日化協LRI中間報告会

劣化マイクロプラスチック由来吸着化学物質の体内動態モデルの構築と影響評価

令和3年8月19日

九州大学農学研究院
大嶋雄治

エコトキシコロジーにおけるマイクロプラスチック(MP)研究の課題

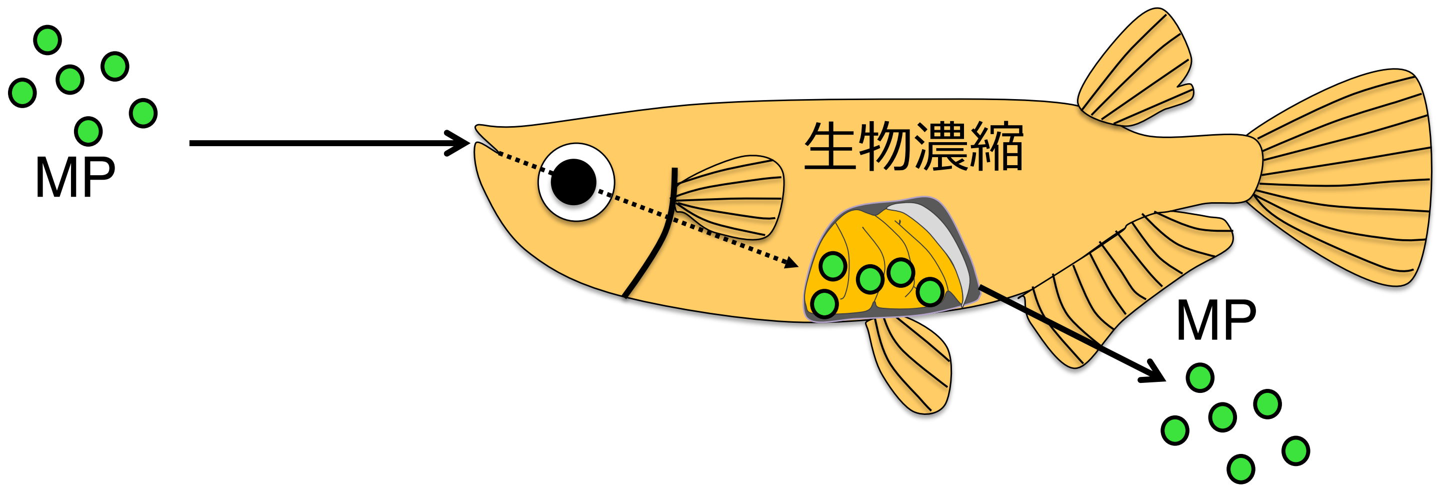
- 水生生物におけるMPの体内動態は未解明

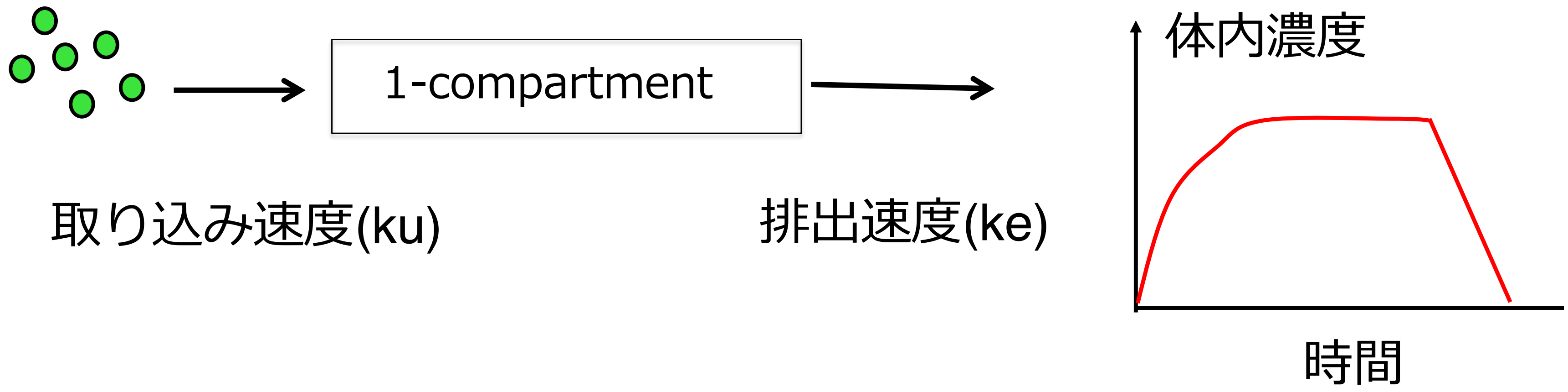
- 研究の殆どは新品の MPで実施されており、劣化 MPで行った研究は少ない　劣化の影響は？

- MPに吸着した有害化学物質の蓄積を介在するベクター効果はあるのか？

魚体に入ったMPの蓄積・体内動態

MPの取り込み・蓄積・排出等の挙動についてはほとんど分かっていない。





MPの体内動態を1-compartmentモデルで解析 シミュレーションによる予測が可能

2, 20, 200 μmMPの曝露試験

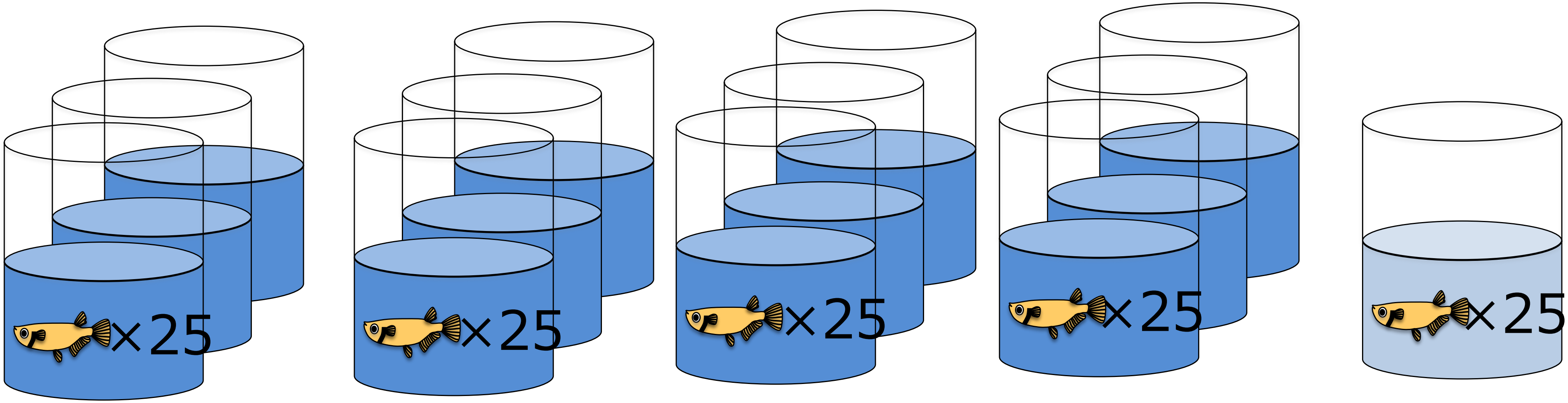
Exposure (14 day)

