

Specific Absorption Coefficients for the Chlorophyll and Suspended Sediment in the Yellow and Mediterranean Sea

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황해와 지중해에서의 클로로필 및 부유입자의 비흡광계수 연구

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Abstract

Light absorption coefficient per unit mass of particles, i.e., specific absorption coefficient, is important as one of the main parameters in developing algorithms for ocean color remote sensing. Specific absorption coefficient of chlorophyll (a_{ph}^*) and suspended sediment (a_{ss}^*) were analyzed with a spectrophotometer using the "wet filter technique" and "Kishino method" for the seawater collected in the Yellow and Mediterranean Sea. An improved data-recovery method for the filter technique was also developed using spectrum slopes. This method recovered the baselines of spectrum that were often altered in the original methods. High $a_{ph}^*(\lambda)$ values in the oligotrophic Mediterranean Sea and low values in the Yellow Sea were observed, ranging 0.01 to 0.12 m^2/mg at the chlorophyll maximum absorption wavelength of 440 nm. The empirical relationship between $a_{ph}^*(440nm)$ and chlorophyll concentrations ($\langle chl \rangle$) was found to fit a power function ($a_{ph}^* = 0.039 \langle chl \rangle^{-0.369}$), which was similar to Bricaud *et al.* (1995). Absorption specific coefficients for suspended sediment (a_{ss}^*) did not show any relationship with concentrations of suspended sediment. However, an average value of a_{ss}^* ranging 0.005 - 0.08 m^2/g at 440nm, was comparable to the specific absorption coefficient of soil (loess) measured by Ahn (1990). The morepronounced variability of a_{ss}^* than a_{ph}^* was determined from the variable mixing ratio values between particulate organic matter and mineral. It can also be explained by a wide size-distribution

range for SS which were determined by their specific gravity, bottom state, depth and agitation of water mass by wind in the sea surface.

* Keywords : light absorption , chlorophyll & suspended sediment, remote sensing.

요 약

해수 중에서 클로로필을 포함하는 식물성플랑크톤 미생물 입자와 그 외 모든 부유입자의 단위 질량 당 광 흡수계수의 크기, 즉 "비흡광계수"는 ocean color 원격탐사 기술개발에서 가장 중요한 요소 중의 하나이다. 분석방법으로는 spectrophotometer를 사용한 "젖은 필터법"과 "Kishino법"을 사용하였다. 황해에서는 직접 광학적 관측으로, 지중해에서는 과거의 databank를 활용하여 클로로필(ph)과 부유침전물(ss)의 "비흡광수계수" (a^*_{ph} 및 a^*_{ss})가 분석되었다. 그리고 필터법에서 측정 중 baseline의 변동에 의하여 발생하기 쉬운 측정오차를 제거하기 위한 새로운 분석방법을 제안하였다. 이것은 흡광 스펙트럼의 기술기를 이용한 것으로, 필터 technique와 Kishino method에서 간혹 발생하는 baseline의 변경을 완전히 복구할 수 있게 되었다. 식물성 플랑크톤의 광흡수 파장인 440nm에서 분석한 결과, 비흡광계수는 지중해의 빈 영양해에서 큰 값이 얻어졌으며, 서해 및 남해의 부 영양해에서는 아주 낮은 값이 관측되었다. 즉, 관측 값의 범위는 약 0.01 - 0.12 m^2/mg 이며, 해수의 영양 등급이 낮을수록 그 값은 증가하는 것으로 밝혀졌다. 클로로필 농도와 440nm의 비흡광수계수의 관계를 회귀 분석한 결과 이 둘 관계는 지수 함수적으로 표현되며 ($a^*_{ph} = 0.039 \langle chl \rangle^{-0.369}$), Bricaud(1995)의 연구결과와 거의 일치되는 것으로 나타났다. 반면에 부유침전물의 비흡광계수는 클로로필 입자와는 다르게 그 자신의 농도와는 별다른 관계를 나타내지 않았다. 그러나 서해 연안해수의 부유침전물의 흡광 스펙트럼의 특징은 Ahn(1990)이 측정된 육상 토양입자의 흡광 스펙트럼과 아주 유사한 것으로 나타났으며 그 값의 범위는 0.005 - 0.08 m^2/g 였다. 그리고 클로로필 입자 보다 훨씬 다양한 침전 부유입자의 광특성은 유기입자와 광물질의 혼합비에 의한 것으로 사료되며 그 외 해수 중에서 생물입자 size 분포 보다 더 광범위한 분포와 다양한 환경(입자의 비중, 해상의 바람, 저질상태, 수심 등)에 의한 것으로 추정되었다.

