EGU General Assembly
04th-8th May 2020

Anthropogenic pollutants and biomarkers for the identification of 2011 Tohoku-oki tsunami deposits (Japan)

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Abstract

Organic geochemistry is commonly used in environmental studies. In tsunami research, however, its application is in its infancy and rarely used. Tsunami deposits may also be able to be characterized by organic-geochemical parameters as tsunami transports not only particulate sedimentary material from marine to terrestrial areas (and vice versa), but also associated organic material. Recently, more attention has been given to the usage of natural organic substances (biomarkers) for tsunami identification. We present results of biomarkers and anthropogenic markers detected in deposits of the 2011 Tohoku-oki tsunami on the Sendai Plain, Japan (Bellanova et al., 2020). As the tsunami inundated the coastal lowland up to 4.85 km inland, sediments from various sources were eroded, transported and deposited across the area. This led to the distribution of biomarkers from different sources across the Sendai Plain creating a unique geochemical signature in the tsunami deposits. The tsunami also caused destruction along the Sendai coastline, leading to the release of large quantities of environmental pollutants (e.g., fossil fuels, tarmac, pesticides, plastics, etc.) that were distributed across the inundated area. Corresponding anthropogenic markers, represented by three main compound groups (polycyclic aromatic hydrocarbons, pesticides, and halogenated compounds), were preserved in tsunami deposits (at least until 2013, prior to land clearing). Organic compounds from the tsunami deposits (Tohoku-oki tsunami) were extracted from tsunami sediment and compared with the organic signature of unaffected pre-tsunami samples using gas chromatography-mass spectrometry (GS/MS) based analyses. Their concentrations differed significantly from the pre- and post-tsunami background contamination levels. Organic proxy concentrations differ also for sandy and muddy tsunami deposits due to various factors (e.g., preservation, dilution, microbial alteration). As tsunami research advanced over the last decades so did the methods used to gain more and more information on the past events. Developing new methods for the identification and characterization of tsunami deposits for recent, historic or paleo events is crucial. Every piece of additional information we gain from event deposits leads us a step further to a better understanding of mechanisms acting during a tsunami. This will help to improve countermeasures and relief efforts. Anthropogenic markers and biomarkers, because of their high source specificity and good preservation potential, have the potential to be a valuable proxy in future studies of tsunami deposits and provide information about sediment sources and transport pathways.

Location

Sendai Plain airport transect
- located in Miyagi prefecture
- 5000 m coastal lowland
- 300 m wide coastal control forest
- coastal dune ridge

Why for organic geochemistry?
- affected by the 2011 Tohoku-oki tsunami
- well-studied by prior studies
- multiple pollution sources
- good preservation potential

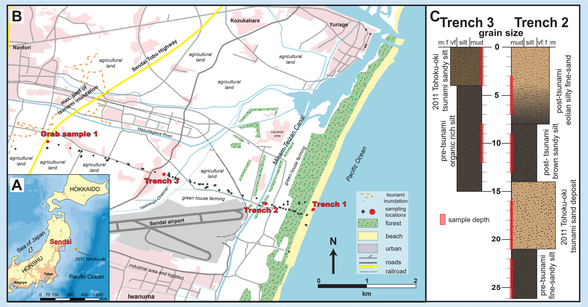
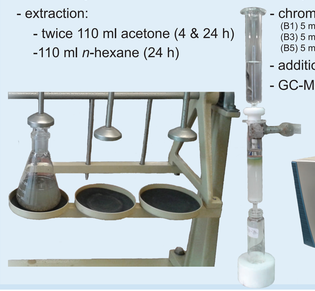
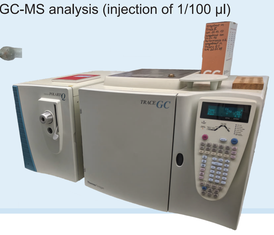


Fig. 1: (A) location of Sendai in Japan; (B) detail of Sendai Airport field site showing the Sendai airport as well as urban, industrial and agricultural areas; black dots = former studies sampling locations; red dots = this study's sampling locations; orange dashed line = tsunami inundation limit; (C) sample depth and grain size