Elimination (10 day)

0 day

14 day

24 day



2 μm

20 μm

20 μm

200 μm

Control

Polystyrene (PS)

Polyethylene (PE)

(10^6 p/ L)
= 4 μg/L

(10^6 p/ L)
= 4 mg/L

(10^6 p/ L)
= 4 mg/L

(10^4 p/ L)
= 40 mg/L

2, 20, 200 μmMPの曝露試験

Ecotoxicology and Environmental Safety 212 (2021) 112007

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Uptake and depuration kinetics of microplastics with different polymer types and particle sizes in Japanese medaka (*Oryzias latipes*)

Yangqing Liu [a], Xuchun Qiu [a,b], Xinning Xu [a], Yuki Takai [a], Hijiri Ogawa [a], Yohei Shimasaki [a], Yuji Oshima [a,c,*]

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[c] Institute of Nature and Environmental Technology, Kanazawa University, Kanazawa 920-1192, Japan

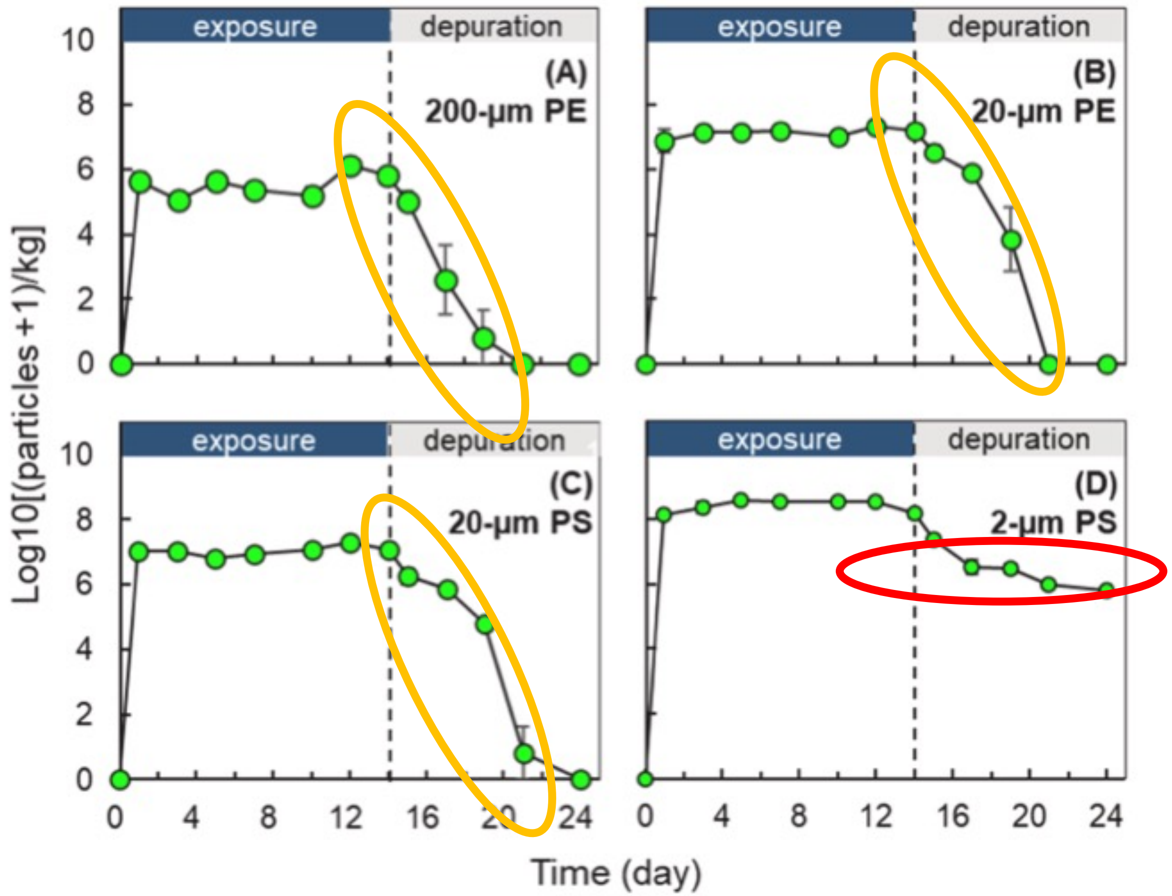

Fig. 5. The concentration of microplastics (MPs) in the Japanese medaka (*Oryzias latipes*). (A) PE-MPs with a diameter of 200 μm; (B) PE-MPs with a diameter of 20 μm; (C) PS-MPs with a diameter of 20 μm; (D) PS-MPs with a diameter of 2 μm. Data are shown as mean ± SD ($n = 5$). The experiment consisted of a 14-day uptake phase (blue bar) and a 10-day depuration phase (gray bar). In some instances, the errors are small and obscured by the symbols.

