Status and future of radiocesium in the seafloor off Fukushima

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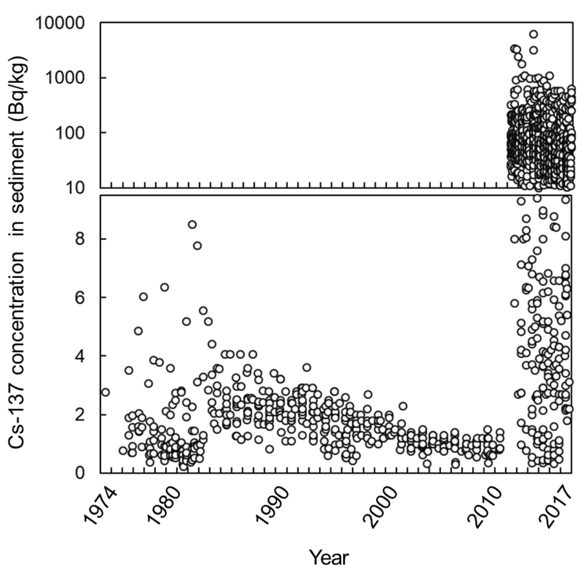
1. Temporal change of ^{137}Cs concentration in surface sediments



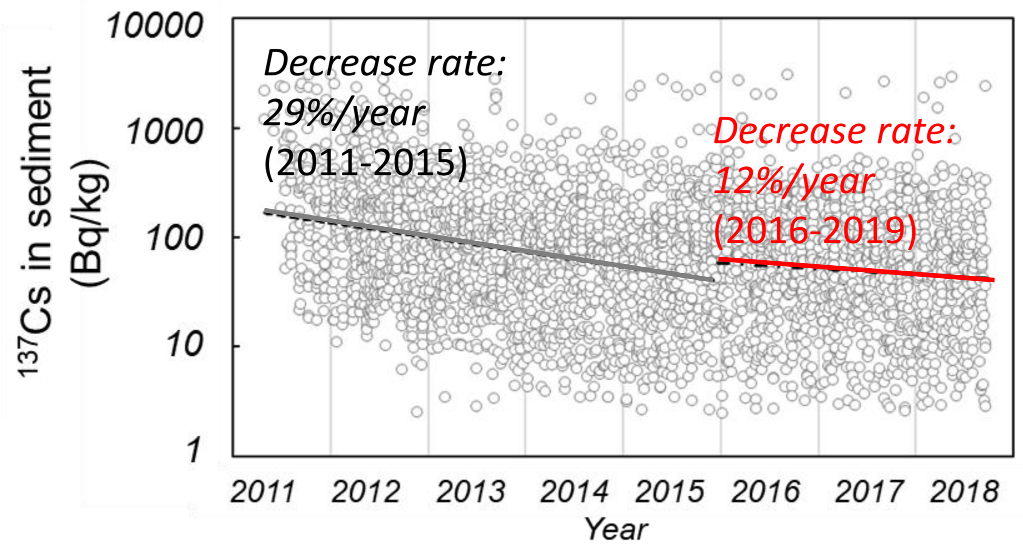
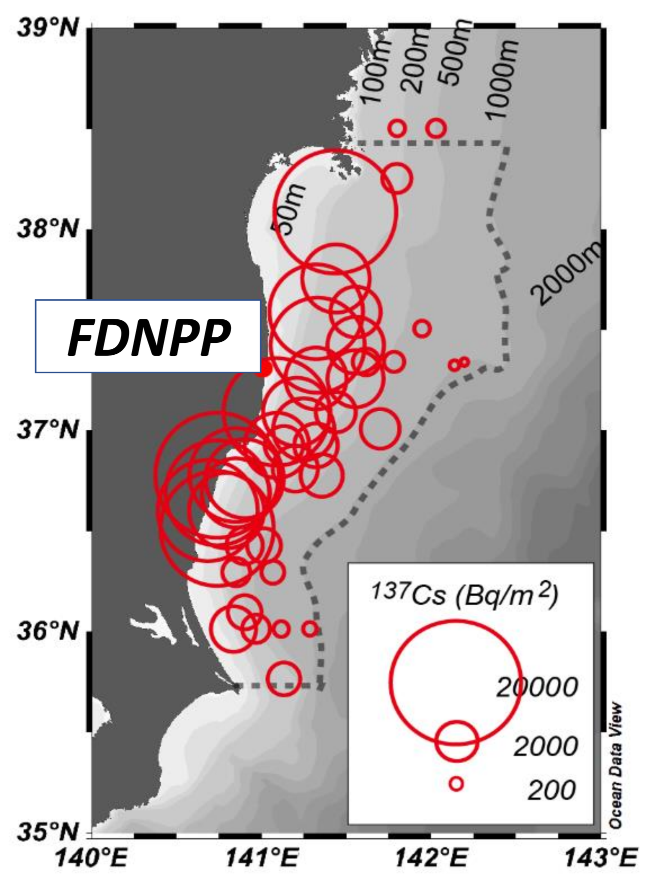