1. Introduction

Absorption characteristics of phytoplankton play a key role in determining the optical properties of Case-I water (Gordon & Morel, 1983). In Case-II water where waters are generally turbid, suspended sediment (SS) is the major particles of water body which is the principal component in describing oceanic processes of such water. When empirically formulating analytical ocean color remote sensing algorithm, the final values extracted from the upwelling radiance are the absorption coefficients. These absorption coefficients should be converted to particle concentrations using internally stable specific absorption coefficients. Therefore, it is important to know the specific absorption coefficient (a^*) of seawater contents, particularly, light

absorption per unit mass of SS and chlorophyll pigments of seawaters in developing algorithms for ocean color remote sensing. In addition, the specific absorption coefficient of phytoplankton is used for modeling the quantum yield (Dubinsky *et al.*, 1984; Morel, 1978) or the primary production.

Morel and Bricaud (1981) was the first to develop theoretical variations of a^* using cultured phytoplankton (ph). The variability of a^*_{ph} values decreased with the increasing phytoplankton size and intracellular pigment concentration even at the same pigment levels. It is called a "package effect" or "discreteness effect". Until now, a^*_{ph} has been assumed to be constant in optical model or in ocean color algorithms (Ahn, 1990) at any trophic levels in waters which generated erroneous simulations in some optical models. For example, Ahn (1990) presented an analytical ocean color model from which the analyzed chlorophyll values were significantly low in high chlorophyll region. The inaccuracy of the model came from the constant a^*_{ph} value used in the model. The coefficient, however, is now known as a variable value for natural phytoplanktonic assemblages (Bricaud and Stramski, 1990). Recently, Bricaud *et al.* (1995) proposed a varying a^*_{ph} with chlorophyll concentrations of seawaters using globally compiled data. The result showed that a^*_{ph} was primarily changed with trophic levels in water or with the types of water.

The Yellow Sea, its name describing the nature of water color, has been recognized as a representative of Case-II water as the name indicates. The Yellow Sea is now identified as Case-II water (Ahn *et al.*, 1997) despite the limpid center of the sea. The optical properties of the Yellow Sea are not thoroughly studied. The specific absorption coefficients for phytoplankton for this region compared with other waters around the globe are not yet known. The specific absorption coefficients of SS are no longer a parameter to be neglected in developing ocean color remote sensing techniques. Withlock *et al.* (1985) measured the optical properties SS in river waters. But, in their work, the absorption spectrum form of SS were not to be reliable according to Ahn's result (1990). Ahn who first studied the optical properties of soils (loess) in seawater using spectrophotometry found that the optical properties of SS in coastal waters are not examined properly in comparison with the precise rates of the optical properties of phytoplankton. Package effect of SS, if any, still needs to be determined. The optical properties of SS are now become indispensable parameters not only for studying Case-II water but also for developing ocean color algorithms.

In order to measure the absorption of SS with a spectrophotometer, a filter technique is considered to be the most convenient method for the particles in the sea. Although there is a problem called " β -factor" (i.e., path length amplification due to multiple scattering inside the filter and between the filter and particles; Kiefer and SooHo, 1982; Ahn, 1990) and frequently altering

base-line values. The β -factor problem is determined with an optical density function (Bricaud and Stramski, 1990), however, the base-line changing problem still needs to be solved for correct measurement of absorption coefficients.

2. Methods and Data

Optical measurements in the coastal and open Yellow Sea (YS) were carried out in June and October 1996 and August 1998 cruises. The data set for the Mediterranean Sea (MEDS) measured during Pre-Eumeli in October 1989 was used as a standard absorption spectrum and as a representative for the oligotrophic water to compare with the results from the Yellow Sea (YS) study. Seawater volumes of 100ml - 1000ml were filtered onto 25 mm glass fiber filter (GF/F). Optical density of total particulate matter (OD_{to}) was measured directly on the wet filters using the method of Truper and Yentsch (1967) with a double beam spectrophotometer (Varian CARY 1E) in spectral range 400 - 750 nm with 2 nm wavelength interval. Absorption coefficients for total particles, $a_{to}(\lambda)$, were calculated using the filtered seawater volume (V), β value and equation as follows:

$$a_{to}(\lambda) = \frac{OD_{to}(\lambda) \times 2.3025}{(V/S) \times \beta} \dots\dots\dots (1)$$

where S is the clearance area of water through the filter (1.77 cm² for the Millipore glass funnel) and 2.3025 is a constant to convert common logarithm function of OD into natural logarithm function for an absorption coefficient. V/S represents the actual path-length of light passing the water in the spectrophotometer. All absorption spectra were corrected for the β -factor by adopting value 2 regardless of wavelength (Ahn, 1990). Absorption spectra of non algal material (mainly detritus and inorganic particles), $a_{ss}(\lambda)$, were also determined experimentally similar to Kishino *et al.* (1985). The filter was then placed in absolute methanol for 1 hour in order to extract pigment. The bleached filters were dried and soaked again in filtered seawater for 1 hour. The same measurements with total absorption were applied for the $a_{ss}(\lambda)$. Subsequently, the absorption spectra of living phytoplankton $a_{ph}(\lambda)$ were obtained by subtracting $a_{ss}(\lambda)$ from $a_{to}(\lambda)$. Additionally, the shape of $a_{ss}(\lambda)$ spectrum was compared to the normalized absorption spectrum of soil particles (\bar{a}_{soil} , Ahn, 1990).

Chlorophyll-a specific absorption coefficients of phytoplankton $a^*_{ph}(\lambda)$ were finally obtained by dividing $a_{ph}(\lambda)$ with chlorophyll-a concentration (<chl>, unit is mg/m³). The specific absorption coefficients of suspended sediment $a^*_{ss}(\lambda)$ were also obtained dividing $a_{ss}(\lambda)$ by SS concentration (g/m³). It was assumed that most of nonalgal particles are originated from

suspended sediments and mineral particles because of strong tidal current of the region and yellow sand deposition from China through atmospheric transport (this phenomenon can be seen easily by satellite images). Pigment concentrations were determined by spectrophotometry (Jeffrey and Humphery, 1975) or by fluorometry.

As mentioned previously, changing baselines during the absorption measurements were frequently observed because of the measured sample filters may not be the same with the reference filters in base-line measurements. This in-situ analytic problem when using the filter technique is only can be removed when all the used GF/F filter have same optical properties(absorption and scattering). Heterogeneity of each filter paper's thickness and texture of the filter surface most probably caused the different optical properties of GF/F. Figure 1 shows an error of absorption spectrum caused by changing baselines (a_{ss} values between 500 - 750 nm are higher than a_{to}). Undoubtedly, a_{ph} values must always be smaller than a_{to} . The baseline of a_{ss} increased in parallel with the wavelength axis during a_{ss} measurement. However, the changing baseline values can be found out using a few correct a_{ss} spectrum slope within a same region; e.g, $a_{ss}(400)/a_{ss}(750)$ ratio value, (C_{ij}), was used to correct absorption spectrum. Sometimes, an

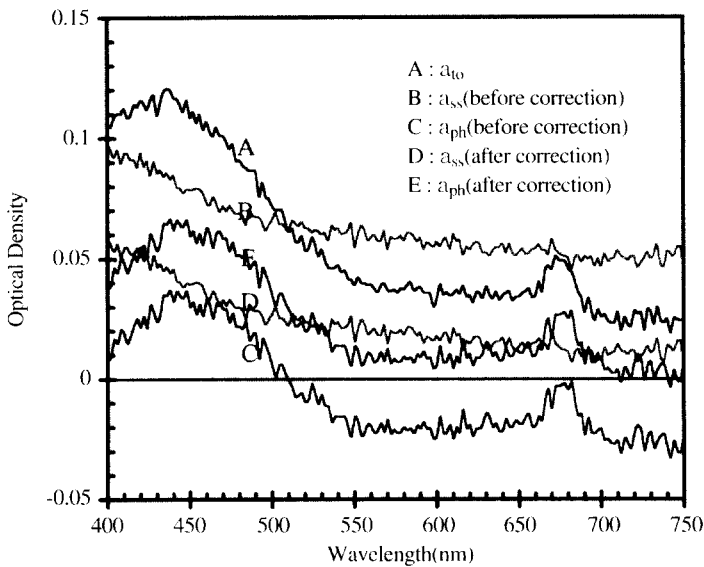


Fig. 1. An example of changing baseline during SS absorption measurement by wet filter technique. Negative absorption spectrum of phytoplankton (a_{ph}), resulted from changing baseline, is displayed. Corrected $a_{ph}(\lambda)$, using equation (2) and (3), is also shown in the figure.

