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VARIABILITY OF LIGHT TRANSPARENCY IN PHYSICALLY AND BIOCHEMICALLY DIFFERENT WATER MASSES: TURKISH SEAS

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SUMMARY: This study describes chlorophyll-a concentrations and light penetration in the water columns of Northeastern (NE) Mediterranean, the Sea of Marmara and the Black Sea. The significant vertical differences were obtained among the regions and compared with each other.

KEYWORDS: Light, chlorophyll-a(Chl-a), Turkish seas.

INTRODUCTION

Transparency in sea water column has usually been used in order to provide information on turbidity, water type, euphotic zone and the biological content. The Mediterranean sea, especially the eastern basin pelagic waters, is among the world's optically clearest waters. Off the Israeli coast Secchi disc transparency (SD) range from 33-46m and downward attenuation coefficient (K_d) is as low as 0.031 to 0.046 m^{-1} [1,2]. In the present article, quantitative data on light characteristics of the NE Mediterranean offshore waters are presented. The study was enlarged to the Sea of Marmara and the Black Sea where there is very little information on transparency.

MATERIAL AND METHODS

The data presented here were collected between 1986 and 1991 with Research Vessel Bilim and the study area is shown in Fig. 1. Turkish seas: NE Mediterranean, the Sea of Marmara and the Black Sea were studied in terms of their transparency and euphotic zone characteristics. The light penetration in the water column was measured by a basic selenium photocell and relative light intensity compared with the surface light. K_d was calculated using the formula of $E_z = E_o e^{-kz}$ [3]; where E_o and E_z are the relative light intensities at the surface and specified depth (z) respectively. Secchi disc transparency was measured by a 30cm diameter white disc. A standard fluorometric method was used for total Chl-a determination [4].