Figure 1 (left). Temporal variation of ^{137}Cs concentrations in surface sediments collected from the Pacific Ocean off Fukushima from 1974 (the year of start of operation of FDNPP) to 2017. Data are from "Database for Environmental radioactivity" by Nuclear Regulation Authority, Japan [1]

Figure 2 (right). Temporal changes in ^{137}Cs activities in surface sediment after March 2011. Data are from TEPCO's monitoring survey [2]. Activities are decay corrected to the sampling date. Dotted and dashed line indicates apparent decreasing rate between 2011-2015 and 2016-2018, respectively.

- **The major ^{137}Cs deposition on the seafloor occurred within six months of the accident.**
- **Concentration of ^{137}Cs in sediment gradually decreases, and the rate of decrease changes with time.**

2. Lateral distribution of ^{137}Cs in sediments



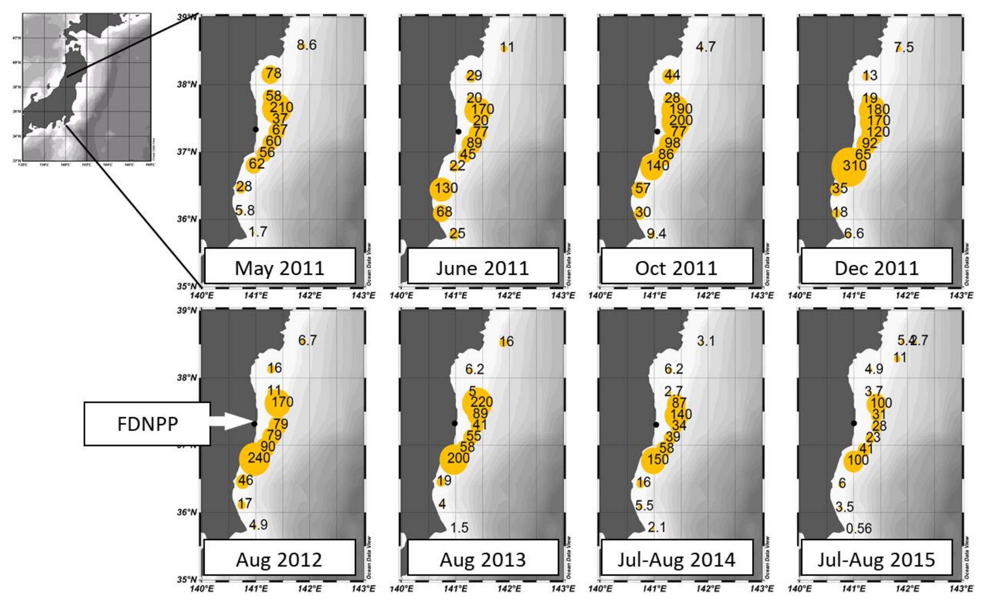


Figure 3 (left). Distribution of sedimentary ^{137}Cs [3] (November 2011: Bq/m^2)