averaged value of $a_{ss}(400)$ and $a_{ss}(750)$ was used when there was a strong signal fluctuation (noise) around these wavelengths. The baseline correction value for SS (X_{ss}) was obtained, assuming that the drift is quasi-neutral throughout the spectrum, using the following equations:

$$X_{ss} = \frac{C_{ij}a_{ss}(400) - a_{ss}(750)}{C_{ij} - 1} \dots\dots\dots (2)$$

where, C_{ij} ranges from 4 in CASE-I open sea waters to 10 in highly turbid coastal waters. In order to correct $a_{to}(\lambda)$, baseline correction values for total particles X_{to} were obtained using experimental results where $a_{to}(750)$ is about 1.05 times greater than $a_{ss}(750)$ (Ahn, 1990).

$$X_{to} = 1.05(a_{ss}(750) + X_{ss}) - a_{to}(750) \dots\dots\dots (3)$$

Finally, the corrected absorption coefficient for total and suspended sediments particles were obtained simply by adding X_{to} and X_{ss} values to measured $a_{to}(\lambda)$ and $a_{ss}(\lambda)$, respectively. Then, $a_{ph}(\lambda)$ is recalculated by subtracting $a_{ss}(\lambda)$ from $a_{to}(\lambda)$.

3. Results and Discussion

1) Specific absorption coefficients for chlorophyll

All spectra for the specific absorption coefficients of phytoplankton measured in the Mediterranean Sea (MEDS) and the Yellow Sea (YS) are shown in Fig. 2. Spectral values of MEDS were obtained at different depths and stations, but spectral values of YS were only from surface waters (0, 20m depth). Wide variations of $a_{ph}(\lambda)$ values are observed with the sampling regions. In surface waters, spectral patterns with the wavelength do not show any significant difference between MEDS and YS. The only spectral difference in MEDS is an absorption shoulder in 450 - 480 nm in place of 440 nm, at depth of 100 m (not clearly displayed in figure 2). The noise signals, appeared on the spectrum of YS are due to the small volume of water filtered.

Variations of a^*_{ph} at the wavelength 440 nm as a function of $\langle chl \rangle$ are shown in Fig. 3. It is clear that $a^*_{ph}(440)$ values in the MEDS are greater than the values of YS (this trend is also seen in Fig. 2). In MEDS, chlorophyll specific absorption values decrease from the surface layers to the deep layers. Small values at coastal waters of YS are found in the lower part of figure, ranging from 0.01 to 0.05 m^2/mg , which exhibit similar values with the Peruvian upwelling waters (Bricaud and Stramski, 1990). This indicates that light absorption of natural phytoplankton (a^*_{ph}) decreases with the trophic level of water (decreasing from oligotrophic water to eutrophic water, ranging 0.01 to 0.12 m^2/mg). In other word, phytoplankton in MEDS has a higher light absorption

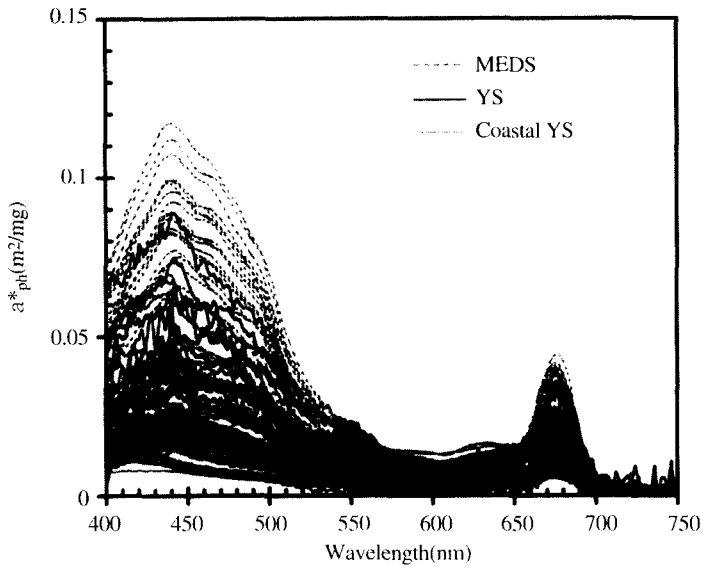


Fig. 2. All specific absorption spectra of natural phytoplankton population measured in the Mediterranean sea, open Yellow Sea and coastal Yellow Sea.

