Ocean turbidity and its effects on marine organisms.

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To understand turbidity.

Why the sea is blue?

Miyakejima Island, Japan
When sun light penetrates into the sea, the light is absorbed and scattered by seawater.
Scattering of water is molecular scattering.

\[ b_w(\lambda); \text{Rayleigh theory is applied on the molecular scattering.} \]

Intensity of Rayleigh scattering

\[ I_\theta = \Pi^2 \eta KT (n^2-1)^2(n^2+2)^2(1+\cos^2\theta) I_0 / 18\lambda^4 \]

That is, \( I_\theta \) is in inverse proportion to \( \lambda^4 \)

\( \Rightarrow \) The shorter the wavelength, the stronger the scattering.

\( \Rightarrow \) Blue light is scattered strongly.

By the absorption and the scattering, we can see ocean is blue.
What is turbidity?

1. Definition

Turbidity of seawater shows the condition that degree of optical clearness of seawater is affected by the existence of dissolved matters and suspended particles.

2. Origin materials of turbidity

Suspended organic matter: phytoplankton, zooplankton, detritus, and so on.

Dissolved organic matter: carbohydrate, saccharide, humic acid, etc.

Suspended inorganic matter: clay particles carried from river and atmosphere, etc.
Optical properties of the materials in seawater.

- **Particulate Organic Matter (POM)**

  POM contributes to scattering and absorption of light. The shorter the wavelength, the larger the diffuse coefficient.

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Diffuse coefficient (m⁻¹)

Wavelength (nm)
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Dissolved Organic Matter (DOM)

DOM contributes absorption only.

The absorption in shorter wavelength is remarkably stronger than longer wavelength.

Light absorption of DOM
(Kalle, 1966)
Particulate Inorganic Matter (PIM)

PIM contributes light scattering only, called Mie scattering.

- Intensity of Mie scattering has no change with wavelength.
- The higher the concentration of particles, the stronger the intensity.
That is · · ·

- In open ocean ⇒ Blue by Rayleigh scattering

- When POM increases ⇒ To longer wavelength

- When DOM increases ⇒ To longer wavelength

“Turbidity of the ocean“ means the materials suspend and/or dissolved in seawater.
How to measure turbidity?

Measurement methods of turbidity are divided into two types. One is an optical method, and the other is a particle analysis method.

In the optical method, there are several devices;
1. beam transmissometer
2. nephelometer, etc.

Today, I introduce a beam transmissometer which is one of the optical methods.
An indicator of turbidity of this method is used a beam attenuation coefficient; $C'(\lambda)$. (Unit: m$^{-1}$)

Turbidity is measured by light diffusion.
Unit of turbidity

- FTU (formazine turbidity unit)
- NTU (nephelometric turbidity unit)
- JTU (Jackson turbidity unit) — not use now.
- ppm (parts per million)
- mg/L
- m⁻¹ (Beam attenuation coefficient)

\[ C' = \frac{1}{r} \cdot \ln \left( \frac{V_{\text{ref}}}{V_{\text{sig}}} \right) \]

where, \( V_{\text{ref}} \) and \( V_{\text{sig}} \): Output voltage of pure water and sample water, respectively.

\( r \): light path length.
How is turbidity of open ocean and coastal sea area?

<table>
<thead>
<tr>
<th>Area</th>
<th>B.A.C.</th>
<th>SS (mg/L)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Kuroshio current</td>
<td>0.11 - 0.12 m(^{-1})</td>
<td>0.3 - 0.4</td>
<td>Matsuike and Morinaga (1977)</td>
</tr>
<tr>
<td>Bearing sea</td>
<td>1.3 - 1.8 m(^{-1})</td>
<td>0.5 - 1.1</td>
<td>Matsuike et al. (1979)</td>
</tr>
<tr>
<td>Persian gulf</td>
<td>0.3 - 1.2 m(^{-1})</td>
<td>0.3 - 0.7</td>
<td>Arakawa et al. (1998)</td>
</tr>
<tr>
<td>Mouth of Tokyo bay (summer)</td>
<td>1.0 - 1.5 m(^{-1})</td>
<td>Ca. 2</td>
<td>Narita et al. (2007)</td>
</tr>
<tr>
<td>Head of Tokyo bay (summer)</td>
<td>3.5 - 5.0 m(^{-1})</td>
<td>Ca.10</td>
<td>Narita et al. (2007)</td>
</tr>
</tbody>
</table>
The most easy measurement of turbidity, Secchi disc depth

- Two types of disc.