Figure 4 (right). Distribution of ^{137}Cs activity concentration in surface sediment (0-3cm). Data are from National Radiation Authority, Japan [4]

- **About 0.5 to 2% of the ^{137}Cs released to the ocean by the accident (0.20 ± 0.6 PBq) was deposited to the seabed**
- **More than 80% of the sedimentary ^{137}Cs (0.16 ± 0.5 PBq) was accumulated in the coastal (<100m depth) regions**

3. Vertical distribution of ^{137}Cs in sediments

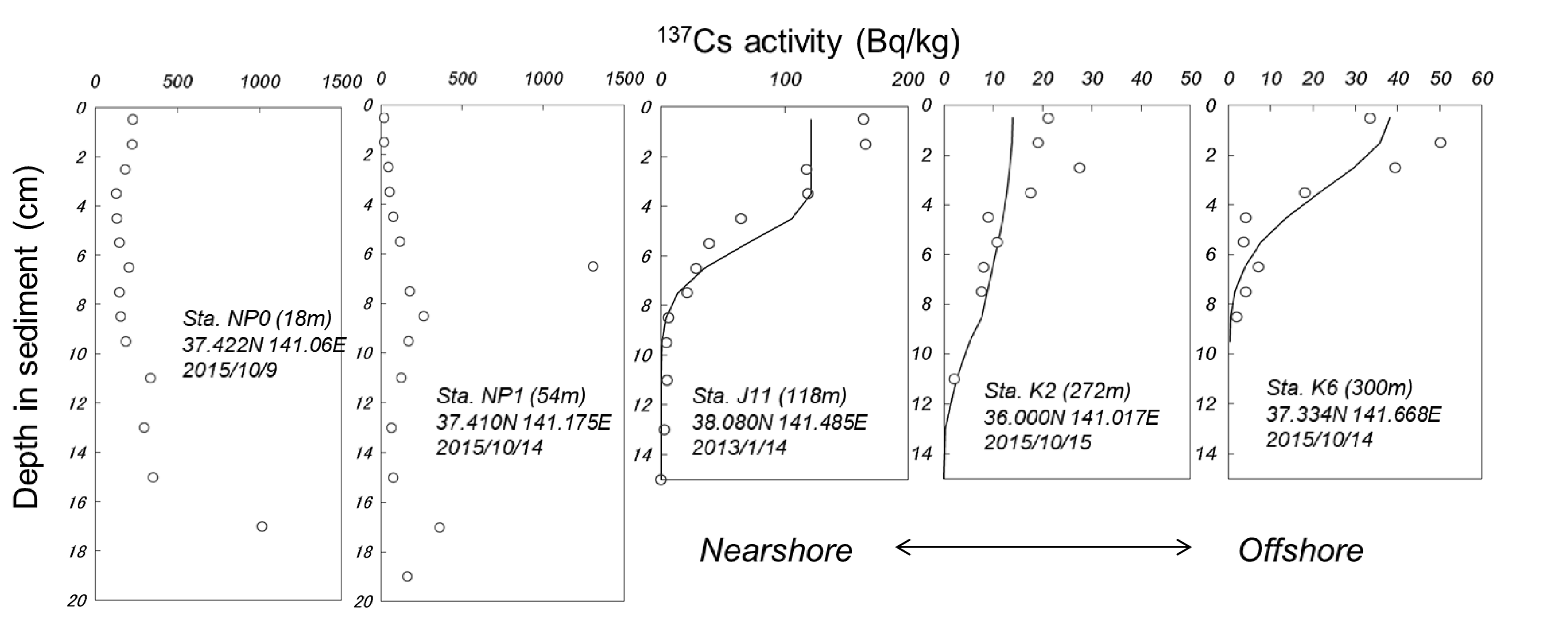


Figure 5 Profiles of ^{137}Cs in sediment five stations off Fukushima. Circle indicate observed data and solid line indicates modelled profile by the 1-D biodiffusion model [5].