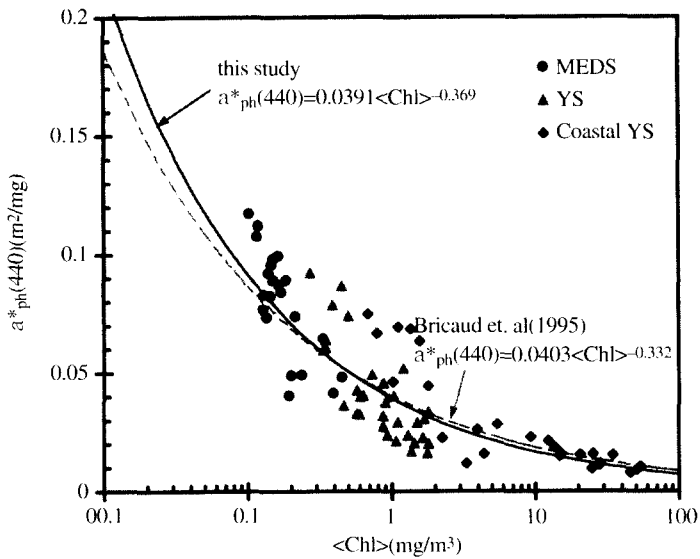


Fig. 3. Variations in chlorophyll-specific absorption coefficients of living phytoplankton at 440 nm as a function of chlorophyll-a concentrations in MEDS and YS. The regression curve is displayed in solid line. Dotted line represents previous research data from Bricaud *et al.*(1995).

efficiency than in YS. If the assumption of much smaller size distribution of phytoplankton in MEDS than that of YS can be confirmed, then the package effect by phytoplankton assemblages in Korean waters would be substantiated. The regression curve obtained between $a^*_{ph}(\lambda)$ and $\langle chl \rangle$ by a least square fit is displayed in the figure. Another curve is from Bricaud *et al.* (1995). The expression for $a^*_{ph}(440nm)$ values with a $\langle chl \rangle$ function is as follows :

$$a^*_{ph}(440) = 0.039\langle chl \rangle^{-0.369} \dots\dots\dots (4)$$

The whole spectrum values, 400 - 750 nm, $a^*_{ph}(\lambda)$ for phytoplankton at an arbitrary chlorophyll concentration can be obtained by multiplying $a^*_{ph}(440)$ value from equation (4) by normalized (at 440nm) and an averaged spectrum for MEDS and YS (see Table 1).

2) Specific absorption coefficients for suspended sediments

All spectra of specific absorption coefficients of suspended sediments, $a^*_{ss}(\lambda)$, measured in coastal and open YS are shown Fig. 4 ($a^*_{ss}(\lambda)$ in the MEDS was not measured). The averaged spectrum in YS is also displayed in the figure.

As previously stated, the figures were corrected by using a baseline correction method. General increases of spectral $a_{ss}(\lambda)$ toward shorter wavelengths were mainly due to non-biogenous materials. The absorption portion of cell organic matters against whole cell (phytoplankton organic matter + pigments) was about 13 % at 440 nm (Ahn, 1990). Therefore, algal detritus did not have strong influence on total absorption when compared with photosynthetic pigments or mineral particles. If spectral patterns were dependent on the wavelengths, the following expression can be obtained (using normalized spectra at 440 nm);

$$\tilde{a}_{ss}(\lambda) = 1.5 \cdot 10^6 \lambda^{-2.34} \dots\dots\dots (5)$$

where $\tilde{a}_{ss}(\lambda)$ is a normalized absorption spectrum at 440 nm for SS, and λ is a wavelength in [nm]. Variations of a^*_{ss} at the wavelength 440 nm as a function of $\langle SS \rangle$ are shown in Fig 5. Extending a $\langle SS \rangle$ range, $a^*_{ss}(440)$ varied from 0.005 to 0.08 [m²/g]. There appeared to be a large difference between the coastal (0.027) and open sea (0.014). Ahn (1990) measured specific absorption coefficients of soil, varying 0.04 - 0.08 [m²/g]. Comparing two groups, the suspended particles in coastal YS were mostly soil and concluded as terrestrial in origin. This was confirmed again in Fig. 6. The pattern of absorption spectra in coastal YS was nearly the same with soil. The variability of a^*_{ss} in seawater must come from the ratio values between the quantity of minerals and organic matters. Therefore, the mixing effect between organic matters and soil gave low

Table 1. Normalized (at 440nm) and averaged specific absorption spectra values for natural living phytoplankton population and suspended sediment sampled in the Yellow Sea and Mediterranean Sea.