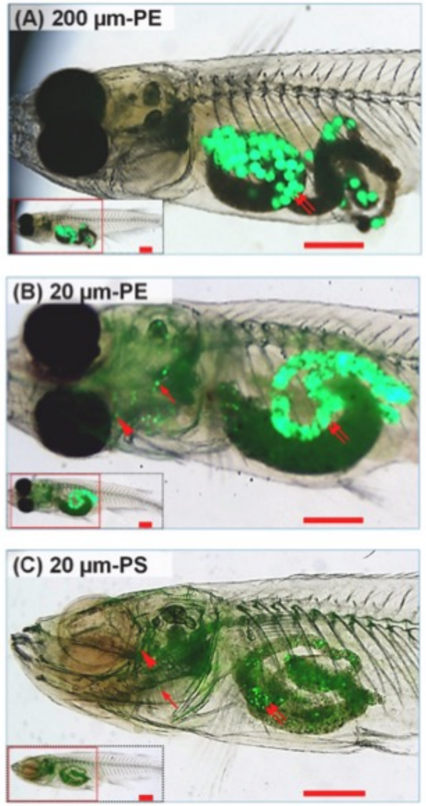

Fig. 3. Representative images of medaka (*Oryzias latipes*) collected during the exposure phase under the visual field of a GFP filter (λ_{em} = 525/50 nm and λ_{ex} = 470/40 nm). (A) PE-MPs with a diameter of 200 μm; (B) PE-MPs with a diameter of 20 μm; (C) PS-MPs with a diameter of 20 μm. The inner figure shows whole-body images. The typical fluorescent signals of MPs are indicated by the double arrow (gastrointestinal tract), single arrow (gill), and arrowhead (head). Bar = 1.0 mm.

20, 200 μmMPは急速に体から出て行く・・・

2, 20, 200μmMPの曝露試験

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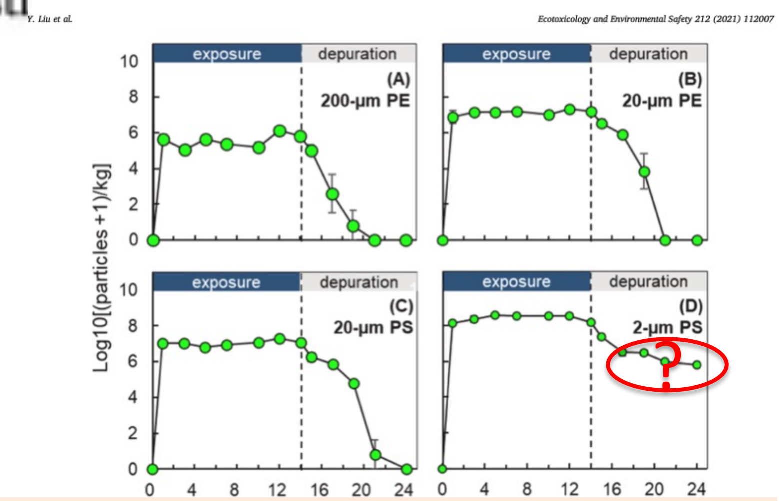
Table 2
Pharmacokinetic parameters of microplastics (MPs) in Japanese medaka (*Oryzias latipes*)[a].

Parameter (unit)	200 μm PE	20 μm PE	20 μm PS	2 μm PS
BCF (L/kg)	74.4	25.7	16.8	139.9
k_u (L/kg/day)	83.7	26.7	15.8	106.1
k_e (/day)	1.13	1.04	0.94	0.76
$T_{1/2}$ (/day)	0.62	0.67	0.74	0.91
MRT (/day)	0.90	1.00	1.12	1.33

[a] PE: Polyethylene MPs; PS: Polystyrene MPs; BCF: bioconcentration factor; k_u: uptake rate constant; k_e: elimination rate constant (esti[illegible] 14–19); $t_{1/2}$: biological half-life; MRT: mean residence time.

?



20, 200 μmMPのBCFは<100と推定された

2, 20, 200μmMPの曝露試験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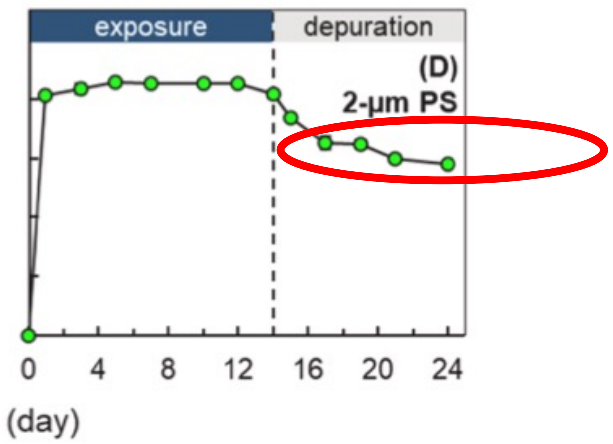
Y. Liu et al. *Ecotoxicology and Environmental Safety 212 (2021) 112007*