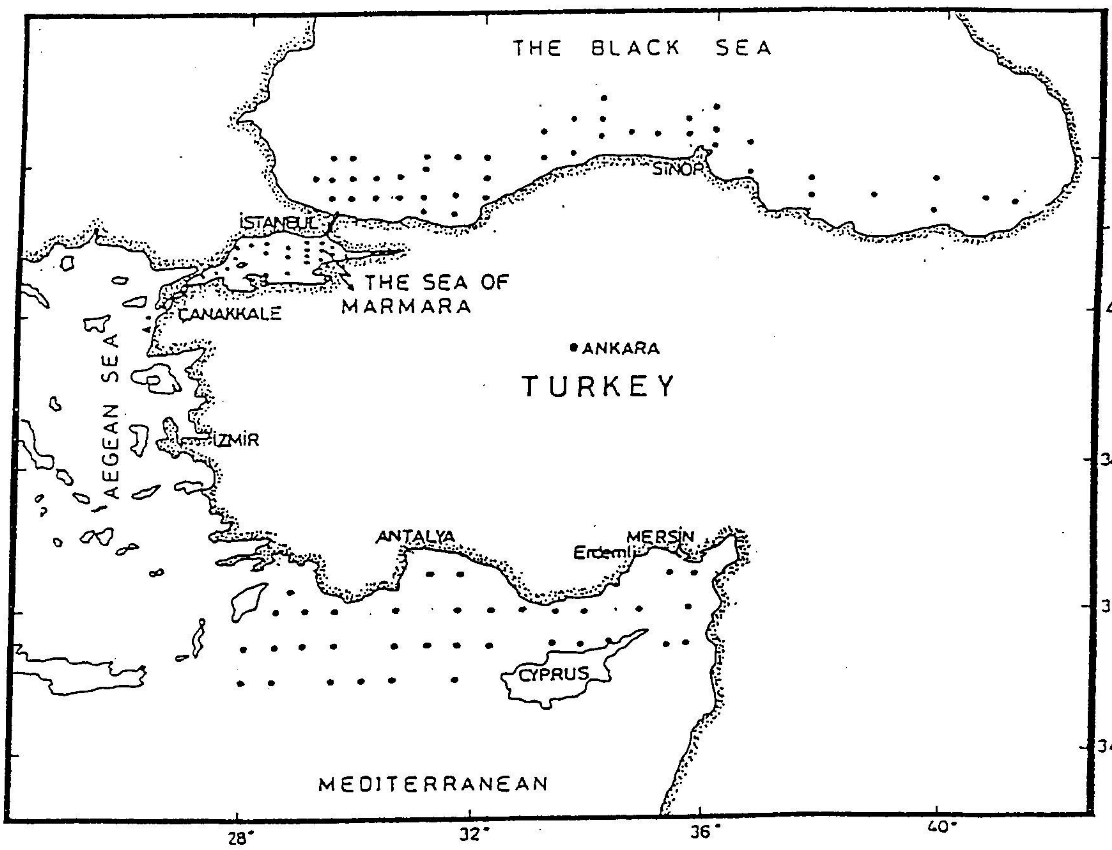

Figure 1. The study area and the station network

RESULTS AND DISCUSSION

Northeastern Mediterranean: As is well known, terrestrial input is quite low for the Eastern Mediterranean, except the Nile contribution [5]. The E. Mediterranean has long been reported as one of the most impoverished seas in the world [6,1]. Recent oceanographic surveys covering the whole basin have indicated the existence of a series of interconnected quasi-permanent anti-cyclonic and cyclonic gyres in the E. Mediterranean [7,8]. The NE Mediterranean is quite oligotrophic and is transparent as the SE Mediterranean [10]. Fig. 2 shows the level of Chl-a, depth of maximum Chl-a and compensation depth among Turkish seas for comparison. Well known characteristics of the Eastern Mediterranean is the deep Chl-a maxima (DCM) its depth could be detected down to 120m where the intensity is still 1% of the surface light [1,2,9,10]. DCM have clearly been observed in the NE Mediterranean and the typical examples are presented with the light penetration data (Fig. 3). Cyclonic (CYC) and anticyclonic (ACYC) systems influence the vertical distribution of Chl-a and the DCM was usually formed at shallower depths in cyclonic eddy fields and in general the depth of DCM coincided with the depth of the top of the nutricline. DCM were observed at relatively deeper layers in anticyclonic regions (Fig.3) and were generally observed to be located near the bottom of the euphotic zone.

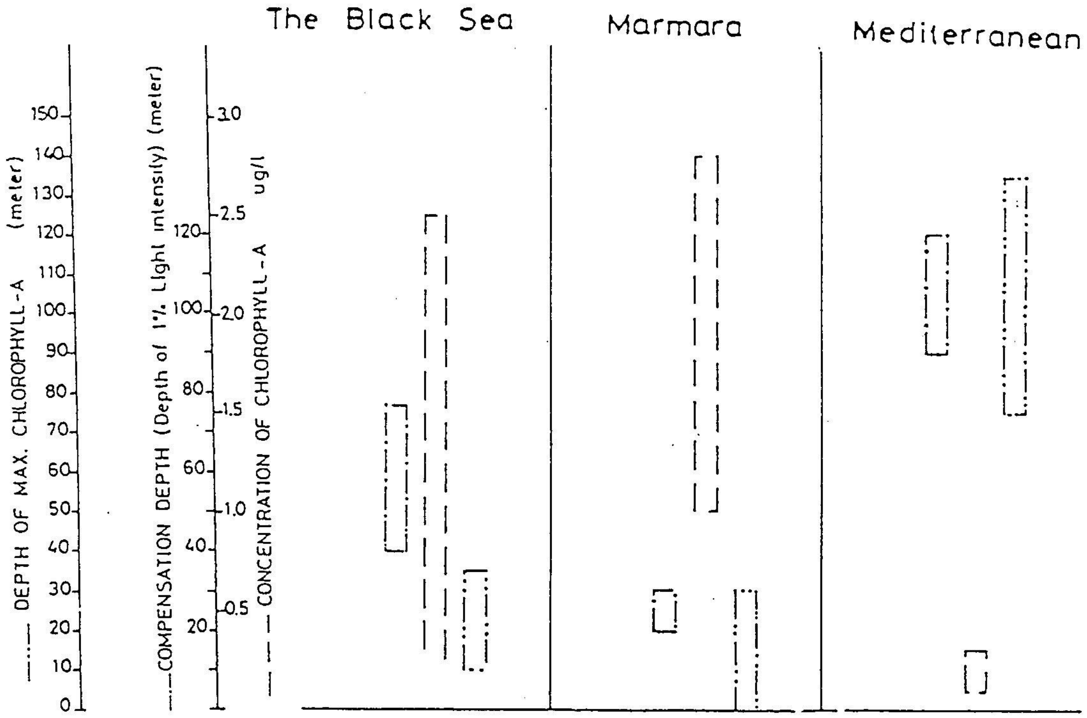

Figure 2. Average water column Chl-a concentration, compensation **depth and depth of maximum chlorophyll-a in Turkish seas**

In general, DCM corresponds to 1-20% of surface light depending on the season and location. In the NE Mediterranean the range of depth of 1% light or the thickness of the euphotic zone was determined as 50-120m for offshore waters the average being 106m (Table 1). The lowest value of K_d was found as low as 0.029 m^{-1} (Table 1) which approximatelly equals to minimum value of K_d in oligotrophic sea water or the clearest seawater like Mediterranean [11]. The average value was calculated as 0.047±0.015 m^{-1} for the whole NE

Mediterranean which is comparable to values of 0.031-0.046 m^{-1} given by [1] for the Southeastern Mediterranean. As shown in Table 1 SD was 28-45m and an average value was calculated as 38m.