λ	\bar{a}_{ph}	\bar{a}_{ss}	λ	\bar{a}_{ph}	\bar{a}_{ss}	λ	\bar{a}_{ph}	\bar{a}_{ss}
400.0	0.593778	1.272867	517.5	0.341342	0.651087	635.0	0.153377	0.399118
402.5	0.617820	1.259259	520.0	0.319851	0.639421	637.5	0.155665	0.397007
405.0	0.645593	1.244945	522.5	0.301228	0.627605	640.0	0.157454	0.394853
407.5	0.677194	1.230361	525.0	0.284899	0.616348	642.5	0.158505	0.392657
410.0	0.710259	1.215832	527.5	0.269215	0.606454	645.0	0.159645	0.390580
412.5	0.744925	1.200669	530.0	0.255188	0.597725	647.5	0.161706	0.388574
415.0	0.777787	1.183933	532.5	0.241400	0.589321	650.0	0.164499	0.386706
417.5	0.806042	1.167045	535.0	0.228790	0.581500	652.5	0.170053	0.384914
420.0	0.831168	1.149416	537.5	0.217245	0.574459	655.0	0.180373	0.383382
422.5	0.853916	1.132597	540.0	0.206869	0.567570	657.5	0.197615	0.382253
425.0	0.877137	1.115169	542.5	0.197818	0.560614	660.0	0.224774	0.380800
427.5	0.902648	1.097129	545.0	0.189608	0.553680	662.5	0.262879	0.378706
430.0	0.929163	1.078542	547.5	0.180978	0.546535	665.0	0.310416	0.376658
432.5	0.954567	1.059004	550.0	0.172120	0.539525	667.5	0.357891	0.374750
435.0	0.975205	1.039226	552.5	0.162745	0.532864	670.0	0.393810	0.372577
437.5	0.990774	1.019656	555.0	0.153015	0.526633	672.5	0.416901	0.369850
440.0	1.000000	1.000000	557.5	0.143788	0.520657	675.0	0.426233	0.366125
442.5	1.001615	0.981282	560.0	0.135507	0.514643	677.5	0.418471	0.362026
445.0	0.994737	0.963825	562.5	0.128627	0.509288	680.0	0.393442	0.358421
447.5	0.982399	0.947677	565.0	0.122889	0.504397	682.5	0.353310	0.355739
450.0	0.968712	0.931641	567.5	0.118507	0.499942	685.0	0.297222	0.353171
452.5	0.953549	0.915966	570.0	0.115411	0.495529	687.5	0.228741	0.350534
455.0	0.939764	0.900231	572.5	0.113610	0.491167	690.0	0.167611	0.347866
457.5	0.929351	0.885226	575.0	0.112685	0.487040	692.5	0.126272	0.345148
460.0	0.922175	0.870755	577.5	0.112229	0.483167	695.0	0.095548	0.342173
462.5	0.913160	0.858226	580.0	0.112679	0.479332	697.5	0.071640	0.339259
465.0	0.903132	0.846598	582.5	0.113464	0.475525	700.0	0.054387	0.336292
467.5	0.891431	0.835860	585.0	0.114544	0.471797	702.5	0.043306	0.333546
470.0	0.877571	0.825791	587.5	0.116214	0.468108	705.0	0.035406	0.331166
472.5	0.860106	0.815772	590.0	0.117576	0.464490	707.5	0.030288	0.328894
475.0	0.843054	0.806527	592.5	0.118637	0.460715	710.0	0.026502	0.326994
477.5	0.826546	0.798019	595.0	0.119299	0.456729	712.5	0.023196	0.325483
480.0	0.809545	0.788928	597.5	0.118761	0.452668	715.0	0.020629	0.323846
482.5	0.789638	0.779051	600.0	0.117509	0.448684	717.5	0.019035	0.321958
485.0	0.766554	0.768671	602.5	0.115949	0.444670	720.0	0.018023	0.320072
487.5	0.744561	0.759082	605.0	0.115146	0.440588	722.5	0.017180	0.318014
490.0	0.722728	0.749723	607.5	0.115538	0.436595	725.0	0.016340	0.315776
492.5	0.698878	0.741374	610.0	0.117490	0.432422	727.5	0.015739	0.313637
495.0	0.670172	0.732992	612.5	0.121102	0.427968	730.0	0.015236	0.311570
497.5	0.634416	0.724412	615.0	0.125184	0.423787	732.5	0.014838	0.309623
500.0	0.593860	0.715963	617.5	0.129446	0.419863	735.0	0.014444	0.307719
502.5	0.551694	0.707842	620.0	0.133829	0.415781	737.5	0.014131	0.305651
505.0	0.507075	0.699933	622.5	0.137587	0.412007	740.0	0.013781	0.303721
507.5	0.464933	0.691954	625.0	0.140928	0.408699	742.5	0.013159	0.302270
510.0	0.425498	0.682932	627.5	0.144319	0.405657	745.0	0.012905	0.301156
512.5	0.394169	0.673179	630.0	0.147511	0.403178	747.5	0.012826	0.299962
515.0	0.366420	0.662582	632.5	0.150599	0.401089	750.0	0.012668	0.298362

