Marine/beach plastic debris as a transport vector of pollutants

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Collaborators

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Satoquo Seino (Kyushu Univ.), JEAN,
Shinya Magome (Sanyo Techno Marine Inc.)

Photo taken at Ishigakijima Island, Japan
March, 2012

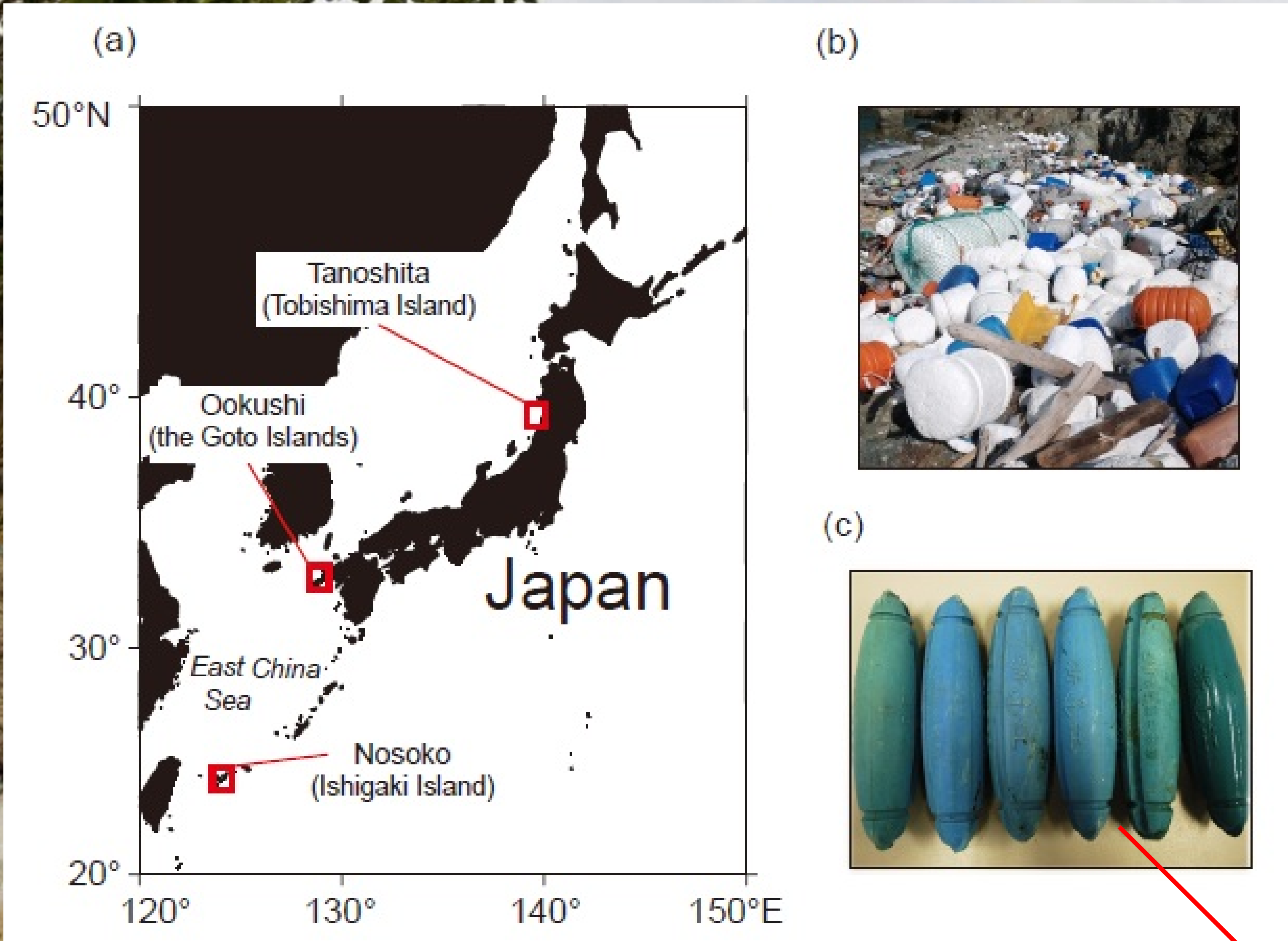
- Plastic debris accounts for about 70 % of marine/beach litter over the world (Derraik, 2003).

- Plastic debris is not only an eyesore which undermines beach tourism value, but also a "transport vector" of POPs (Rices and Gold, 1984; Mato et al., 2001; Endo et al., 2005; Rices et al., 2007; Ogata et al., 2009), and <u>toxic metals (this presentation)</u>.

- The present study focuses on toxic metals originally contained in plastic debris as stabilizers, catalysts, and pigments.