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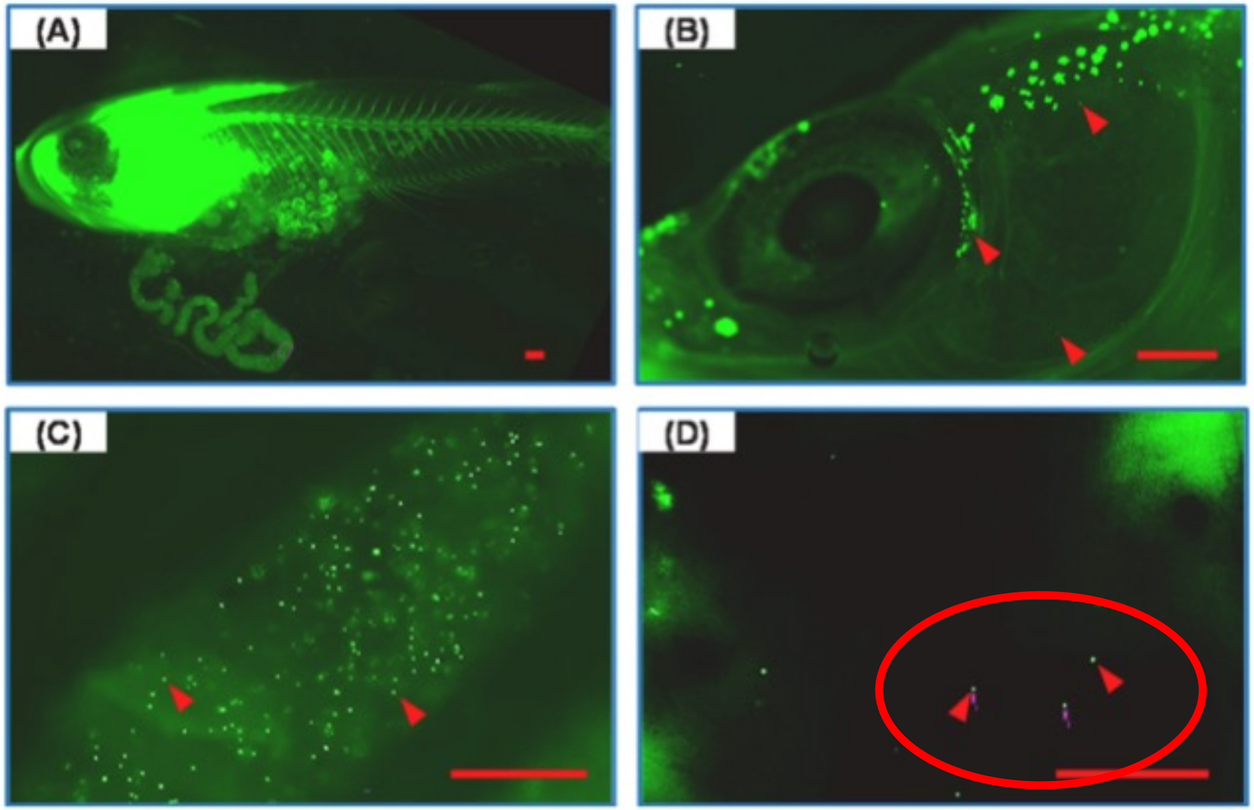
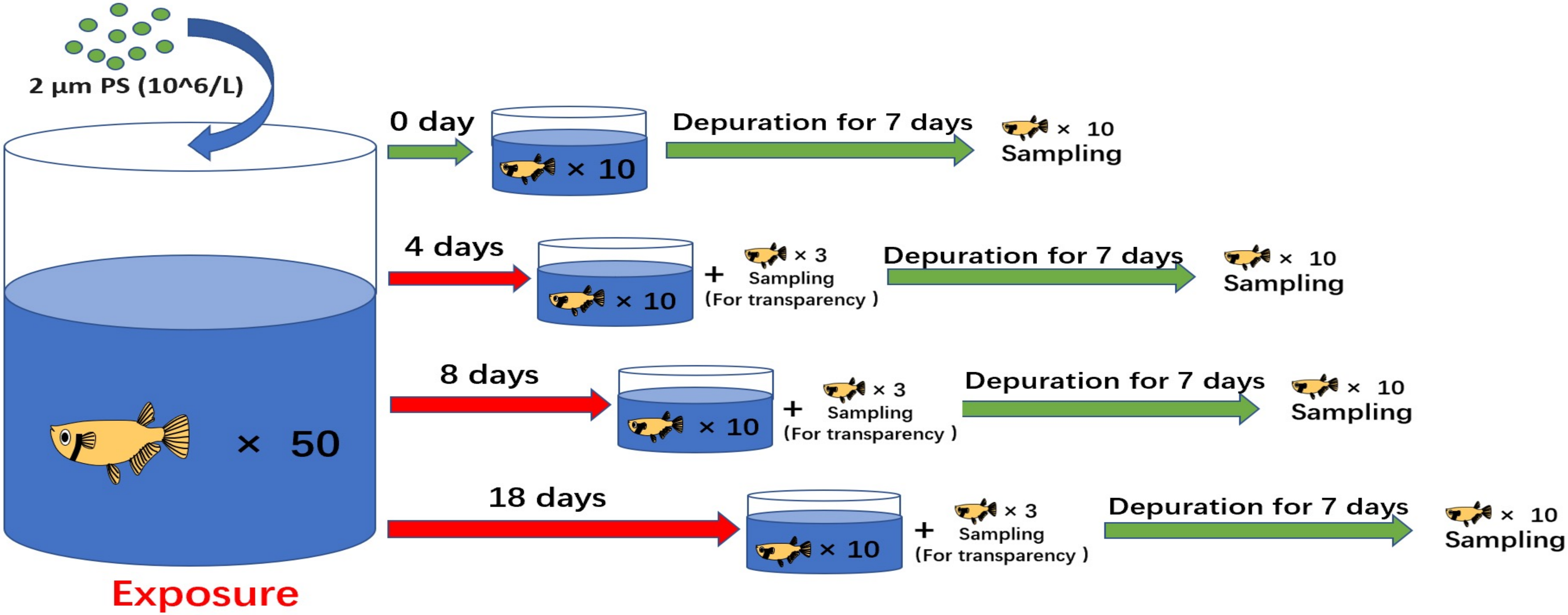


Fig. 4. Typical fluorescent signal in the head and gastrointestinal tract of medaka (*Oryzias latipes*) exposed to 2 μm polystyrene microplastics (MPs) under the visual field of a GFP lens (λ_{em} = 525/50 nm and λ_{ex} = 470/40 nm). (A) representative whole-body image; (B) MPs in the head of fish sampled on day 1; (C) MPs in gastrointestinal tract of fish sampled on day 7; (D) MPs in the gastrointestinal tract of fish sampled on day 24 (the last day of the depuration phase). The typical fluorescent signal is indicated by an arrowhead. Bar = 1.0 mm.