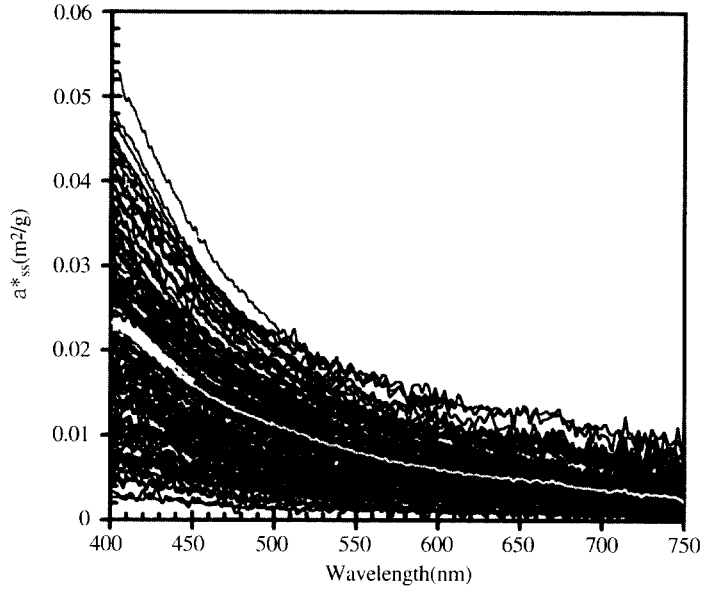


Fig. 4. All specific absorption spectra of suspended sediments determined in the Yellow Sea. The averaged spectrum is displayed in bold line.

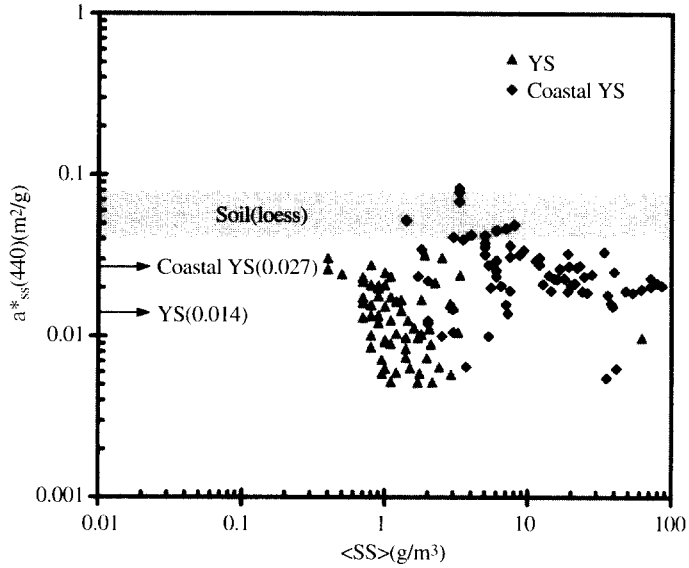


Fig. 5. Variations in specific absorption coefficients of suspended sediments at 440 nm as a function of SS concentrations $\langle SS \rangle$. The range of specific absorption coefficients for soil is also represented in the figure. Averaged values of $a^*_{ss}(\lambda)$ in coastal and open YS are shown and compared.

