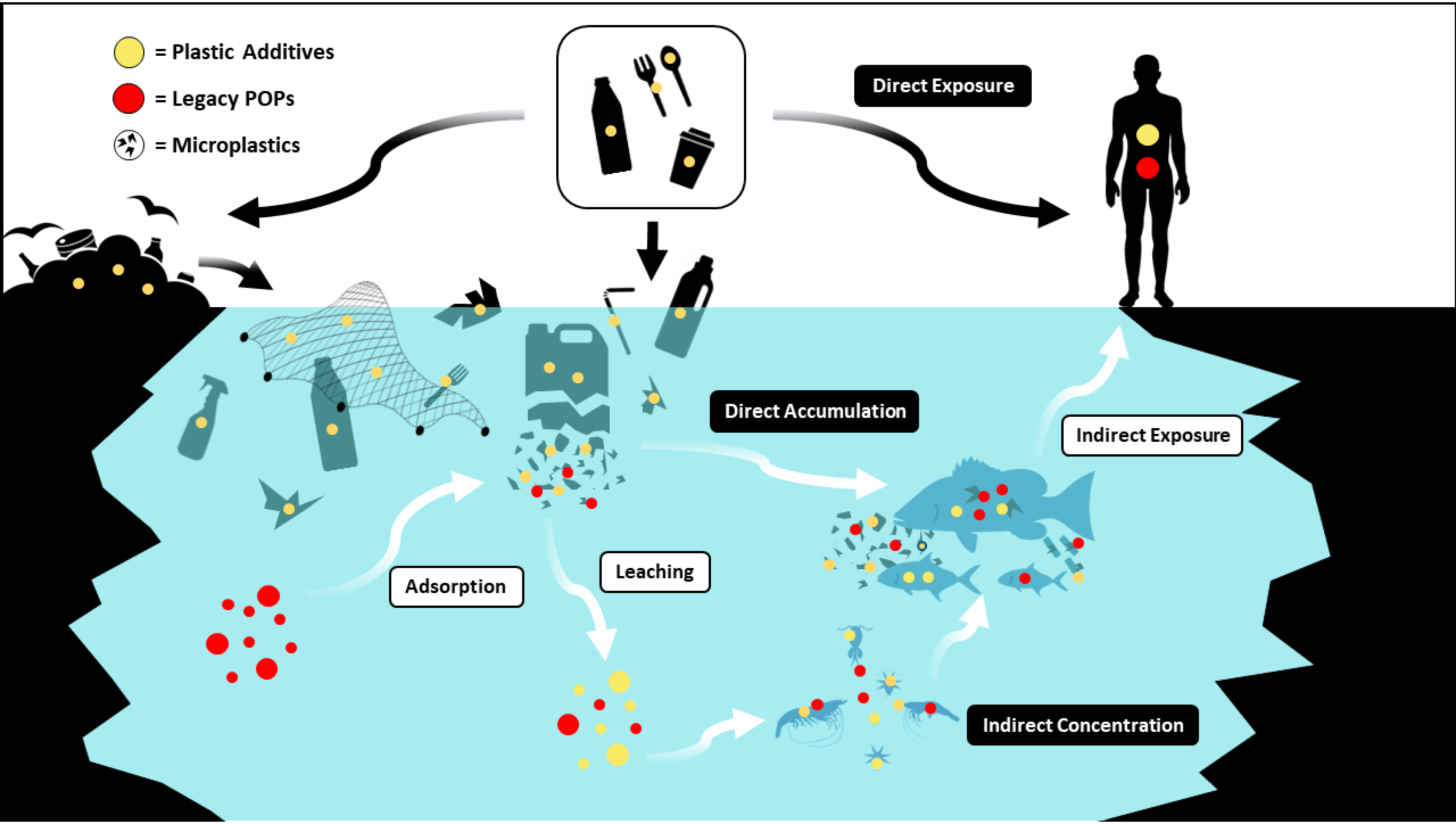
発表雑誌名： Nutrients

年： 2022　　DOI： 10.3390/nu14040895

調理済み食品のうち、市販の弁当（週1回以上）または冷凍食品（週1回以上）の摂取頻度は、妊娠12週以降の死産と関連を認めた。その他の調理済み食品（レトルト食品、インスタント食品、缶詰食品）の摂取頻度と死産は関連がなかった。また、妊娠中のカフェインを含む飲料の摂取頻度は、妊娠帰結と関連があった。特に死産については、ペットボトルや缶で販売されている飲料であっても、自身でコーヒー豆や茶葉から抽出した場合でも、摂取頻度が高いことと関連を示した。

エコチル調査に参加した94,062組の親子のデータを解析対象とし、調理済み食品およびカフェインを含む飲料の摂取頻度と妊娠帰結との関連について、ロジスティック回帰分析により調整済みオッズ比を算出した。

プラスチックの使用が増えると人間への環境ホルモンの曝露が増える



Credit: Shige Takada and Manuel Brunner (co-authors).