- **Especially in the coastal regions, radiocesium is transported to the deep sediments.**

4. Existence form of radiocesium in sediments

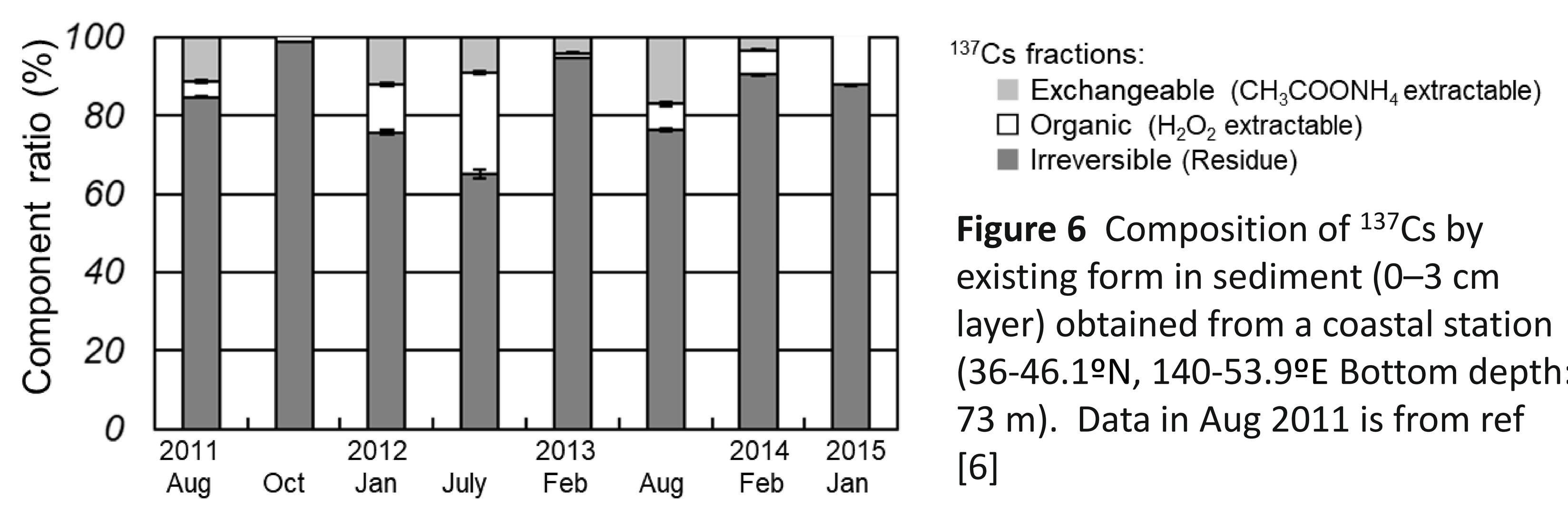


Figure 6 Composition of ^{137}Cs by existing form in sediment (0–3 cm layer) obtained from a coastal station (36-46.1ºN, 140-53.9ºE Bottom depth: 73 m). Data in Aug 2011 is from ref [6]

- **Not all radiocesium in sediments is strongly incorporated into sediment particles and some fractions may be bioavailable.**