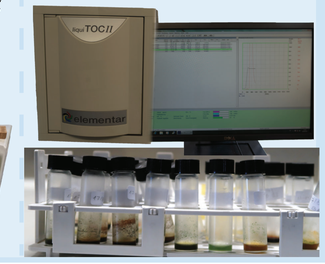
Methods

Extraction
- 10 – 100 g sediment material
- extraction:
  - twice 110 ml acetone (4 & 24 h)
  - 110 ml *n*-hexane (24 h)
- dehydration with anhydrous sodium sulfate
- chromatic fractionation into 6 fractions
  (B1) 5 ml *n*-pentane (*n*-p)
  (B2) 8.5 ml *n*-p/DCM 95/5 v/v
  (B3) 5 ml *n*-p/DCM 90/10 v/v
  (B4) 5 ml *n*-p/DCM 40/60 v/v
  (B5) 5 ml dichloromethane
  (B6) 5 ml methanol
- addition of internal surrogate standard
- GC-MS analysis (injection of 1/100 µl)





Loss of Ignition
- 100 mg grinded & dried sample material
- ignited at 550 °C for 30 minutes



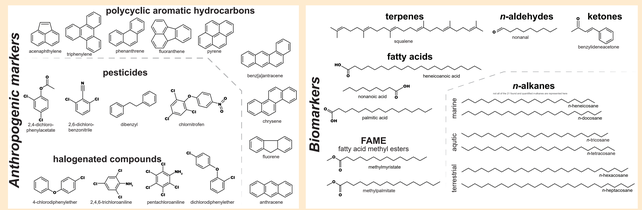


Fig. 2: specific anthropogenic markers, biomarkers, and compound groups analyzed in this study

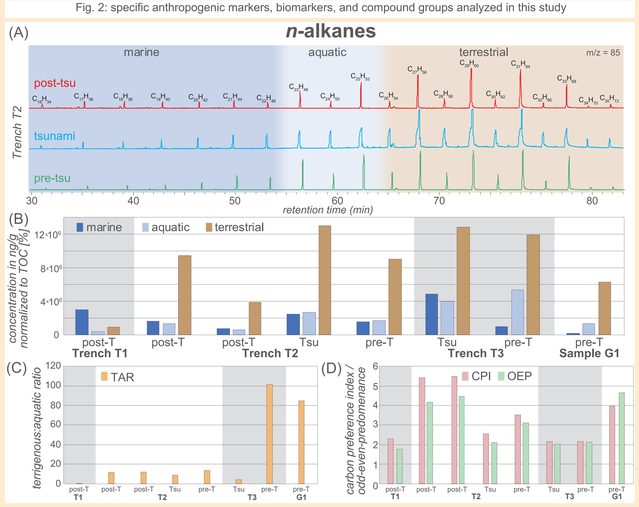


Fig. 3: Overview of *n*-alkane results: (A) representative chromatograms (B) marine, aquatic & terrestrial *n*-alkane concentrations (C) terrigenous:aquatic ratio (TAR); (D) carbon preference index (CPI) and odd-even predominance (OEP)

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Results

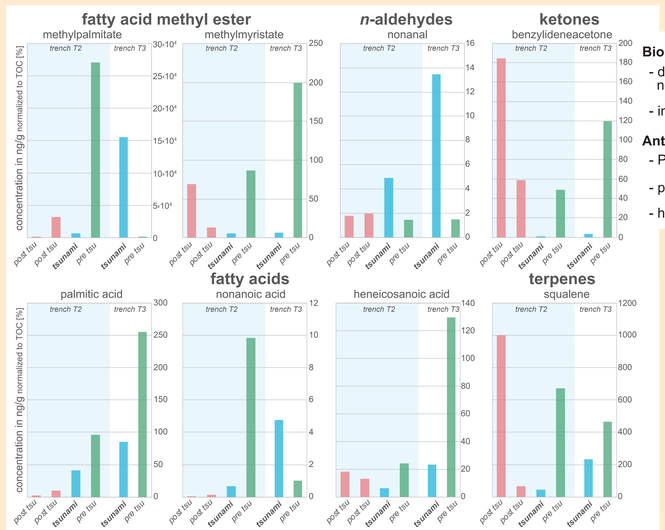


Fig. 4: Concentrations of the five analyzed biomarkers groups in trenches T2 and T3 for tsunami deposits (blue bars) and pre- and post-event sediments (green and red).