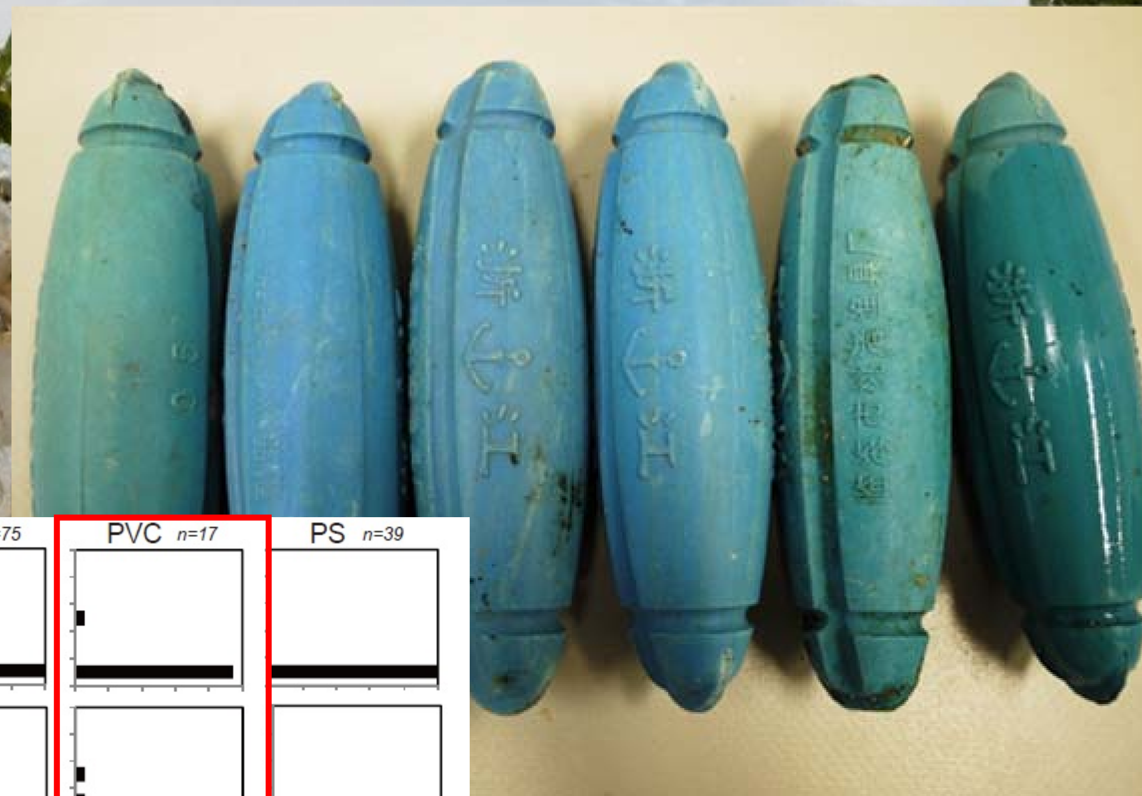
Kako et al., (2011) "Establishment of numerical beach litter hindcast/forecast models: an application to Goto Island, Japan" *Marine Pollution Bulletin*, **62**(2), 293-302.

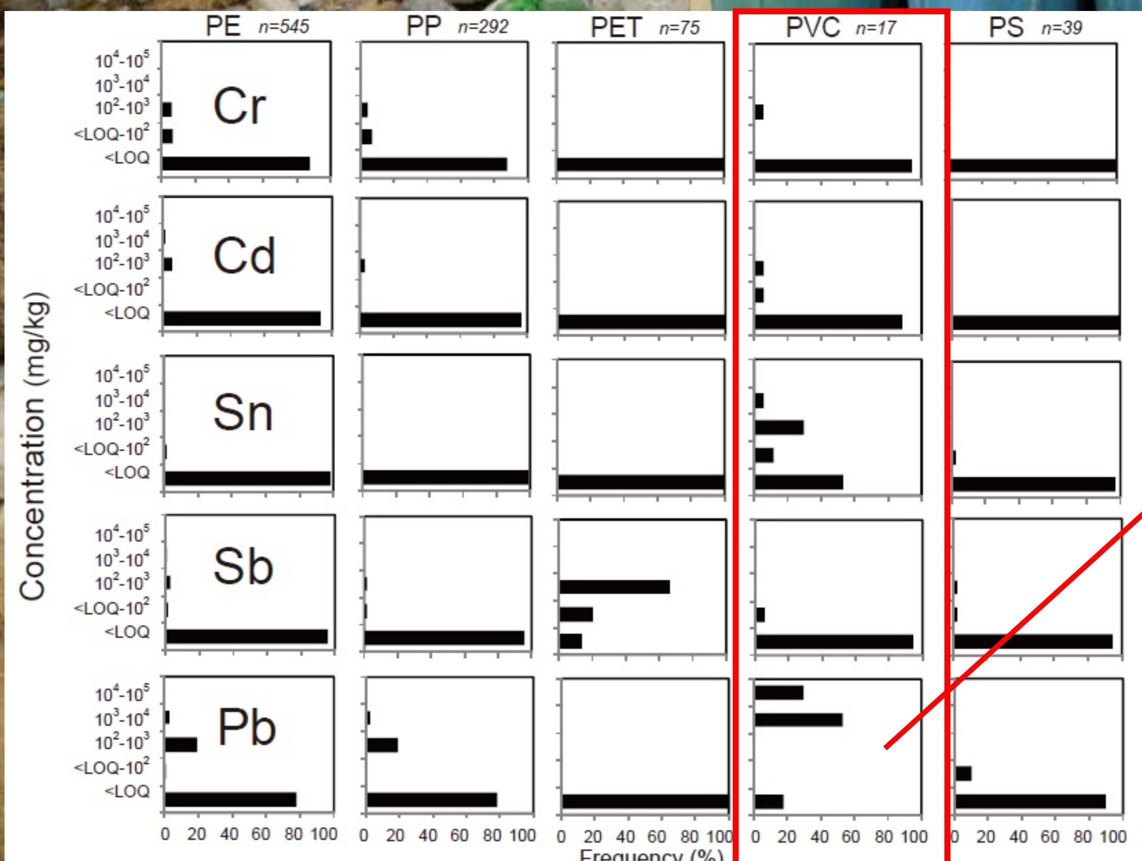
Nakashima et al. (2012) "Quantification of toxic metals derived from macro plastic litter on Ookushi beach, Japan" *Environmental Science & Technology*, 46, 10099-10105.



Our attention is focused on a fishing float made from polyvinyl chloride (PVC) polymer, which is very familiar plastic litter around the East Asia.

