ISSUES OF VARIABILITIES THAT MAY NEED TO BE CONSIDERED FOR APPLICABILITY OF PLANETARY BOUNDARY CONCEPT FOR CHEMICAL POLLUTION

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Introduction

Recent proposal of the "planetary boundary"[1] could be an important idea for the discussion of global control of environmental impacts by anthropogenic activities. Now three boundaries on climate change, biodiversity loss and nitrogen cycle already proposed as "safe operating space" by the authors[1], however, the boundary on chemical pollution issues is not yet well discussed. Although the concept is somewhat simple, especially for several established examples in the text, the planetary boundary for chemical pollution is not yet defined. In our understanding the issue of chemical pollution is not a single issue in terms of variety of chemicals, variety of impacts, variety of social context, and variety of time and space of those factors. Pollution phenomena by chemicals could finally be a global system, but the extent how local part of the system be connected to global system could be significantly different from one chemical or impact to any other cases. In this abstract, we present the spatial variability of global contamination of POPs by multimedia fate model and argue the issues variability that need to be considered when we discuss the applicability of planetary boundary concept for chemical pollution based on the information of modeling output.

Materials and methods

To show the spatial distribution of chemicals over globe, we present example of global distribution of PCB congeners in ocean water and corresponding levels in biota, by combining our recent study of multimedia fate model and multi-route bio-transfer scheme. Figure 1 shows the general scheme of multimedia fate model FATE[2]. The model is spatially-resolved global multimedia fate model, in which oceanic transport of chemicals can be simulated in detail. Figure 2 shows the outline of the multi-route bio-transfer scheme. Output data from the FATE model for PCB congeners in sea-water and plankton are used as the input to the scheme to estimate the level of fish from multi-route bio-transfer.

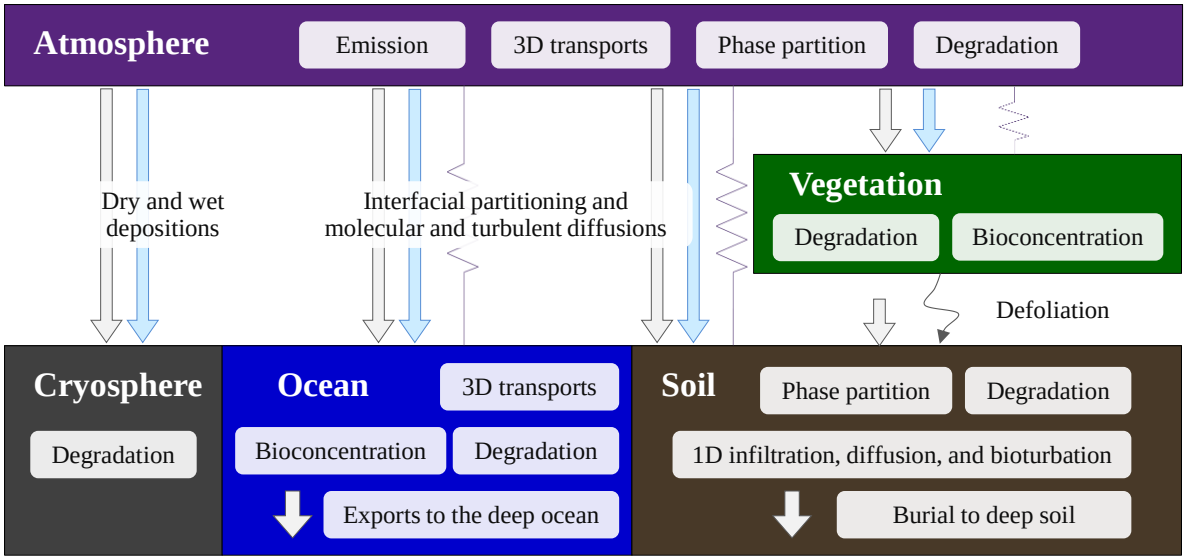

Figure 1. General scheme of the multimedia fate model FATE[2]

Output data from FATE model in surface sea-water concentration in dissolved phase and in plankton in ocean surface layer are used to derive cumulative relative frequency distributions of output levels of PCB congener in fish. Bio-transfer to fish is assumed to occur at the surface layer from the concentrations above. Cumulative statistical distribution is developed for data from each 2.5 by 2.5 degrees cells, which is the horizontal resolution of the model. Input data for bio-transfer model does not necessarily reflect realistic species nor biological condition but reflecting availability of data.