The Minderoo-Monaco Commission on Plastics and Human Health

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Global Health

Volume 89 I March 21, 2023
SPECIAL COLLECTION

THE MINDEROO-MONACO COMMISSION ON PLASTICS AND HUMAN HEALTH

BOSTON COLLEGE
MINDEROO FOUNDATION
CSM CENTRE SCIENTIFIQUE DE MONACO

The Minderoo-Monaco Commission on Plastics and Human Health

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*Author affiliations can be found in the back matter of this article

Conclusions: It is now clear that current patterns of plastic production, use, and disposal are not sustainable and are responsible for significant harms to human health, the environment, and the economy as well as for deep societal injustices.

The main driver of these worsening harms is an almost exponential and still accelerating increase in global plastic production. Plastics' harms are further magnified by low rates of recovery and recycling and by the long persistence of plastic waste in the environment.

The thousands of chemicals in plastics—monomers, additives, processing agents, and non-intentionally added substances—include amongst their number known human carcinogens, endocrine disruptors, neurotoxicants, and persistent organic pollutants. These chemicals are responsible for many of plastics' known harms to human and planetary health. The chemicals leach out of plastics, enter the environment, cause pollution, and result in human exposure and disease. All efforts to reduce plastics' hazards must address the hazards of plastic-associated chemicals.

プラスチックは人間の健康への悪影響がある。

プラスチック関連化学物質（添加剤、反応助剤、モノマー、非意図的生成物）

During use and also in disposal, plastics release toxic chemicals including additives and residual monomers into the environment and into people. National biomonitoring surveys in the USA document population-wide exposures to these chemicals. Plastic additives disrupt endocrine function and increase risk for premature births, neurodevelopmental disorders, male reproductive birth defects, infertility, obesity, cardiovascular disease, renal disease, and cancers. Chemical-laden MNPs formed through the environmental degradation of plastic waste can enter living organisms, including humans. Emerging, albeit still incomplete evidence indicates that MNPs may cause toxicity due to their physical and toxicological effects as well as by acting as vectors that transport toxic chemicals and bacterial pathogens into tissues and cells.

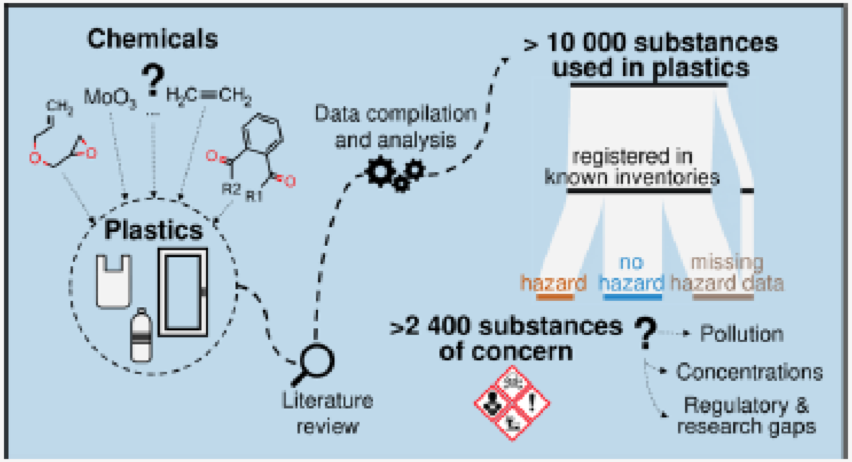
使用時と廃棄の時点での有害化学物質の曝露

粒子毒性および化学物質と病原微生物の輸送媒体としての問題

Deep Dive into Plastic Monomers, Additives, and Processing Aids

Helene Wiesinger,* Zhanyun Wang,* and Stefanie Hellweg

Cite This: *Environ. Sci. Technol.* 2021, 55, 9339−9351



ABSTRACT: A variety of chemical substances used in plastic production may be released throughout the entire life cycle of the plastic, posing risks to human health, the environment, and recycling systems. Only a limited number of these substances have been widely studied. We systematically investigate plastic monomers, additives, and processing aids on the global market based on a review of 63 industrial, scientific, and regulatory data sources. In total, we identify more than 10'000 relevant substances and categorize them based on substance types, use patterns, and hazard classifications wherever possible. Over 2'400 substances are identified as substances of potential concern as they meet one or more of the persistence, bioaccumulation, and toxicity criteria in the European Union. Many of these substances are hardly studied according to SciFinder (266 substances), are not adequately regulated in many parts of the world (1'327 substances), or are even approved for use in food-contact plastics in some jurisdictions (901 substances). Substantial information gaps exist in the public domain, particularly on substance properties and use patterns. To transition to a sustainable circular plastic economy that avoids the use of hazardous chemicals, concerted efforts by all stakeholders are needed, starting by increasing information accessibility.