5. Distribution of radiocesium in porewater

Figure 7 Multiple corer and sediment cores

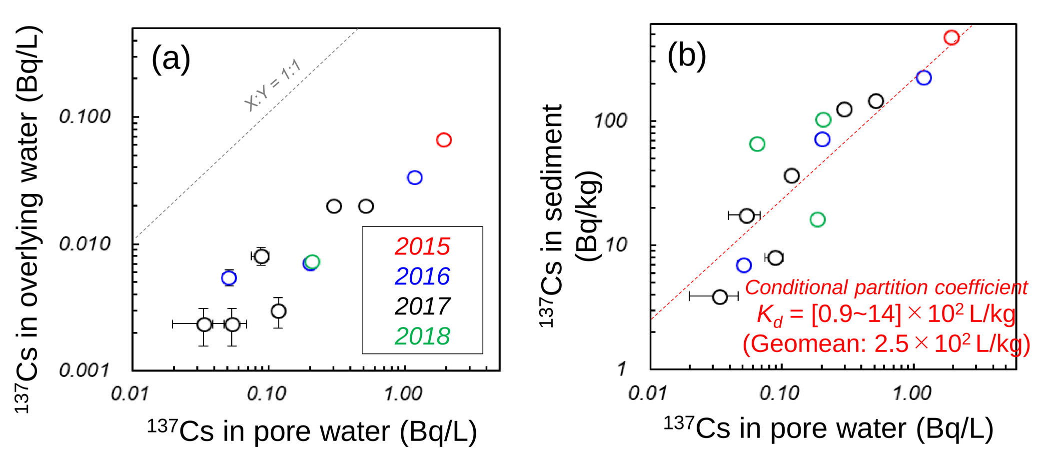


Figure 8 ^{137}Cs in pore water vs (a) overlying water, (b) surface sediment [7]

- **^{137}Cs concentrations in the porewater are 10~30 times higher than in seawater**
- **An equilibrium of ^{137}Cs between sediment and porewater is established**