values of specific absorption for suspended sediments in seawater. However, the scattered points seemed to have no significant relationship between $\langle SS \rangle - a_{ss}^*$ and the package effect (decreasing with increasing of SS values). The exact reason is unclear why the values for a_{ss}^* were variable. Nevertheless, the widely scattered values were related to the variability in size distributions of suspended sediment which was again linked to other physical environment parameters, such as specific gravity of particles, wind strength, stratification of water, tidal current, bottom conditions, and water depth, and etc.. However, the absolute value of $a_{ss}^*(\lambda)$ can be obtained multiplying $\bar{a}_{ss}(\lambda)$ by the average value of 0.021 at 440 nm.

Comparison of the normalized absorption spectra $\bar{a}_{ss}(\lambda)$ according to each region and $\bar{a}_{soil}(\lambda)$ is displayed in Fig. 6 and the results showed that all spectra are similar to each other in terms of increasing absorption toward the shorter wavelengths. The difference was the slope of spectrum. The absorption ratio values (C_{ij}) at 400 nm / 750 nm for SS and soil were ranged approximately from 4 to 10. The steep slope, particularly between 400 - 550 nm, was found in soil spectrum. The slow curve was found in open seawater where biogenous matters dominated the composition of SS similar to MEDS. Again, the different slopes were the consequence of the seawater particulate composition ratio, which meant that the slope of SS absorption spectrum could be changed depending on particular types and conditions of seawaters.

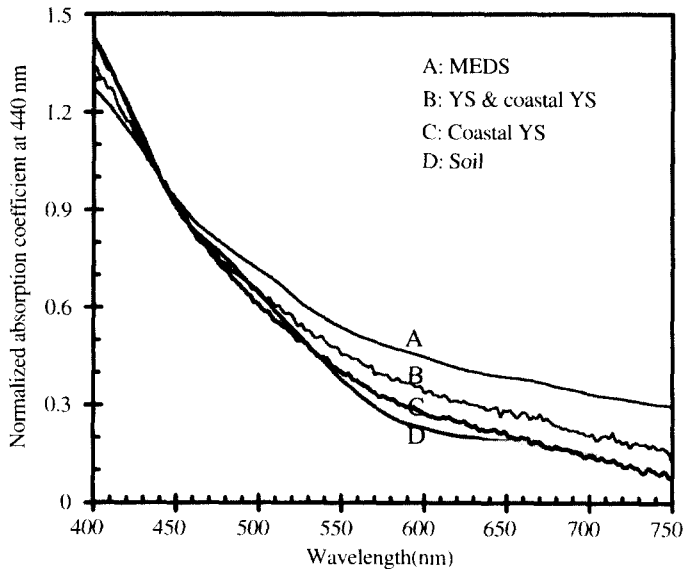


Fig. 6. A comparison of normalized absorption spectra (at 440 nm) for suspended sediments in the Mediterranean Sea , open and coastal Yellow Sea and soil (Ahn, 1990).

4. Conclusions

The specific absorption coefficients for phytoplankton observed in the Mediterranean and Yellow Sea are compared. The differences between two regions were large, probably due to the package effect caused by the relative cell size distributions. A reference spectrum of absorption for natural phytoplankton populations was proposed. A certain relationship between a^*_{ph} and chlorophyll concentrations ($a^*_{ph}(440) = 0.0391 \langle chl \rangle^{-0.369}$) was found. This relationship is expected to improve the future ocean color algorithm.

The normalized spectrum of the absorption coefficients for SS decreased toward the longer wavelengths approximating an exponential function; $\tilde{a}_{ss}(\lambda) = 1.5 \cdot 10^6 \lambda^{-2.34}$. The slope of SS absorption spectrum was related to the particulate composition (organic matters and mineral particles) of seawaters. Since there still are uncertainties on the specific absorption of SS, further researches are needed, especially in coastal waters. The problem in measuring absorption coefficient for natural particles, missing or changing baselines in using wet filter technique was also solved.

The inherent backscattering optical properties for natural phytoplankton and suspended sediments are not yet to be studied but urgently needed for the coastal and Case-II water researches.

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