Significance of organic geochemical compounds
- *n*-alkanes indicate a stronger marine influence in tsunami deposits
- biomarkers are excellent environmental markers
  ➡ reflect (in part) sediment sources of tsunami deposits
- increased PAHs & pesticides indicate soil erosion and local destruction
  ➡ compounds with high source specificity:
  - chlornitrofen = herbicide used in rice farming
  - 2,6-dichlorobenzonitrile = herbicide used in rice farming
  - PAHs from fossil fuel sources (e.g., destruction & fires)
- good preservation potential
  ➡ no dilution through water
  ➡ persistency & immobility of compounds

Biomarkers
- distinct differentiation between tsunami and non-tsunami deposits
- indication of marine input (e.g., *n*-alkanes)

Anthropogenic markers
- PAHs generally enriched in tsunami deposits
- pesicides indicate variation in the transect
- halogenated compounds enriched in tsunami

click here for the full paper

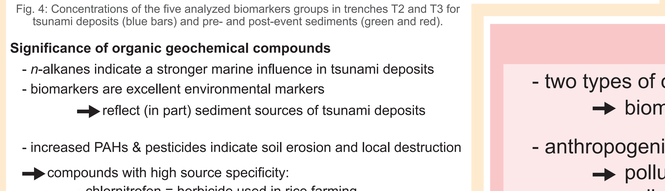


Fig. 5: Delta plots of analyzed anthropogenic markers. Concentrations of pre-tsunami and post-tsunami deposits are plotted relative to the concentrations of tsunami deposit.

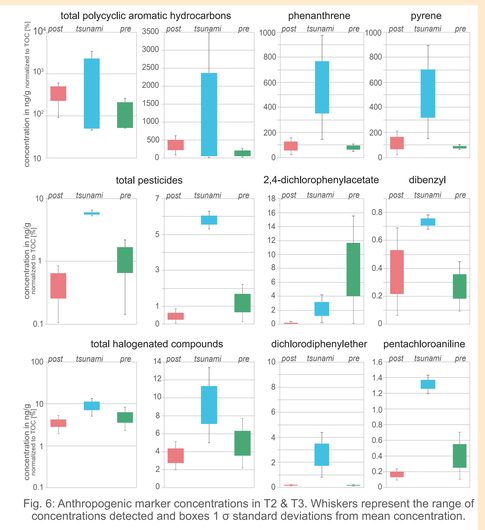


Fig. 6: Anthropogenic marker concentrations in T2 & T3. Whiskers represent the range of concentrations detected and boxes 1 σ standard deviations from mean concentration.

Conclusion

- two types of organic geochemical compounds detectable:
  ➡ biomarker & anthropogenic marker
- anthropogenic marker useful for tsunami characterization
  ➡ pollution sources
  ➡ soil erosion
- ➡ high source specificity of anthropogenic markers
- good preservation potential of organic compounds
- new insights + additional proxy for future tsunami studies

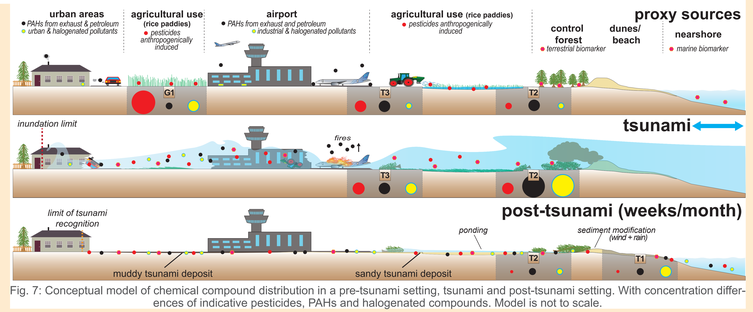


Fig. 7: Conceptual model of chemical compound distribution in a pre-tsunami setting, tsunami and post-tsunami setting. With concentration differences of indicative pesticides, PAHs and halogenated compounds. Model is not to scale.