X-ray fluorescence analyzer





Lead

7,300 ±1,700 mg/kg

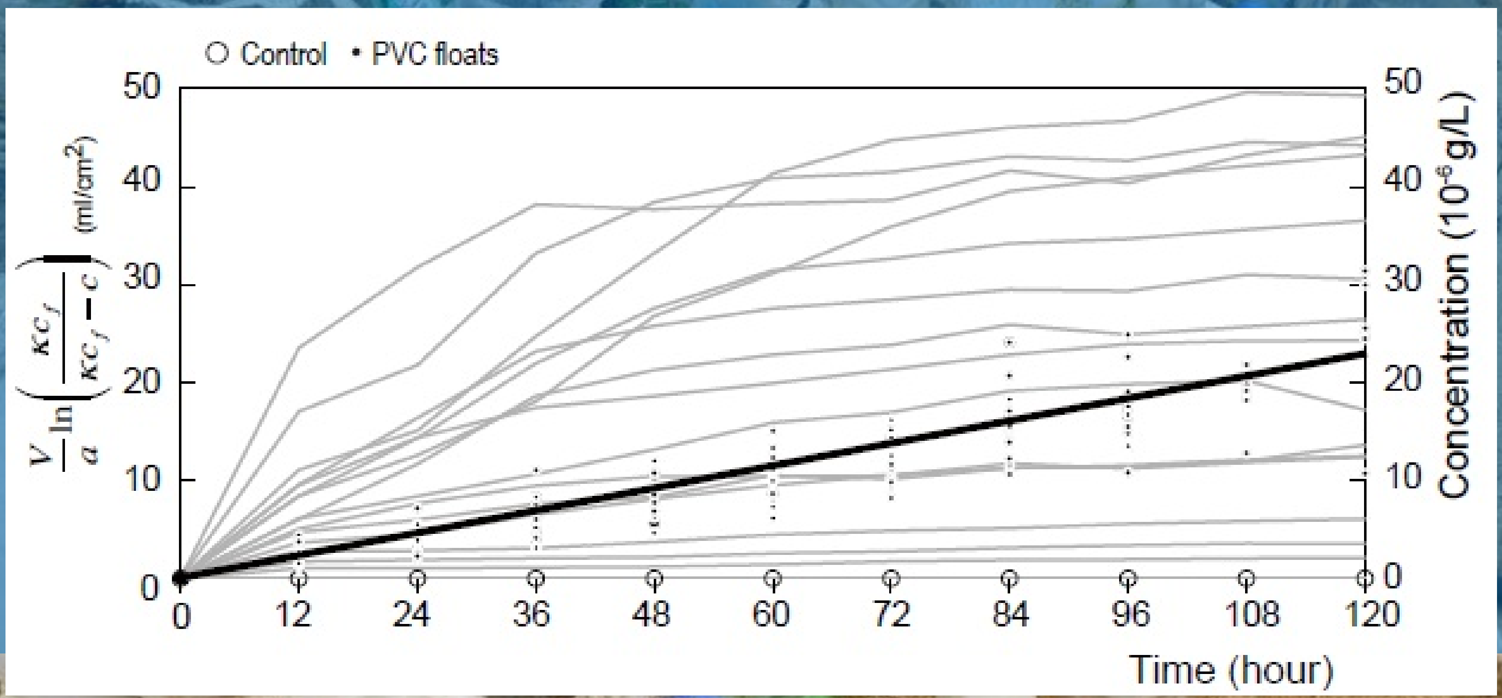
>> 1000 mg/kg (RoHS/WEEE)

$Pb(C_{18}H_{35}O_2)_2$ (lead stearate) is added as a stabilizer when manufacturing PVC floats

Does lead in PVC floats contaminate beaches?

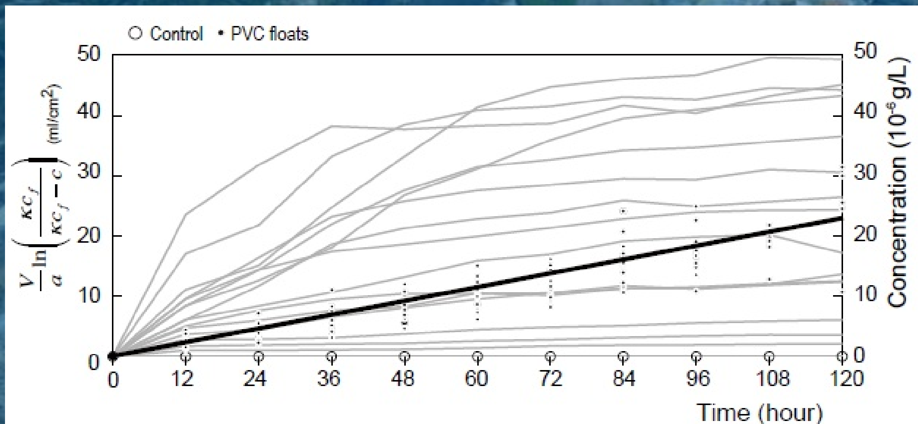
Leaching experiments (15 experiments in total)

- A single PVC float was placed into a glass vial filled with 820 mL of E[...]ater.
- [...] was shaken continuously for 120 hours.
- [...] water was sampled from the glass vial every 12 hours, and w[...]ed into an ICP-MS to measure the concentration of Pb.



Does lead in PVC floats contaminate beaches?

A Fickian laminar film model to evaluate the leaching flux of Pb
(Nakashima *et al.*, 2012, *ES&T*)



$$V\frac{dc}{dt} = a\nu(\kappa c_f - c)$$

$$\Rightarrow \frac{V}{a}\ln\left(\frac{\kappa c_f}{\kappa c_f - c}\right) = \nu t$$

V: volume of Elix water (820 mL), c: Pb concentration in the vial

a: area of float surface, c_f: mass of Pb per unit volume in each PVC float

ν: leaching rate of Pb; κ: partition coefficient ($=c_\infty/c_f$),

c_∞ :saturated Pb concentration

Pb leaching flux (leaching mass per unit area & time) on beaches (R [$g/cm^2/s$])

$$R = \nu\overline{\kappa c_f} \approx 3.4\times10^{-12}\, g/cm^2/s$$

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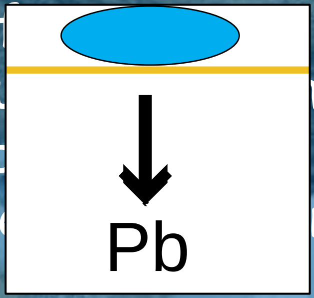


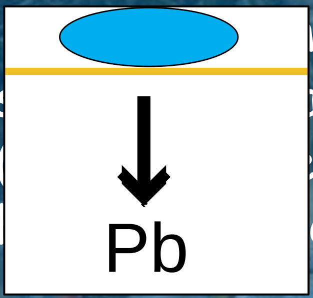
If [illegible] that leaching process occur only in rainy days (r~16% in su[illegible]), and that leaching Pb is accumulated in the upper 10 cm (c[illegible], the growth rate of Pb concentration accumulated in be[illegible]nsity(ρ) =1600 kg/m3) can be estimated to

$$G = Rr/(d\rho) \approx 1\, mg / kg / year$$

It [illegible]tion value (250 mg/kg; US EPA) by a single PVC float.