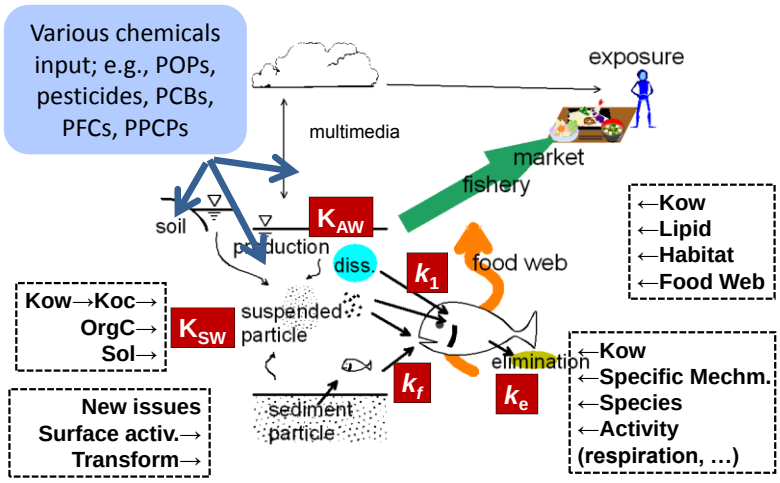

Figure 2. Outline of multi-route bio-transfer scheme

Results and discussion

Figures 3 and 4 show horizontal spatial distribution of simulated fish levels for PCB#52 and #153. Figure 5 shows cumulative relative frequencies of the data shown in Figures 3 and 4. Data plots of Figure 5 show the range of concentration distribution over 5 orders of magnitudes. Although the span of ranges are similar to the results for PCB#52 and #153, spatial distribution of two congeners may be slightly different as shown in Figures 3 and 4. Spatial distribution of PCB#153 seems more homogeneous than PCB#52, as indicated by the relatively homogeneous levels of #153 in the ocean in southern hemisphere, which may be attributed to the higher persistence of the congener #153.

