Phaeocystis globosa: a giant colonial harmful species in the WESTPAC waters

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Giant colony of *Phaeocystis globosa*

*P. globosa* giant colony have been reported in the coastal waters of China since 1997 (Lu and Huang, 1999; Qi et al., 2004), Vietnam since 2002 (Doan et al., 2008; Tang et al., 2004), and the Arabian Sea (Madhupratap et al., 2000).
Outline

- Taxonomy and life cycle
- Distribution
- *Phaeocystis globosa* blooms in China
- The effects of *Phaeocystis* blooms
- *Phaeocystis* and its potential risk to nuclear power plant
Six recognized species

Colony-forming species:
- *P. antarctica* Karsten
- *P. puchetii* (Hariot) Lagerheim
- *P. globosa* Scherffel
- *P. jahnii* Zingone

Non-colony forming:
- *P. cordata* Zingone et Chretiennot-Dinet
- *P. scrobiculata* Moestrup
- *P. rex* Andersen, Bailey, Decelle & Probert sp. nov

number of species in the genus is still underestimated.
Maximum-likelihood phylogeny of 17 *Phaeocystis* species/strains and other prymnesiophytes referred from 18S rDNA (Lange et al. 2002)
**Phaeocystis globosa**

1. Polymorphic life cycle
2. Alternating free-living cells (3-9 μm in diameter) and gelatinous colonies (100 μm - 3 cm)
3. Accumulations of mucilaginous foam at the sea surface and on the beaches (Rousseau et al., 1994; Chen et al., 2002)
4. Haemolytic substance (He et al. 1999)
Transitions of *Phaeocystis globosa* life cycle stages
The haploid-diploid life cycle of *P. globosa*. The haploid flagellates are characterized by stars, filaments, scales and have a size in the range 3.6-5.8 μm when live. Colonial cells, in the size range 5.8-10.4 μm when live, present two short appendages on their apical side, are deprived (Rousseau et al. 2007).
Conceptual model of development of diatom and flagellate blooms (Phaeocystis globosa and Noctiluca scintillans) in Binh Thuan Province, Viet Nam, during the SW monsoon season. Notes: Dashed circle/irregular shapes — Phaeocystis globosa at different stages of life cycle; Noc—Noctiluca scintillans; T — temperature; DO — dissolved oxygen; + and −indicate tendencies toward higher and lower concentrations (Hai et al. 2010)
Different morphotypes reported for the 6 Phaeocystis species
(Rousseau et al. 2007)

<table>
<thead>
<tr>
<th></th>
<th>Flagellates with scales, threads and stars</th>
<th>Flagellates with scales</th>
<th>Flagellates without scales, threads and stars Same size range as colonial cells</th>
<th>Colonial cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>P. globosa</td>
<td>X (n)</td>
<td>X (n)</td>
<td>X (2n)</td>
<td>X (2n)</td>
</tr>
<tr>
<td>P. pouchetii</td>
<td>X (2n)</td>
<td>–</td>
<td>X</td>
<td>X(2n)</td>
</tr>
<tr>
<td>P. antarctica</td>
<td>X</td>
<td>–</td>
<td>X</td>
<td>X(2n)</td>
</tr>
<tr>
<td>P. jahnii</td>
<td>–</td>
<td>X</td>
<td>–</td>
<td>X</td>
</tr>
<tr>
<td>P. cordata</td>
<td>X (n)</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>P. scrobiculata</td>
<td>X</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
</tbody>
</table>
Factors involved in the transition from free-living cell to colonial stage in *P. globosa* (Rousseau et al. 2007)