Secchi disc

The Whipple Sector Disk, (Whipple, 1933)
The records of Secchi disc depth

- The world record of Secchi disc depth
  Sargasso sea 66.5m
  (measured by a canvas of 2m in diameter)
  Eastern Mediterranean 53m

- The worst in Japan.
  Head of Tokyo Bay 0.3m Jul. 1972

In other sea area:

- Kuroshio current: 30-40m
- Oyashio: 10-15m
- Pacific ocean: 30-40m
- Indian ocean: 30-40m
Influence on marine organisms exerted by turbidity of seawater.

Review

- Scattering & absorption of light
- Shading of phytoplankton & macrophytes
- Inhibition of photosynthesis
- Reduced vision
- Sheding of benthos
- Gill clogging
- Blanketing of benthos
- Reduction of zoospore adhesion
- Inhibition of respiration and particle uptake
- Seaweed
- Clam

The main effects of suspensoids on fish. For explanation, see text. Closed circles: suspensoids, open circles: phytoplankton, open blocks: zooplankton and zoobenthos. The arrows show the extent to which suspensoids cause light to be scattered or absorbed.

(Bruton, 1985)
Influence on seaweed forests.

Communities of large brown algae are termed as marine forests. However, depletion of marine forests, called “Isoyake”, has been observed in many localities in Japan, recently.

Isoyake phenomenon on Touji, Shizuoka pref. in 1975.

Ordinary or recovery feature of marine forest.
Marine forest depletion “Isoyake” on the coast of Japan.

(Yanase, 1981)
Causes of Isoyake.

1. Ecology factors
   (1) Change of inorganic environment
       - Ocean conditions (temperature, nutrition, current, etc.)
       - Briefly impacts (eruption of volcano, mass river water.)
   (2) Impacts by other organisms
       - Grazing pressure by herbivorous animal.

2. Artificial factors
   (1) Poor management
   (2) Effect by turbidity of seawater
       - Lower transparency, suspension, sediment, drifting particle.
   (3) Inflow of artificial materials such as waste water of industry and human activity.  

(Taniguchi, 1998)
Isoyake by turbidity.

- One of common features of “Isoyake” sea areas are that there is an inflow of muddy river water and the seawater has a high turbidity.

- That is to say, the small particles which are suspended in seawater and/or deposited on the sebed may have a causative effect on the depletion of seaweed forests.
Kinds of particle impact to seaweed.

- Influence on brown algae zoospores adhesion on substrate exerted by suspended particles and sediments.

- Influence on survival of gametophyte covered by sediments.

- Influence on survival of zoospore exerted by drifting particles.
1. Influence on brown algae exerted by suspended particle of seawater

Life cycle of 3 species of brown algae
Influence on zoospore exerted by suspended particles.

Adsorption of zoospore (A) and suspended kaolinite particle (B).

Relationship between concentration of suspended particle and adsorption rate of zoospore.
Decrease of zoospore adhesion rate to substrate by turbidity.

Atr = 100 \exp (-0.0339 C), \quad r^2 = 0.799

where Atr: adhesion rate (%),
C : concentration of suspended particles (mg/L).

Relationship between concentration of suspended particles and adhesion rate.
Influence on zoospores exerted by seabed sediment.

Asr = 100 \exp(-1.02 \, Q), \quad r^2 = 0.970

where Asr : adhesion rate (%) on the substrate
Q : quantity of sediment cover (mg/cm²).