MPは急速に体から出て行くが 2μm MPは残留する

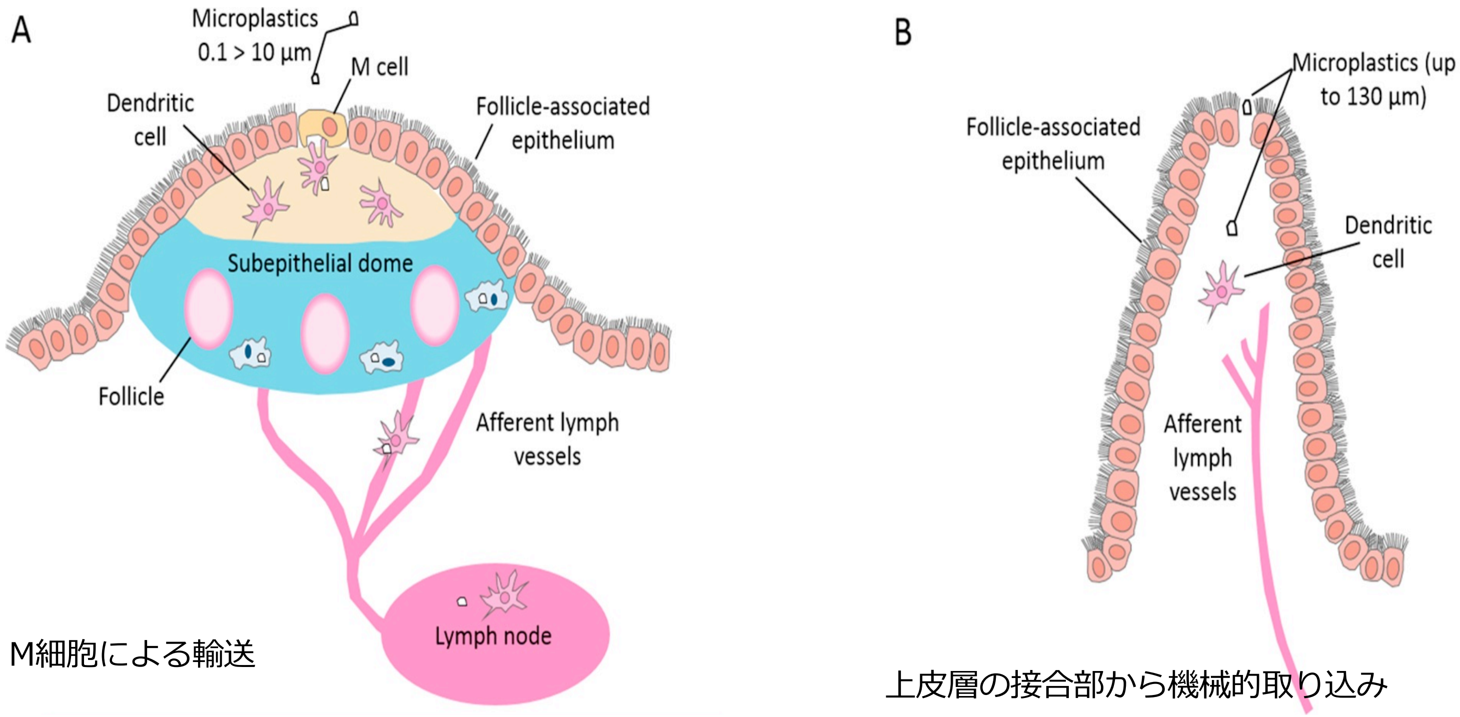
メダカに2 μm MPを4, 8, 18日間曝露し7日間排泄させた



Subjectives: 2 months of Japanese medaka (Oryzias latipes); Fluorescent polystyrene(PS)
Exposure concentration: 1×10^6 particles/L
Water was changed every 2 days
The ten fish sampled during the depuration period:
Five fish for transparency and count the number of MP, another five fish preserve for histology.

小腸上皮における微細MPの予想される挙動

Predicted pathways of microplastic uptake from the gastrointestinal tract (GIT)



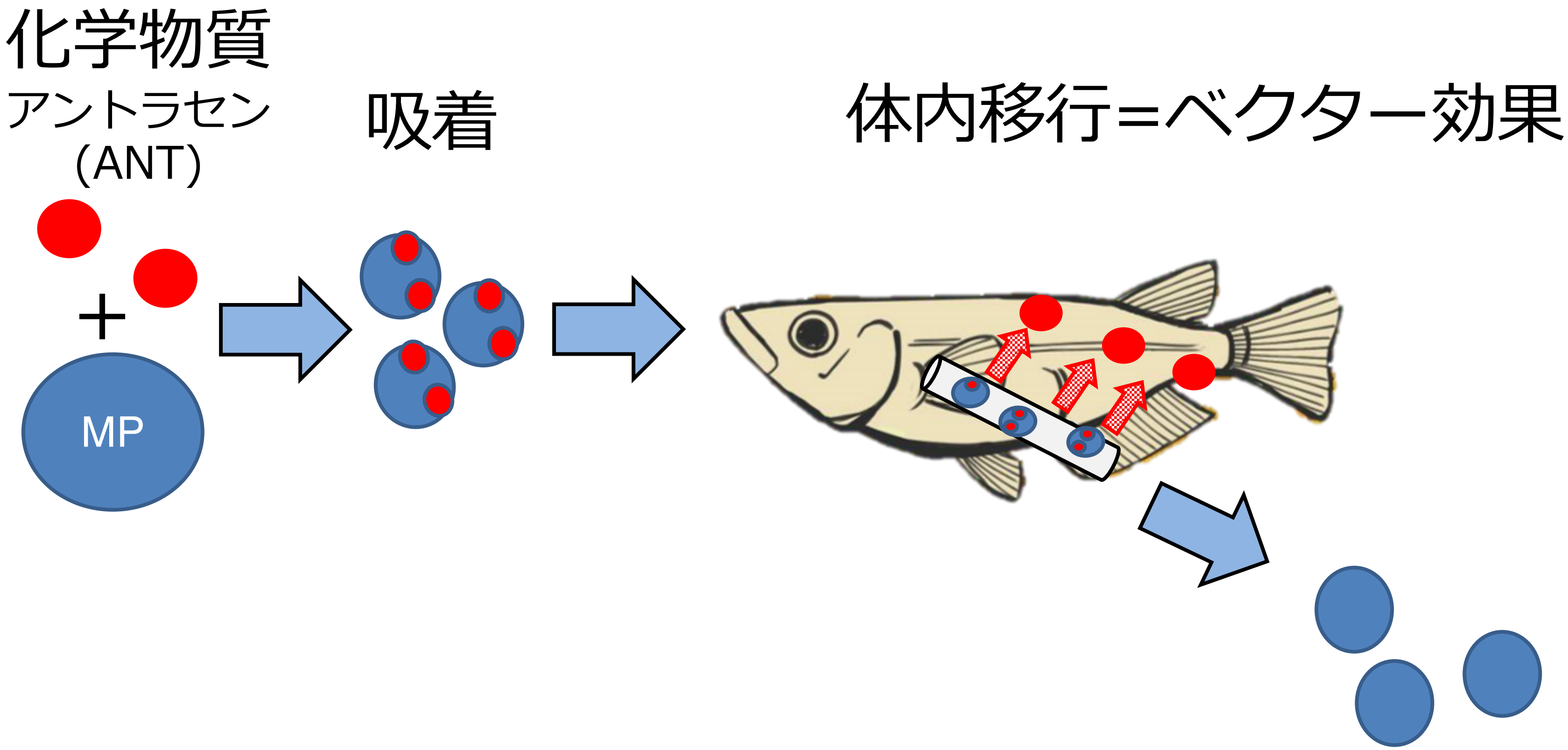
(Wright and kelly et al., 2017)