<table>
<thead>
<tr>
<th>References</th>
<th>Factors investigated</th>
<th>Exp. cond.</th>
<th>Free-living cell origin</th>
<th>Terms used and available cell characterization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kornmann (1955)</td>
<td>Light</td>
<td>C</td>
<td>Natural seawater</td>
<td>Flagellates</td>
</tr>
<tr>
<td>Kayser (1970)</td>
<td>Solid substrate</td>
<td>C</td>
<td>Colonial cells released from colony disruption</td>
<td>Non-motile free-living cells</td>
</tr>
<tr>
<td>Boalch (1987)</td>
<td>Solid substrate</td>
<td>F</td>
<td>Natural pre-bloom populations</td>
<td>Motile stage, biflagellated cells</td>
</tr>
<tr>
<td></td>
<td>Diatom exudate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Veldhuis and Admiraal (1987)</td>
<td>Phosphate</td>
<td>C</td>
<td>Fractionation (&lt;20 µm) of a culture (colony + cells)</td>
<td>Single cells</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Free-living motile cells (7 µm diameter)</td>
</tr>
<tr>
<td>Peperzak (1993)</td>
<td>Light</td>
<td>C</td>
<td>Fractionation (&lt;20 µm) of culture (colony + cells) Clone Ph91</td>
<td>&gt;100 W h m⁻² day⁻¹: mesoflagellates (4.1 µm) &lt; 100 W h m⁻² day⁻¹: microflagellates (3.1 µm)</td>
</tr>
<tr>
<td>Rousseau et al. (1994)</td>
<td>Solid substrate</td>
<td>C</td>
<td>Colonial cells released from colony disruption</td>
<td>Free-living cells</td>
</tr>
<tr>
<td>Cariou et al. (1994)</td>
<td>Phosphate Solid substrate</td>
<td>C</td>
<td>Colonial cells released from colony disruption</td>
<td>Non flagellated, flagellated cells, diploid cells</td>
</tr>
<tr>
<td>Schapira (2005)</td>
<td>Turbulence</td>
<td>C</td>
<td>Fractionation (&lt;5 µm) of culture (colony + cells)</td>
<td>Flagellated and non-flagellated cells</td>
</tr>
</tbody>
</table>

Experimental conditions are reported as C: cultures; F: field; M: mesocosms

Only one field study!
Enhancement of colony size in the grazing treatment was evident after 5 to 8 d. Grazing by *N. scintillans* increased the mean colony size by up to 50% relative to the controls, (Jakobsen and Tang, 2002)
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- Taxonomy and life cycle
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  - *Phaeocystis* and its potential risk to nuclear power plant
Global Distribution of the genus *Phaeocystis*

Geographical distribution of the genus *Phaeocystis*. *P. pouchetii* is indicated by dark blue triangles, *P. globosa* by green triangles, *P. antarctica* by light blue squares, *P. scrobiculata* by a yellow triangle, *P. jahnii* and *P. cordata*, which have the same location, by an orange circle. The unidentified or unclear species of *Phaeocystis* are represented by pink circles. (Schoemann et al. 2005)
Phaeocystis SPP.

Phaeocystis blooms
Global distribution of *Phaeocystis globosa*

*(redraw from Schoemann et. Al. 2005)*
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From SCS to Bohai Sea
From China to Asia

The first bloom in 1997, causing 7 million USD economic losses of Mariculture.
Phaeocystis globosa

Single cell motile stage

Colony

First recorded in Guangdong Province in 1997
Molecular phylogeny referred from 18S rDNA of Chinese Strain of *Phaeocystis globosa* (Chen. 2002)
Haemolytic substance from *Phaeocystis globosa*

The structure of haemolytic toxin from *Phaeocystis globosa* Scherffel (He et al. 1999)

Isolation of haemolytic substance from a strain of *P. globosa* during bloom, which was similar with the structure of digitonin, a non-conventional non-ionic surfactant.
Samping stations in Gulf of Beibu in 2016
Colony collection

Molecular probe application

Field Sampling and Observation of the *Phaeocystis globosa*
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1. Fish Kills

Fish kills have been reported in China (Lu and Huang 1999, Qi et al. 2004), a bloom caused mortality of cultured fish making a loss of 75 million RMB (ca. 12 million USD) in 1997, and Viet Nam (Doan et al., 2003; Nguyen et al., 2012). In July 2002, about 90% of animal and plant species in tidal reefs of Phan Ri Bay were destroyed by a bloom, causing a loss of over VND10 billion (ca. $US 650,000).
Mussel mortalities were discovered in the western part of the Oosterschelde on May 10, 2001.

A 10 million kg mussel mortality occurred in spring 2001 in SW Netherlands during a *Phaeocystis* bloom. Salinity data reveal that the bloom was transported towards the mussels due to a change in wind direction, most likely followed by sedimentation and anoxia.