KEYWORDS: *plastic products, plasticizers, plastic pollution, chemical inventory, production volume, substances of concern, circular economy, regulatory status*

Recommendations: To protect human and planetary health, especially the health of vulnerable and at-risk populations, and put the world on track to end plastic pollution by 2040, this Commission supports urgent adoption by the world's nations of a strong and comprehensive Global Plastics Treaty in accord with the mandate set forth in the March 2022 resolution of the United Nations Environment Assembly (UNEA).

International measures such as a Global Plastics Treaty are needed to curb plastic production and pollution, because the harms to human health and the environment caused by plastics, plastic-associated chemicals and plastic waste transcend national boundaries, are planetary in their scale, and have disproportionate impacts on the health and well-being of people in the world's poorest nations. Effective implementation of the Global Plastics Treaty will require that international action be coordinated and complemented by interventions at the national, regional, and local levels.

This Commission urges that a cap on global plastic production with targets, timetables, and national contributions be a central provision of the Global Plastics Treaty. We recommend inclusion of the following additional provisions:

プラスチック条約でプラスチックの生産量に制限を設けることが必要

提言

マイクロプラスチックによる水環境汚染の生態・健康影響研究の必要性とプラスチックのガバナンス

令和２年（２０２０年）４月７日

日　本　学　術　会　議

必要な検討

(1)　プラスチック製品の添加剤の内分泌かく乱作用（広く免疫系への影響や生殖毒性も含む）の調査と多成分（添加剤などを含めたプラスチック製品）に同時に曝露される際の作用の評価、及びそれに基づく使用規制が必要である。添加剤としては、ベンゾトリアゾール系紫外線吸収剤、ベンゾフェノン系紫外線吸収剤、臭素系難燃剤、リン系難燃剤、フタル酸エステル類、ノニルフェノール、ビスフェノールA、有機フッ素化合物等があげられる。
(2)　環境中のプラスチックに含まれる添加剤の網羅的分析が必要である。マイクロプラスチック、特に1 mm以下の微細なマイクロプラスチック中の添加剤の測定、粒径別含有量の調査は重要である。
(3)　プラスチックの微細化と添加剤の溶出特性の関連の把握（微細化すると溶出しやすいのか？餌や食品中の油分で溶出が促進されるのか？）が必要である。
(4)　マイクロプラスチックを介した添加剤の魚貝類への移行・蓄積の検討が必要である。
(5)　食物連鎖を通した添加剤の生物増幅の検討が必要である。

必要な調査

(6)　トータルダイエットスタディ、血液や尿の分析等によるプラスチック添加剤の食事からのヒトへの曝露量と、その影響の把握の研究が必要である。加えて、その他の曝露源、大気（ハウスダストも含む）、水、土壌からの曝露調査も行い、健康リスク評価のための知見を収集する必要がある。
(7)　予防的な対応として、プラスチック添加剤の規制を溶出試験に基づくものから含有試験に基づくものに切り替える必要がある。すなわち、プラスチックごみとなり環境へ放出され、微細化されたものが、生物への取り込みを経て、最終的にヒトへ曝露される可能性があるため、製品からの直接の溶出だけでなく、製品そのものに含有される添加剤や、構成するモノマー・オリゴマーの毒性を対象にし、その含有量に基づく規制を行うことが予防的な対策として必要である。

上述のように、解決すべき課題は多いが、プラスチックに含まれる有害化学物質の影響を過小評価せず、予防原則的な観点からプラスチックの排出量を削減していく必要がある。

予防的な対策

必要な研究

異なるレセプターへの結合に起因する異常、
さらに異なる作用機序を持つ添加剤が共存する場合の
総合的な毒性の評価

TEF, TEQを超えるアプローチ

内分泌攪乱 (Estrogen, Androgen, ……..)
Drug metabolism（AhR, …..)
Carcinogenicity
Neuro-toxicity
Immuno-toxicity

e.g., particle toxicity + endocrine disruption

Take-home message

疎水性化学物質はプラスチックから生物に移行･蓄積する。

油分と界面活性剤は疎水性化学物質の移行･蓄積を促進する。

微細化は疎水性化学物質の移行･蓄積を促進する。

従来Biologically-inertと考えられていた添加剤とLegacy POPsをBioavailableな形にして生態系、生体システムの中にMP/NPが運び込んでいる

予防原則的対応：プラスチックの使用削減