Endocytosis

Persorption

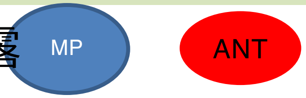
消化管内壁に2 μmMPが入り込んだ可能性が高い

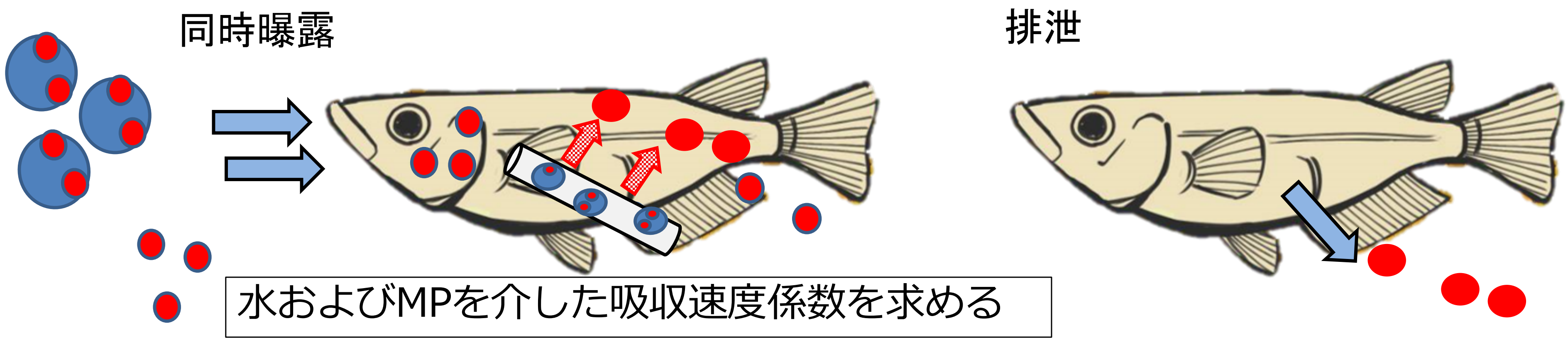
MPによる化学物質蓄積へのベクター効果は起こるか？
その劣化による影響は？



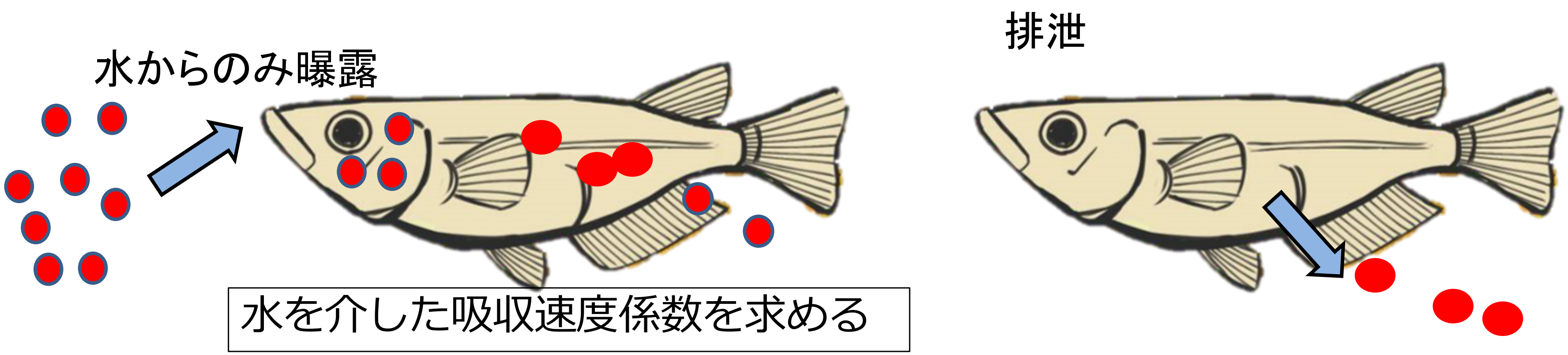
ベクター効果検証実験

I) アントラセン(ANT)の水+MP同時曝露





II) アントラセン(ANT) 曝露



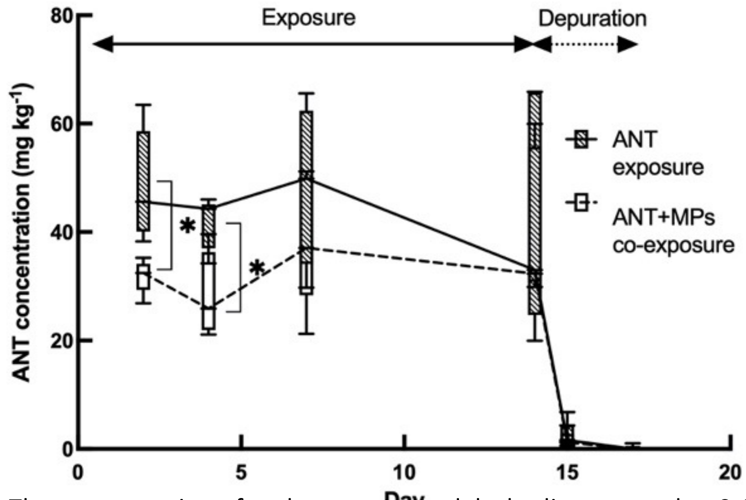
III) シミュレーションでMPを介したベクター効果を推定

水およびMPを介した吸収速度係数でコンパートメントモデル計算した蓄積プロファイル

ー水を介した吸収速度係数でコンパートメントモデル計算した蓄積プロファイル

＝MP経由の蓄積（ベクター効果）

粒状PEとANTを同時曝露したメダカにおける体内ANT濃度



The concentration of anthracene in medaka bodies exposed to 0.1 mg L^{-1} for 14-day ex and 3-day depuration in ANT exposure and ANT+MP co-exposure groups (n=5)