Does lead in PVC floats contaminate beaches?

A Fickian laminar film model (Nakashima *et al.*, 2012, *ES&T*) to evaluate the growth rate of Pb in soil



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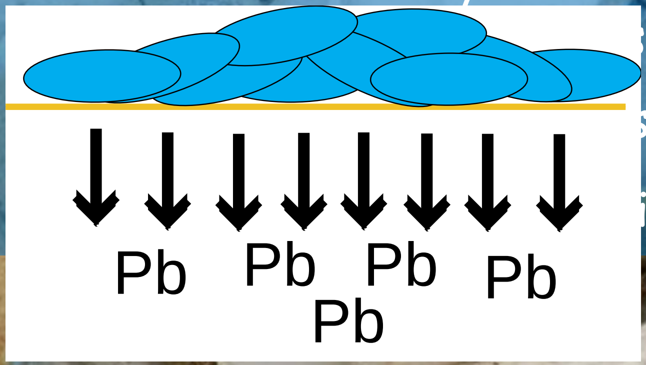
These estimates may shorten if plastic debris washed ashore on beaches … likely).



…ssue to our grandkids

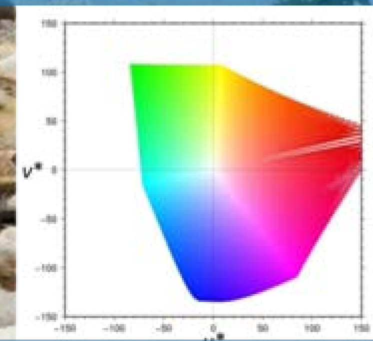
…issue to our kids

We are monitoring marine debris washed ashore on beaches using ten webcams set around Japan Islands (Kataoka et al., 2012, *MPB*)

once in each two-hour

Processing of webcam images to compute areas covered by marine debris (Kako et al., 2012, MPB; Kataoka et al., 2012MPB)

1) To compute areas precisely, RGB images are converted into photos to which our sight line is perpendicular.



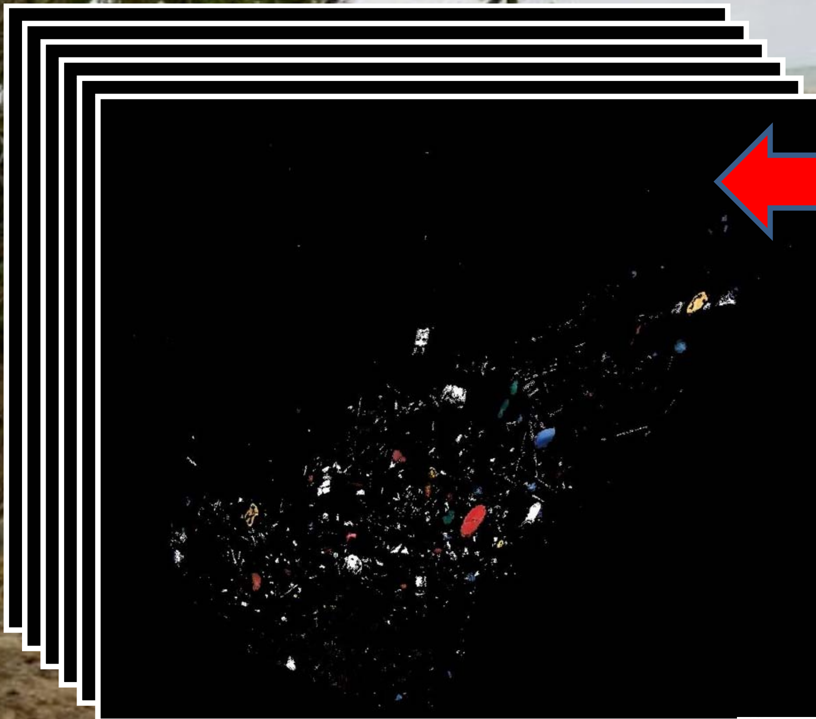
2) Anthropogenic things (e.g., plastics) in the RGB images are automatically separated from natural things (driftwoods, background sand) by an image processing technique.