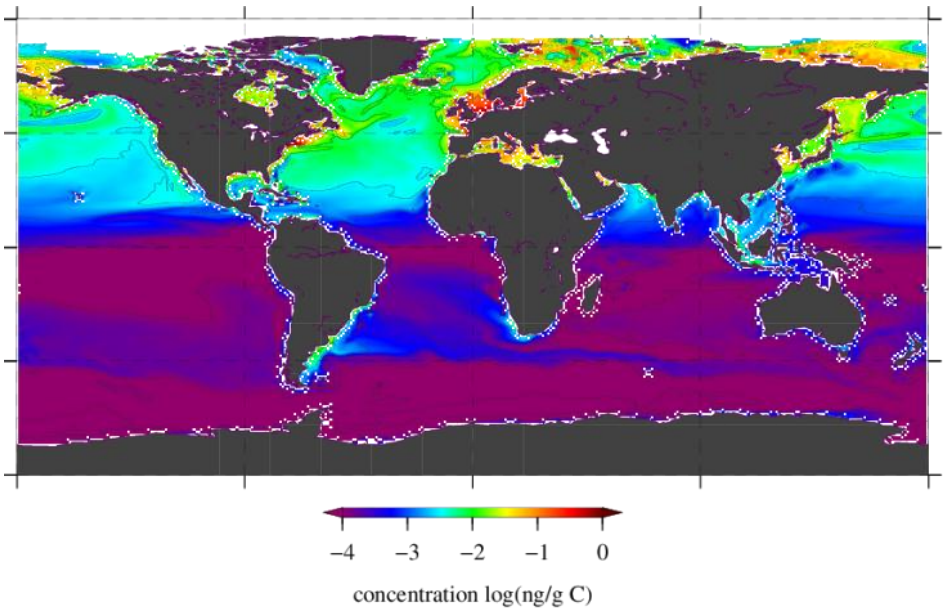

Figure 3. Simulated spatial distribution of PCB#52 in fish

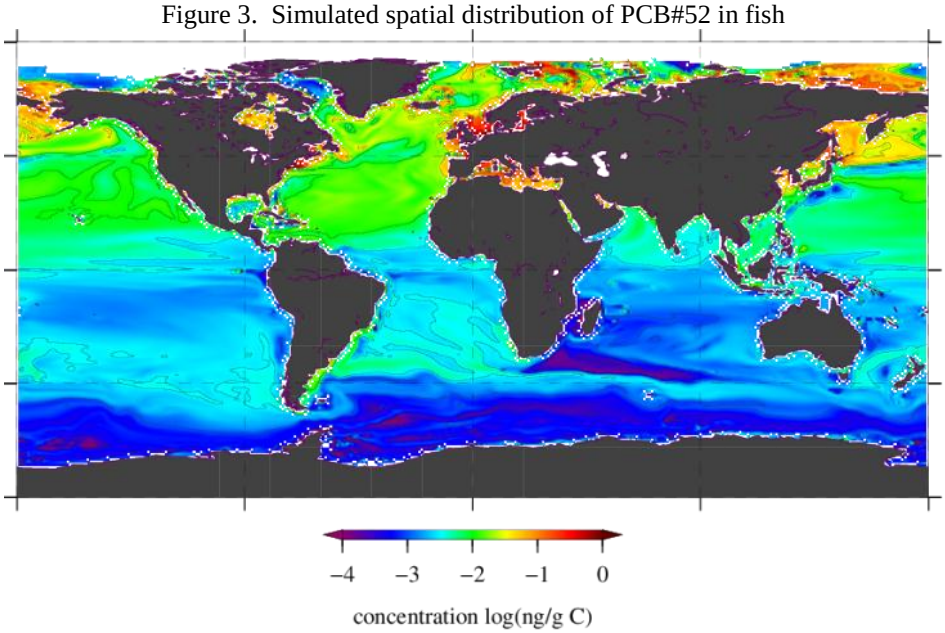

Figure 4. Simulated spatial distribution of PCB#153 in fish

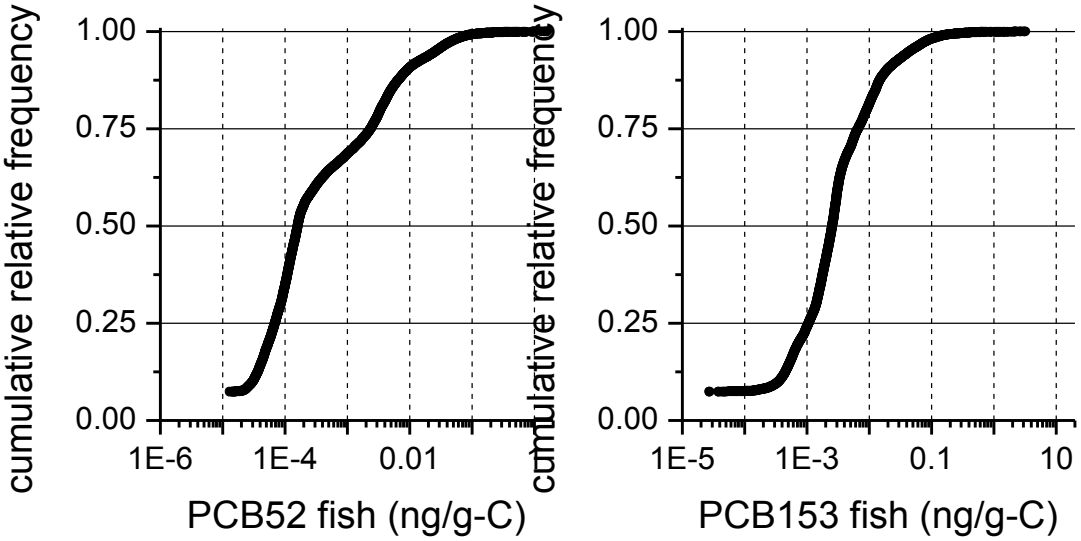

Figure 5. Cumulative relative frequencies of PCB#52 (left) and PCB#153 (right) levels in fish

The results imply a wide range of levels and characteristic spatial distribution for each congener, reflecting emission, fate and biological mechanisms in combination. The wide range of level distribution is also observed in regional scale in our former study[4]. Please note that the results presented here are only to show the possible range and distribution of the levels, and absolute levels could not be discussed further. Validation of the model and the scheme is further necessary to establish absolute levels of PCB congeners.

For the concept of planetary boundaries[1,3], the authors introduced the several terms such as “safe operating zone”, “zone of uncertainty”, “threshold”, “dangerous level” and “planetary boundary”. In their explanation, planetary boundary locates at the border between “safe operating zone” and “zone of uncertainty” or “dangerous zone”. The “threshold” or “dangerous level” exists above the location of planetary boundary, i.e. at the location of more severe damage would be expected. Based on this understanding, where can the variability of the levels of chemical pollution be located in the conceptual definition?

Several different sources of variabilities and/or uncertainties can be discussed for chemical pollution issues, such as:

- Variability of environmental levels of chemicals over globe, which may be in the 5 orders of magnitudes over globe as indicated in this presentation.
- Variety of species of concern, which may result in different type of impact depending on the nature of species in concern
- Variety of toxic responses, which may imply different endpoint of concern or different social context
- Species sensitivity distributions, reflecting the characteristics of species and toxic responses
- Variety of social context, which may different for chemicals but also for cultural background of the society

The “Zone of uncertainty” can be attributed to various different sources of uncertainties or variabilities or both. The discussion implies that issues of chemical pollution is not a single issue, but issues consisting of various different dimensions such as chemicals, impacts, species, social context and probably many others. In that sense, “variability” consideration may need to be discussed in addition to, or in separate from “uncertainty” consideration. Integration of wide-range of variability could be one point of discussion to establish planetary boundary of chemical pollution. To reach such goal, we think that the characterization of threshold may be important. Threshold may be absolute/pseud zero such as precautionary sense, or may be percentiles or related statistical expressions such as 95 percentile in terms of source of variabilities or may be other such as acceptable levels. In any case, more discussions should be necessary on both conceptual and methodological aspects to establish planetary boundary for chemical pollution.

Acknowledgements
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References:

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