(Peperzak & Poelman, 2008)

2. Mussel Mortalities
3. Impact on intertidal benthic compartment

( Spilmont et. al. 2009)

Synthesis of the effects of the *Pheocystis* bloom on the physical and/or biological environment with their consequences on the benthic communities from the different shore types studied

<table>
<thead>
<tr>
<th>Bloom stage</th>
<th>Early stage</th>
<th>Late stage</th>
<th>Estuarine sediments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shore type</td>
<td>Rocky shore</td>
<td>Sandy shore</td>
<td>Sandy shore</td>
</tr>
<tr>
<td><em>Pheocystis</em> effect on the physical and/or biological environment</td>
<td>Decrease in the light penetration and $NH_4^+$ availability in the water column</td>
<td>Active cells deposits in calm conditions</td>
<td>Settlement of foam including active phytoplanktonic cells and bacteria</td>
</tr>
<tr>
<td>Consequences on the benthic communities composition/functioning</td>
<td>Low primary production and low growth rate for underlying macroalgae</td>
<td>Increase in the sediment primary production</td>
<td>Increasing community primary production and respiration, $NH_4^+$ release</td>
</tr>
<tr>
<td>Recovery after the bloom</td>
<td>Rapid</td>
<td>Rapid</td>
<td>Rapid dramatic decrease in the species richness and density Macrofauna directly accessible to shorebirds.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Energy flow modification</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Slow</td>
</tr>
</tbody>
</table>

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4. Clogging of Cooling System of Power Plant
Conceptual model illustrating the current view of the biogeochemical cycle of DMSP and DMS in seawater and the atmosphere (Kiene et al., 2000)
DMS results in cooling of the earth’s atmosphere & thereby reduce the effects of greenhouse gases such as CO₂. Most prolific and one of only two phytoplankton producer of dimethyl sulfide (DMS).

Wang et al., 2010
DMS and DMSP contents during *Phaeocystis globosa* bloom in Bohai Sea (Yang et al. 2006)

<table>
<thead>
<tr>
<th>No. of Samples</th>
<th>DMS</th>
<th>DMSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>55.10</td>
<td>--</td>
</tr>
<tr>
<td>2</td>
<td>37.84</td>
<td>442.72</td>
</tr>
<tr>
<td>3</td>
<td>34.77</td>
<td>471.15</td>
</tr>
<tr>
<td>4</td>
<td>50.54</td>
<td>394.59</td>
</tr>
<tr>
<td>5</td>
<td>34.33</td>
<td>354.86</td>
</tr>
<tr>
<td>6</td>
<td>59.16</td>
<td>453.30</td>
</tr>
</tbody>
</table>
Outline

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- Colony formation and regulation
Physiological adaptations that allow the cells to minimize respiratory losses and modify carbon partitioning would facilitate the quick formation of large colonies and dense blooms. Growth slows down, and eventually ceases, in old and large colonies due to the fact that photosynthetic carbon is insufficient to maintain the integrity of colonial mucoid envelope.

Generation time of giant colonies (growth from a colony of 0.2 cm to its maximal size of 1.4 cm) predicted from model sensitivity analyses.

Relationship between amount of POC per unit colony surface and colony size for the giant *P. globosa* colonies.

(Liu, et al. 2015)
Surface current field for SW monsoon in Southern Vietnam
(Dippner, Lam et. Al. 2011)
Relationship between total and mucous POC concentration per unit area of colony surface and colony size

(Smith, et al. 2014. Giantism and its role in the harmful algal bloom species *Phaeocystis globosa*)
Light:Dark Cycle

Fig. 1. The growth rates of *P. globosa* solitary (solid bars) and colonial cells (open bars) in different light:dark cycle regimes.

Fig. 2. The percentage of colonial cells relative to the number of total cells in different light:dark cycle regimes.

(Wang et al. 2014)
Unique Characteristics of giant *Phaeocystis* colonies

1. Exceptionally large up to 3 cm in diameter
2. Physical clogging of civil and industrial facilities
3. Toxicity of haemolytic activity to make fish kills
4. Mucilage production to make foams
5. DMS production

Ecological Significance
Future works

1. Such giant phytoplankton are extremely unusual in marine systems. How does the giant colony survive and proliferate in a turbulent marine environment.

2. *In situ* life cycle from a single cell to a giant colony.

3. The triggering factors for colony formation. The factors regulating synthesis rates of the extracellular polysaccharides composing the *Phaeocystis* colony matrix.

4. Why does the giant colony only frequently bloom in China and Viet Nam? The possibility to expand to other WESTPAC neighbor countries.