3) Computing areas covered Anthropogenic things

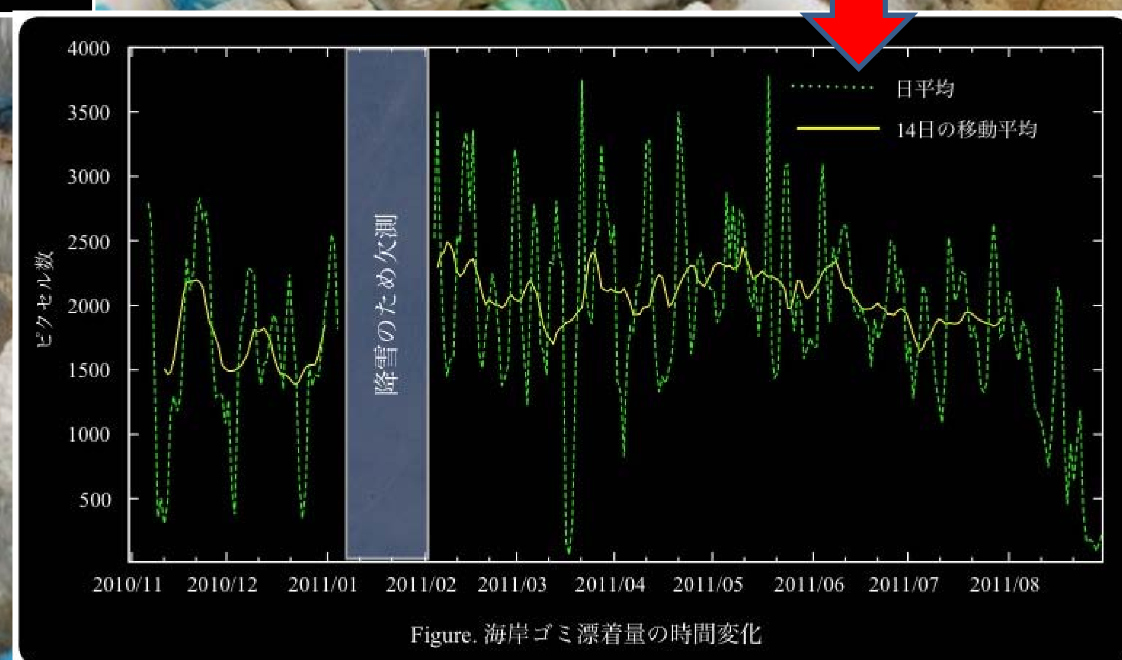
Anthropogenic things

natural things

Sequential photos of anthropogenic things taken by webcams at a fixed point



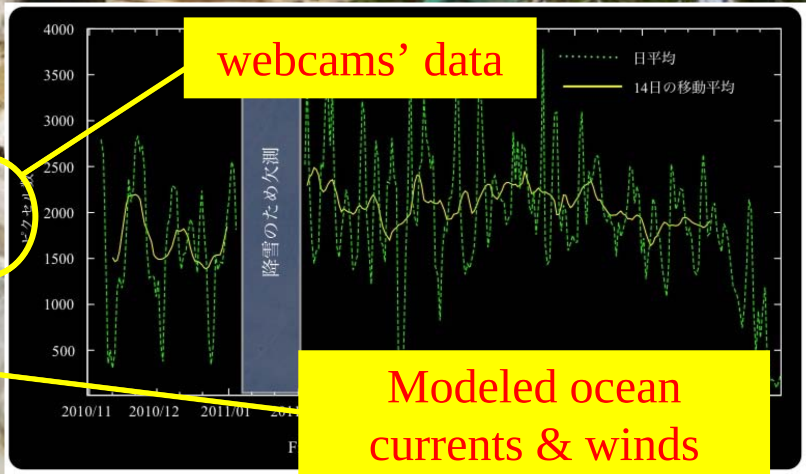
Time series of areas covered by anthropogenic things (marine debris) washed ashore on the beach