Aquatic Toxicology 228 (2020) 105643
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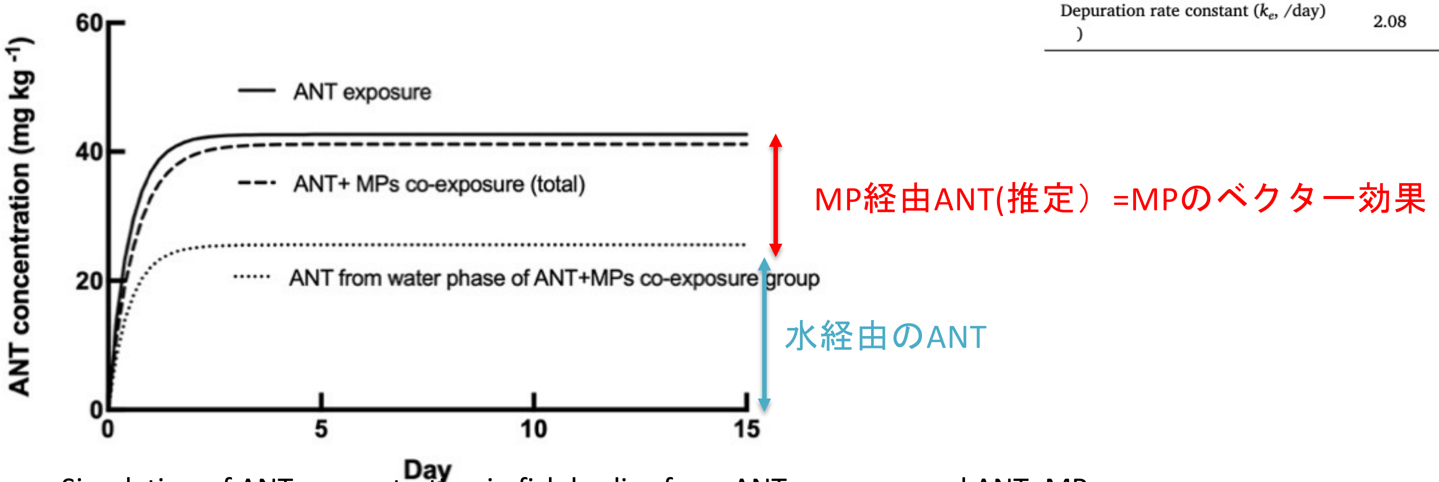
Quantifying the vector effects of polyethylene microplastics on the accumulation of anthracene to Japanese medaka (*Oryzias latipes*)

Xuchun Qiu[a,b], Souvannasing Saovany[b], Yuki Takai[b], Aimi Akasaka[c], Yoshiyuki Inoue[c], Naoaki Yakata[c], Yangqing Liu[b], Mami Waseda[b], Yohei Shimasaki[b], Yuji Oshima[b,d,*]

Table 1
Pharmacokinetic parameters of anthracene (ANT) in Japanese medaka (*Oryzias latipes*) in theANT exposure and ANT-MPs co-exposure groups.

Parameters	ANT exposure	ANT-MPs co-exposure
ANT in water (on day 14; mg/L)	0.037	0.074 (containing MPs) 0.022 (water phase)
ANT in medaka (on day 14; mg/kg)	42.8	41.1
Bioconcentration factor (BCF; L/kg)	1170	556 (containing MPs)
Uptake rate constant (k_u, L/kg/day)	2432	1078
Depuration rate constant (k_e, /day))	2.08	1.94



Simulation of ANT concentration in fish bodies from ANT exposure and ANT+MP co-exposure group

PE-MPはアントラセン蓄積でベクター効果を持つ

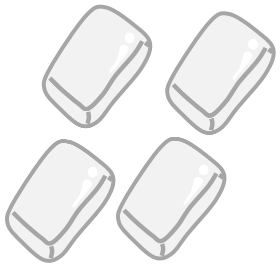
MPの劣化度や形状による違い

実験に使用したモデルPE粒子
（環境中のMPとは形状や劣化が異なる）

一般に使用されているものと分子量、結晶度が大きく異なるので注意が必要

粒状PE, 破砕PE, 破砕PS劣化試験

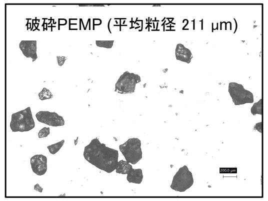
約200 µm粒状ポリエチレン（PE）、粉砕PE, PSのマイクロプラスチックを作製し、実環境中の1.5および5年に相当する紫外線を照射して劣化させた粒状及び粉砕PEを作製した結果、PEの劣化度は低かったが、PSは劣化が確認された。