6. Lateral transport of radiocesium-bound particles near the seafloor

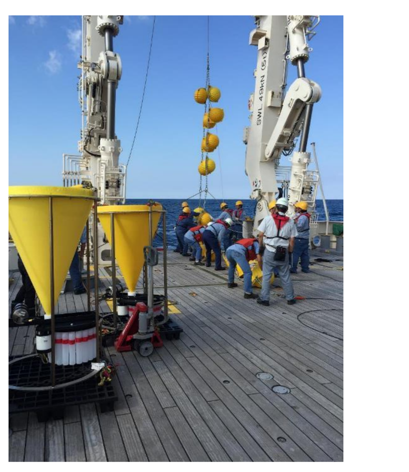


Figure 9 Sediment traps

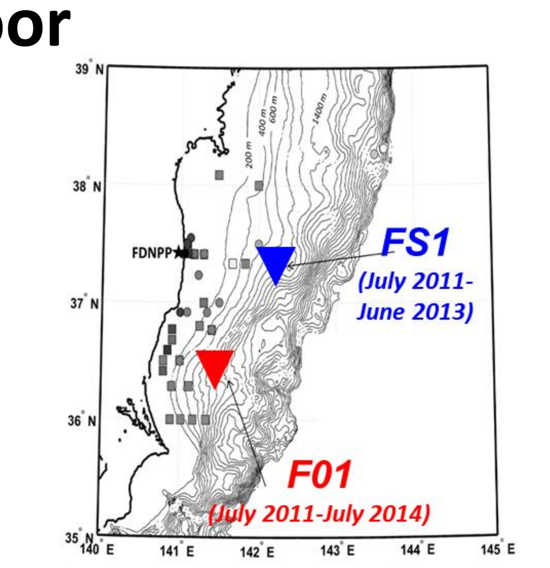


Figure 10 Sampling locations

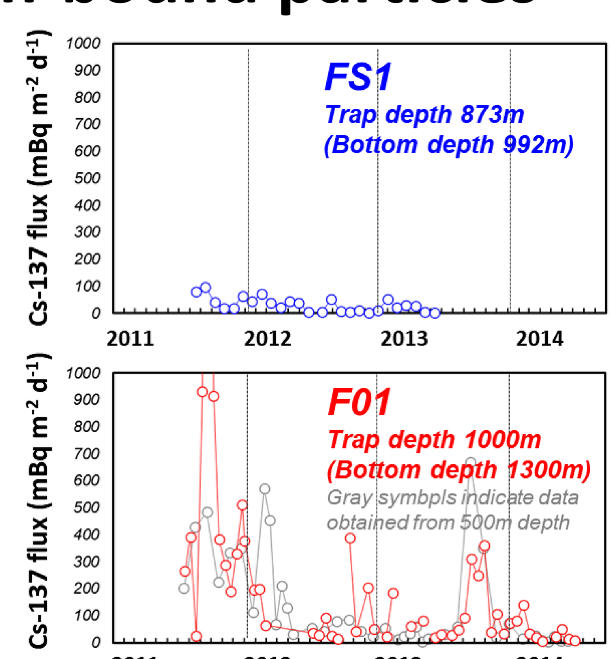


Figure 11 Temporal changes of sinking flux of ^{137}Cs (daily sinking amount of particulate ^{137}Cs per 1m^2) at stations. Data are from refs [8] and [9]

- **Radiocesium-bound particles are moving southward as a whole.**
- **Disturbance of the coastal sediment may also affect the transport.**

Summary: ^{137}Cs budget in coastal sediments off Fukushima

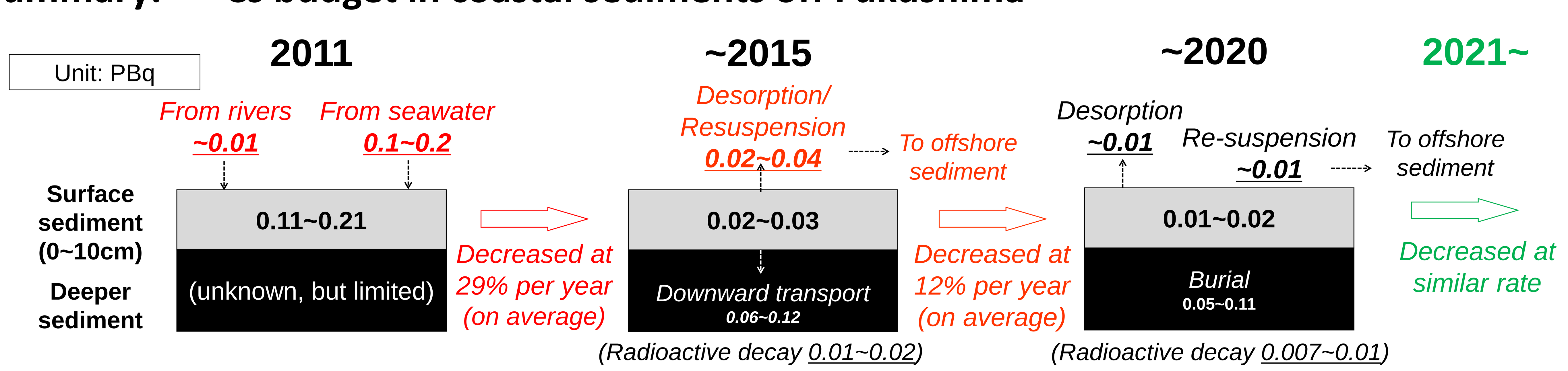


Figure 12 Considerable processes affecting decrease in abundance of radiocesium in the coastal (~100m) region and estimated mass balance of ^{137}Cs (updated with ref [5]).

References

[1] NRA (Nuclear Regulation Authority, Japan), https://search.kankyo-hoshano.go.jp/servlet/search.top [2] NRA http://radioactivity.nsr.go.jp/ja/list/280/list-1.html [3] S. Otosaka and Y. Kato, *Environ Sci Process Impacts,* 16, 978-990 (2014). [4] NRA, http://radioactivity.nsr.go.jp/ [5] S. Otosaka, *J Oceanogr.* 73, 559-570 (2017). [6] S. Otosaka and T. Kobayashi, *Environ Monit Assess*, 185, 5419-5433 (2013). [7] S. Otosaka *et al.*, *Environ Sci Technol*, 54, 13778-13785 (2020). [8] S. Otosaka *et al.*, *Environ Sci Technol*, 48, 12595-12602 (2014). [9] K.O. Buesseler *et al.*, *Environ Sci Technol*, 49, 9807-9816 (2015).

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