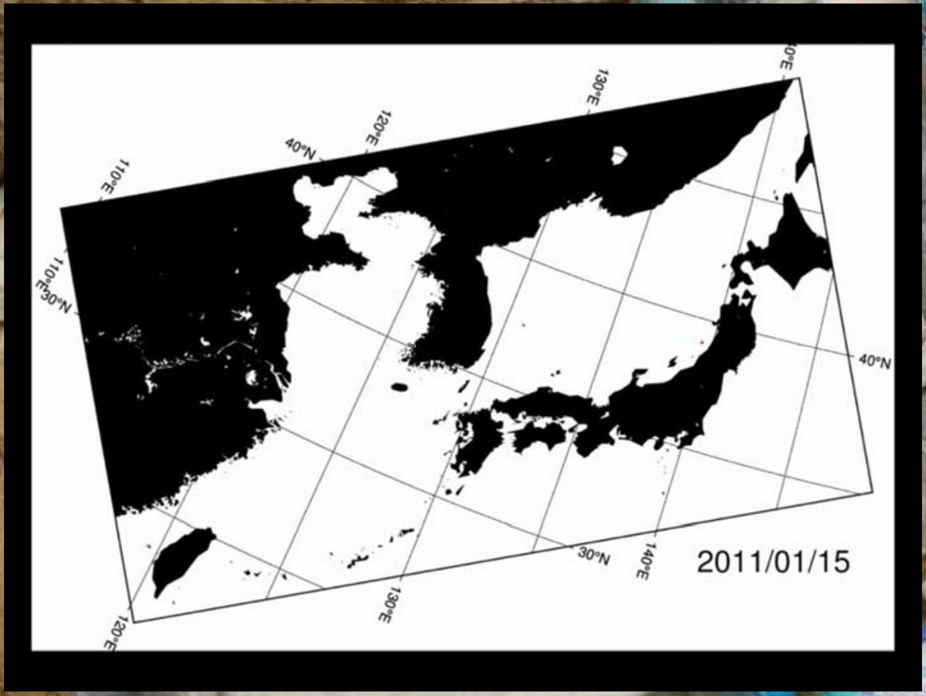


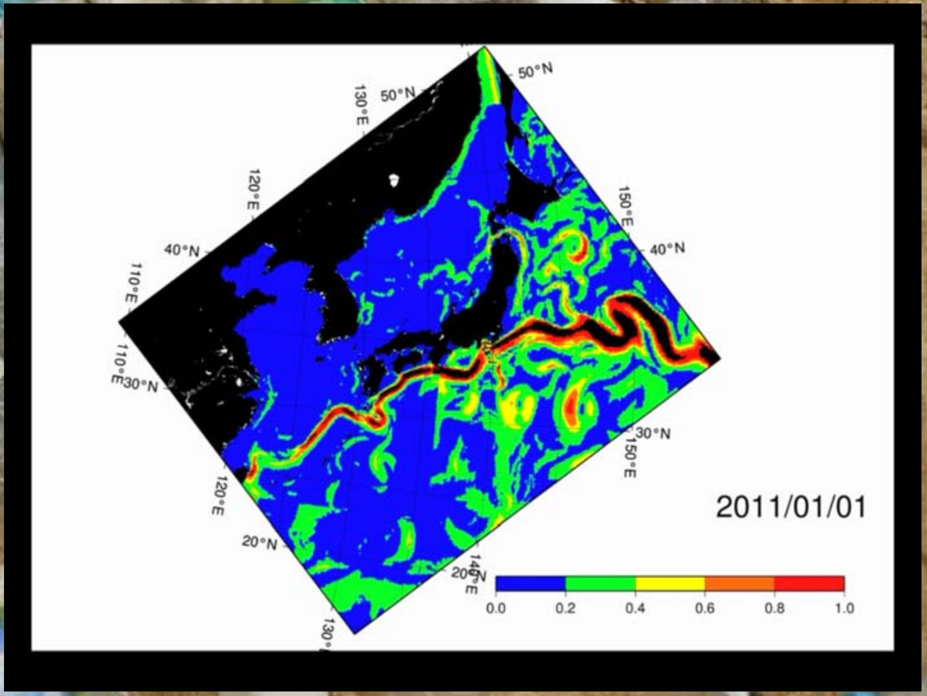
Finding sources of marine debris using webcam data
→ An inverse problem established by Kako et al., (2010, *J.Oceanogr.*)

$$\left(f_1^{M-l},\quad f_2^{M-l},\quad f_3^{M-l}, \ldots\ldots, f_{N-2}^{M}, \quad f_{N-1}^{M}, \quad f_N^{M} \right) \begin{pmatrix} g_1 \\ g_2 \\ g_3 \\ . \\ . \\ g_{N\times(l+1)} \end{pmatrix} = z$$

locations, months, and quantities of debris occurrence







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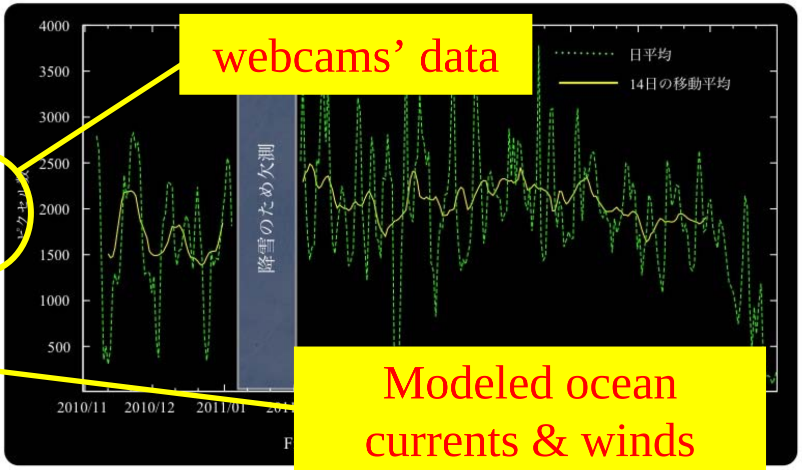
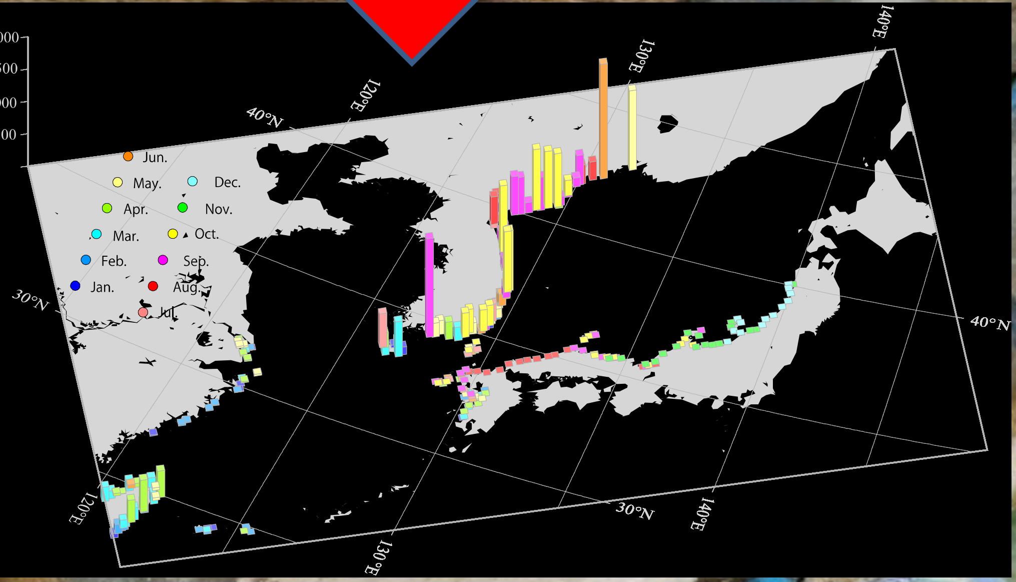
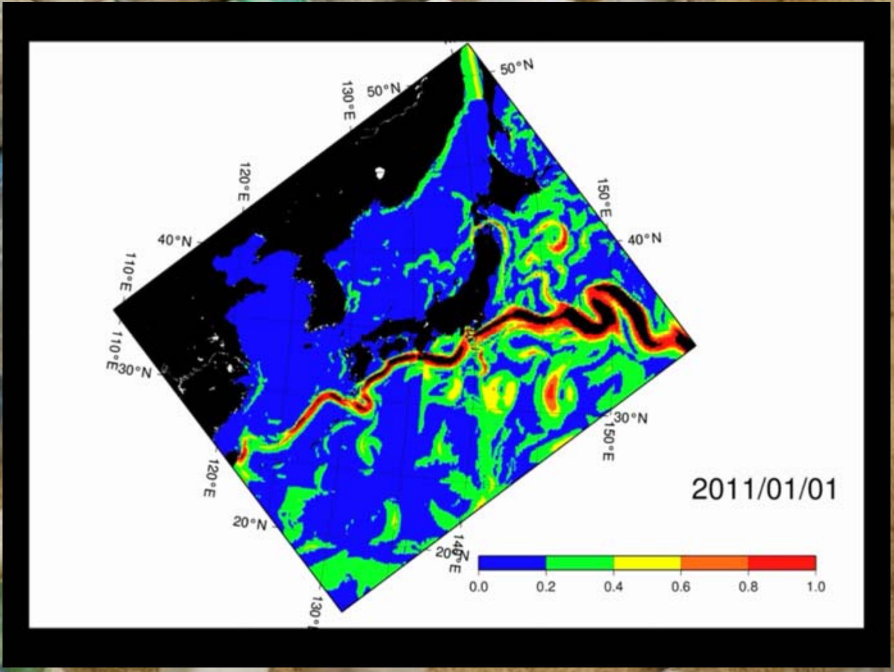
locations, months, and amount of debris occurrence