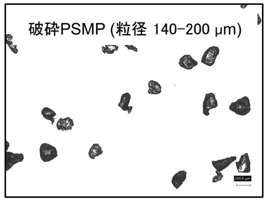


PE、PS ペレット

破砕

ふるい分け

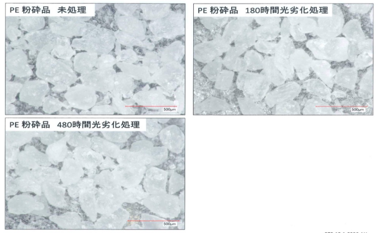




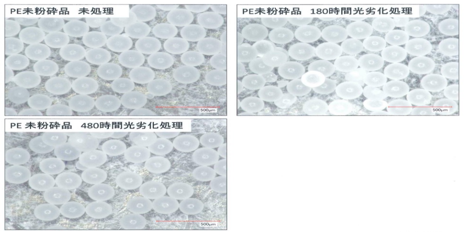
紫外線照射

劣化MPの作製

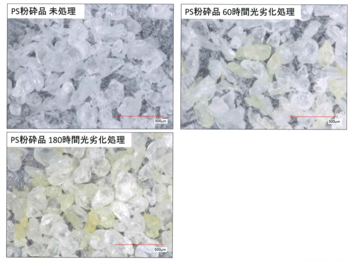
粉砕劣化PE紫外線照射
（1.5年、5年分）

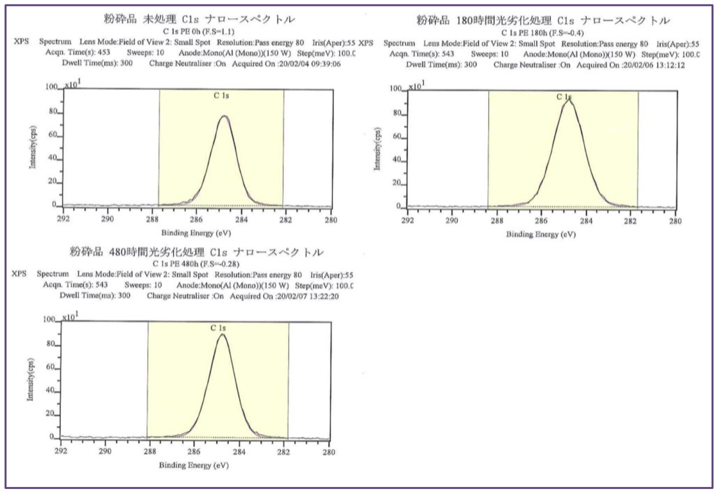


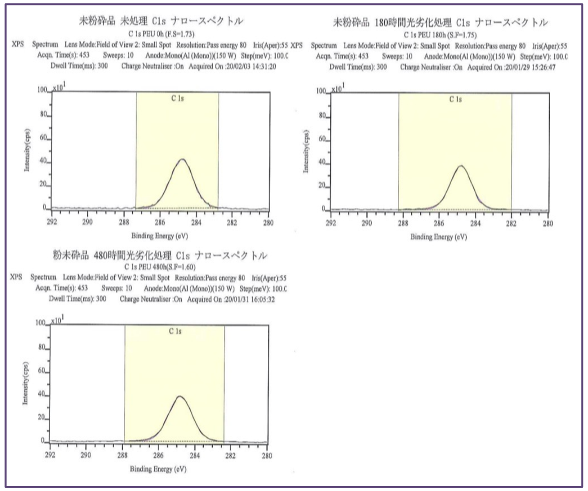
粒状劣化PE紫外線照射
（1.5年、5年分）

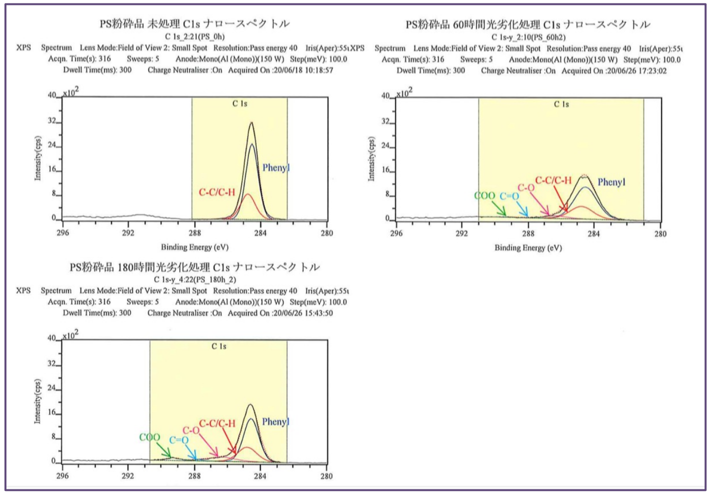


粉砕劣化PS紫外線照射
（0.5年、1.5年分）



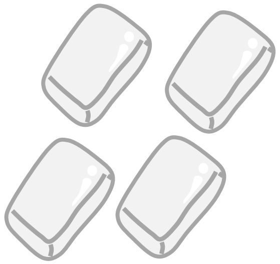






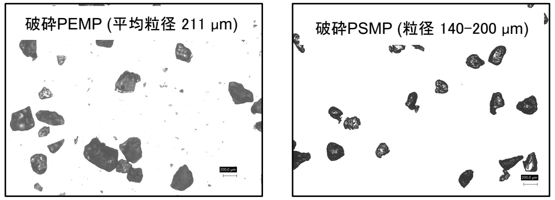
2021年度　進行状況

- 約200 μm粒状高密度ポリエチレン（HDPE）を作製・洗浄し、微細MPを除去後、紫外線を照射して劣化させた粉砕PEを作製し、その劣化による影響を調べる。



HDPE ペレット

破砕



紫外線照射

劣化HDPEの作製
8月末終了予定

洗浄による微細粒子の除去

耐候性試験 紫外線照射による促進耐候性試験
　超促進メタルハライドランプ使用　250時間
　光促進劣化処理　20g

- これまでの結果を基に実環境中での影響（ベクター効果）を予測した

9月より

- メダカ曝露試験(アントラセン、4種クロルベンゼン）による曝露試験を行い、ベクター効果における劣化PEの影響を評価

まとめ

- 水生生物の体内動態は未解明

  BCFはメダカでは10^2程度－＞蓄積はしない

  微細MP（2 μm以下）では蓄積する可能性がある

- 食物連鎖を介しての蓄積はあるのか？

  6 μm以上であれば魚類では起こりにくい

- MPに吸着した有害化学物質の蓄積を介在するベクター効果はアントラセンーPEMPではある。ただしMPの濃度が高濃度(>数mg/L)の場合

劣化マイクロプラスチック由来吸着化学物質の体内動態モデルの構築と影響評価

今後の研究課題

- ベクター効果は実環境（MP濃度、化学物質の種類と濃度）では起こっていない？追試が必要（ANT-PEMPのみ実施）

- どの位のMP濃度であれば実質有害となるか
  ->モデルの検証、精緻化、化学物質の種類を増やす必要

- 自然にある粒子（粘土鉱物やシルトとの比較）との比較検証が必要

謝辞・発表論文

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- 環境研究総合推進費(SII-2-2(2), JPMEERF18S20206)
- 日本化学工業協会LRI (19_R05-01)
- CERI 共同研究

1) Assas, M., Qiu, X., Chen, K., Ogawa, H., Xu, H., Shimasaki, Y., Oshima, Y., 2020. Bioaccumulation and reproductive effects of fluorescent microplastics in medaka fish. Mar. Pollut. Bull. 158, 111446.

2) Qiu, X., Saovany, S., Takai, Y., Akasaka, A., Inoue, Y., Yakata, N., Liu, Y., Waseda, M., Shimasaki, Y., Oshima, Y., 2020. Quantifying the vector effects of polyethylene microplastics on the accumulation of anthracene to Japanese medaka (Oryzias latipes). Aquatic Toxicology 228, 105643.

3) Liu, Y., Qiu, X., Xu, X., Takai, Y., Ogawa, H., Shimasaki, Y., Oshima, Y., 2021. Uptake and depuration kinetics of microplastics with different polymer types and particle sizes in Japanese medaka (Oryzias latipes). Ecotoxicol. Environ. Saf. 212, 112007.