Relationship between quantity of sediment and zoospore adhesion rate
Influence on gametophytes exerted by seabed sediment.

\[ Sr = 100 \exp(-0.22 \cdot Q), \quad r^2 = 0.971 \]

Where \( Sr \): survival rate (%) of gametophytes
\( Q \): quantity of sediments (mg/cm\(^2\)).

Relationship between quantity of sediment and survival rate of gametophyte.
Comparison of influence on adhesion rate of zoospores of the three species with quantity of sediment cover.

- *Eisenia bicycl.*
- *Ecklonia cav.*
- *Undaria pinnatifida.*

Comparison of influence on adhesion rate of zoospores of the three species with quantity of sediment cover.
Influences on survival of zoospore exerted by drifting particles.

It is well reported that the production of seaweed, *Laminaria* spp. on the Japan sea coast of Hokkaido is often poor if during the winter season strong effects of heavy wind and wave occur. This phenomenon is considered to be due to the effect of drifting particles in the rapid water currents.

**Experimental apparatus**

**Size distributions of experimental particles.**
Impacts of concentration and size of particles.

Relationship between concentration of particle weight and survival rate of zoospore.
Cause of marine forest depletion Isoyake off Mio, west coast of Kii peninsula, Central Japan.
Annual variations of marine environment on Isoyake sea area.

**Temperature**

**Salinity**

**Secchi depth**

**Precipitation**
Feature of Hidaka-gawa river after precipitation.

August 23, 2001
Precipitation:
August 21; 339mm
22; 37mm
Variation of quantity of sediments.
The rate of total loss (TL (%)) of zoospores and gametophytes of *Eisenia bicyclis* was obtained from the following equation:

\[
TL = 100(1 - \exp(-0.0339C) \exp(-1.24Q)),
\]

where, 
- \( C \) (mg/L) : concentration of suspended particles in seawater
- \( Q \) (mg/cm\(^2\)) : sediment on the substrate.

Concentration of suspended particles: 
14.6 mg/L (Maximum value off Mio)

Sediment on substrate: 
6.7 mg/cm\(^2\) (Mean value off Mio)
Effects on behavior of bivalves.

The bivalve Manila clam, *Ruditapes philippinarum*, were caught in the coastal waters all around Japan. However, the resource of the clam is being decreased year by year.

Annual variation of catch of Manila clam.

(Sasaki, 2001)
Life cycle of Manila clam

- **Egg** (60−70 μm)
- **Trochophore** (100 μm)
- **D shape veliger** (100−130 μm)
- **Pediveliger** (130−180 μm)
- **Full grown veliger** (180−230 μm)
- **Benthic larva** (200−300 μm)
- **Benthic**
- **adult** (over 25mm)
- **growth** (8−12 months)
- **Planktonic stage** (2-3 weeks)
- **Release**
Veliger absolved suspended particles

In filtered seawater

In seawater suspended particles
Influence on veliger larva of manila clam by suspended particles

- Filtered seawater
- 10mg/L
- 30mg/L
- 50mg/L
- Filtered seawater (No food)

![Graph showing the effect of different concentrations of suspended particles on veliger larva growth.](image-url)
Influence on fine particle in seabed sediment

Manila clam

Particles for seabed (glass Bead or kaolinite)
Effect of fine particle in bottom material on submerged sand behavior.

Relation between particle size of bottom and clam number submerged.

0.006 mm: kaolinite, 0.037-7.8 mm: glass bead
Effect of fine particle on submerged sand action.

Relation between percentage of kaolinite content and individual number submerged.

![Bar chart showing the relation between percentage of kaolinite content and individual number submerged](image-url)
Conclusion

1. Turbidity is one of an important environmental factors in the ocean.

2. Turbidity gave a grave Impact on marine organisms.

We need to observe turbidity of the ocean in long term at good accuracy.

Thank you for your attention!!!