webcams' data

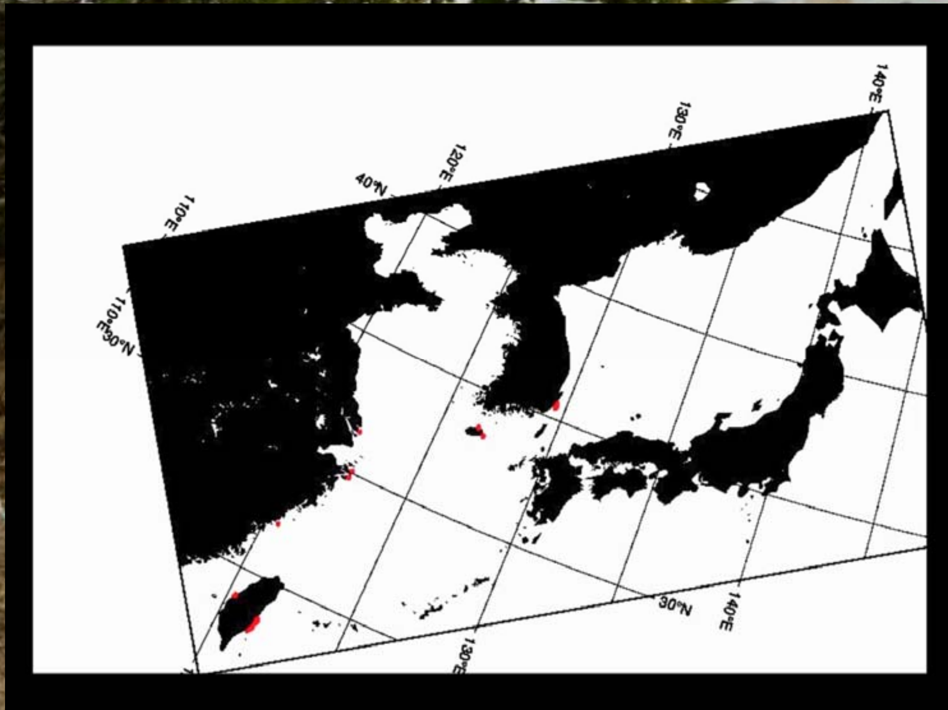
Modeled ocean currents & winds







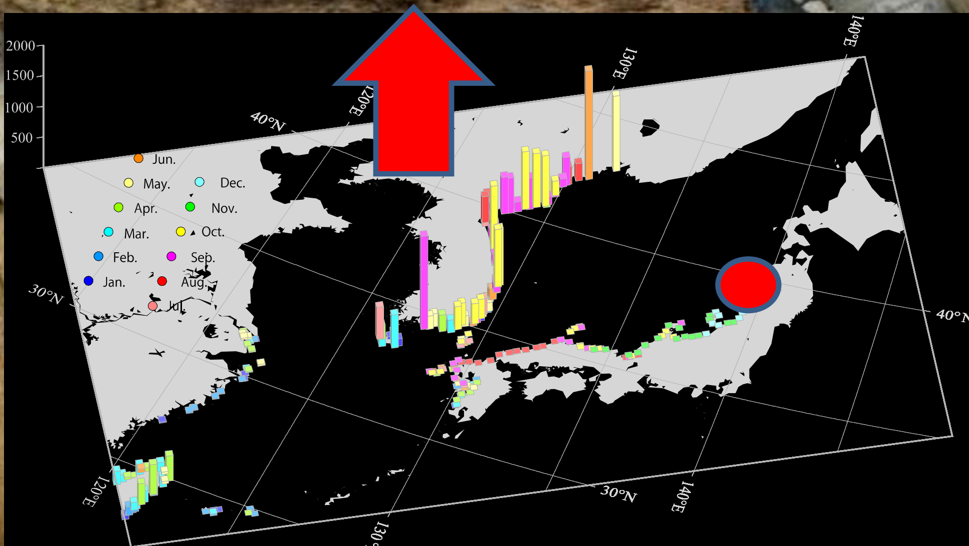
Hindcasting marine debris behavior using numerical models

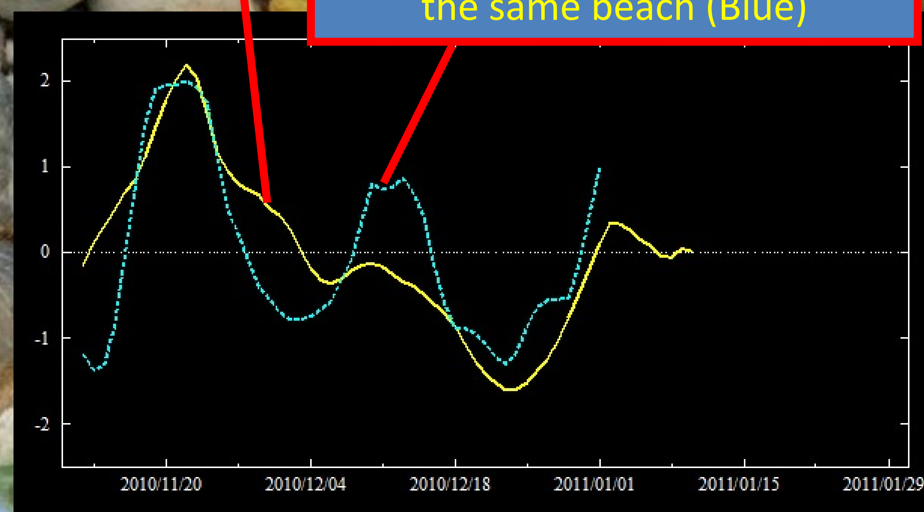


Particle tracking model using the modeled currents with the original directions.

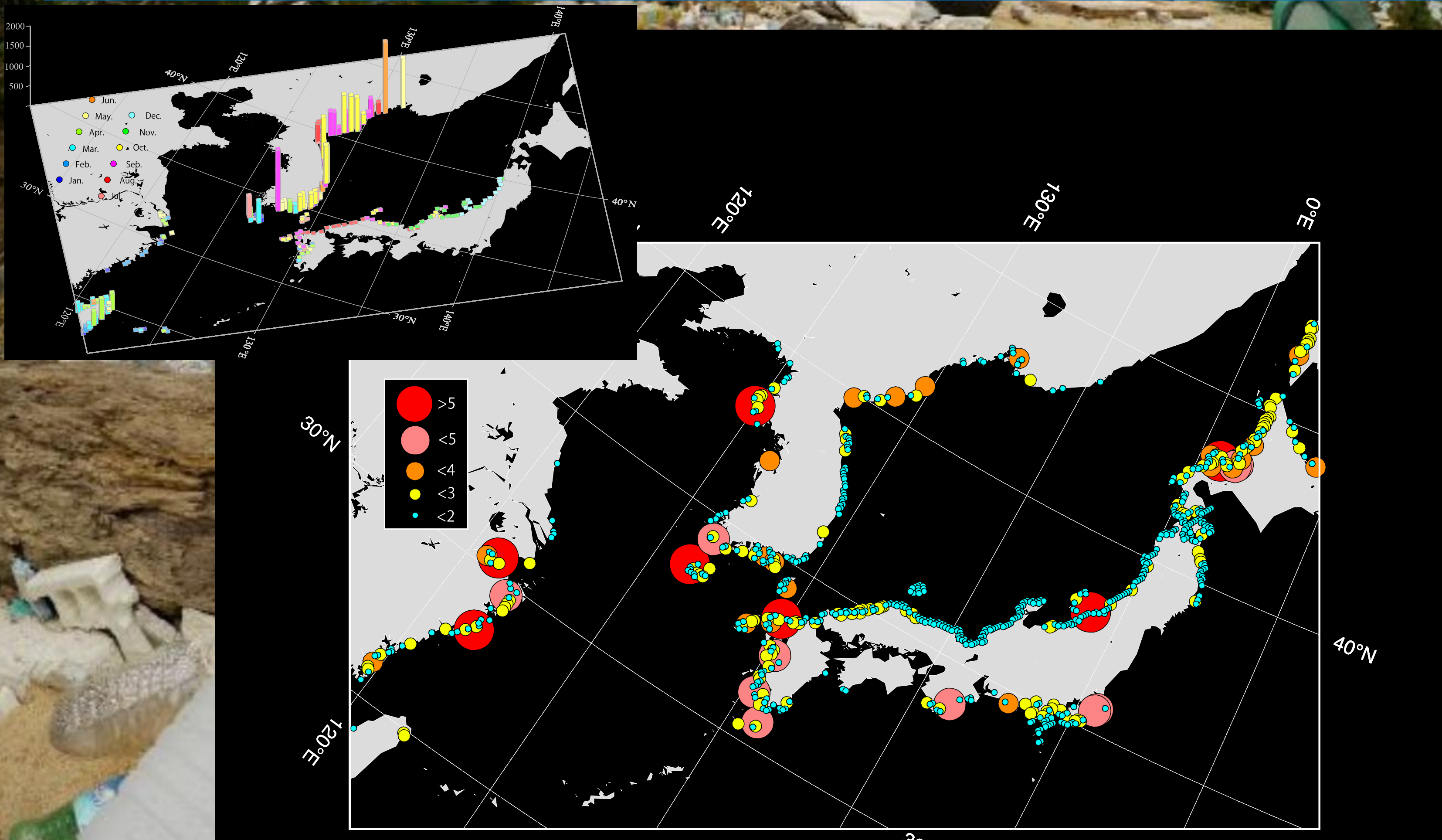
Number of modeled particles reaching on the beach pointed by the red spot (Yellow).

Smoothed time series of areas covered by marine debris monitored using a webcam at the same beach (Blue)





If the quantities of marine debris released at all sources are increased **twofold**, how much the marine debris washed ashore on beaches increase? ~relationships between source & receptor~



On some beaches, the quantities of marine debris washed ashore are increased more than **fivefold** due to a complicated combination between ocean currents and winds

Conclusion

- Part of plastic debris acts as a "transport vector" of toxic metals from their sources to beach environment.

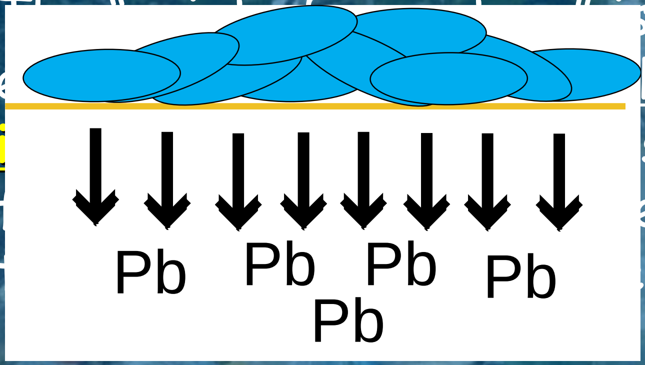
s estimated to ~250 years. However, this

lastic debris washed ashore on beaches

s is likely).

e to our grandkids

to our kids



- Model analyses suggest that these estimates may shorten if plastic debris released at the sources **increases moderately**.