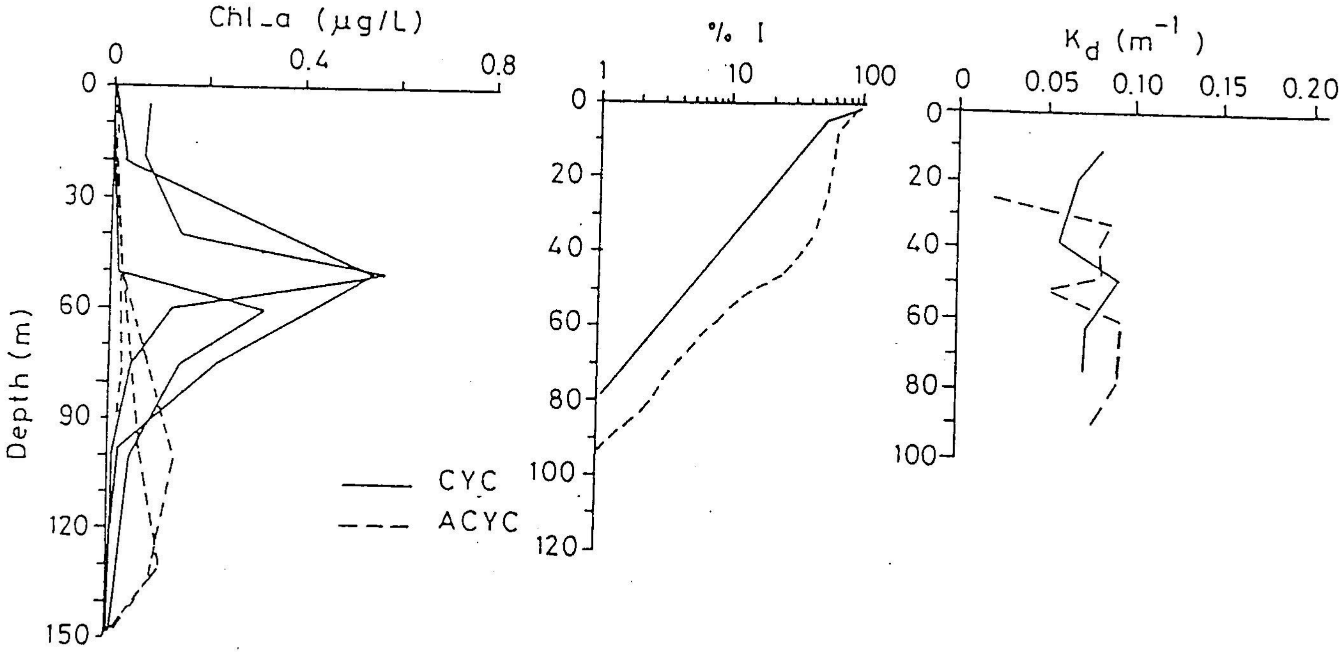

Figure 3. Typical vertical profiles of chlorophyll-a (Chl-a,μg/L), light (% I, logarithmic scale) as the percentage of surface value and downward attenuation coefficient (K_d,m^{-1}) in the NE Mediterranean

Table 1. Depth of 1% incident light(a); Attenuation coefficient (b); Secchi disc transparencies,SD(c) in Turkish seas

		Black Sea	MarmaraSea	NEMediterranean
(a)(Depth of %I,m)	Range	28-50	15-40	50-120
	mean±S	40±7.2	25±6.9	106±9
	n:	24	54	75
(b) (K_d,m^{-1})	Range	0.050-0.160	0.070-0.352	0.029-0.079
	mean±S	0.101±0.047	0.136±0.045	0.047±0.015
	n:	24	54	75
(c) (SD,m)	Range	12-28	8-14	28-45
	mean±S	20±5	9±3	38±4
	n:	40	27	50

± S: Standard deviation

The Sea of Marmara: With respect to physical properties, the Sea of Marmara shows a transitory character between the Black Sea and the Aegean or respectively Mediterranean. Less saline (20-22 ppt) Black Sea origin waters is underlied by more saline (38.5 ppt) bottom waters of Mediterranean origin, form a two-layered system. Consequently this semi-enclosed sea is permanently stratified at about 25-30m depth. Sigma theta of about 28 is generally considered as indicator of the interface and this stability influences the mixing conditions and hence reaeration of the subhalocline waters [13]. Light transparencies of the water column are quite distinctive in the Sea of Marmara with respect to other seas, which is characterised by a thin euphotic zone and high K_d at around 25-30m depth (Fig.4).(Table 1).

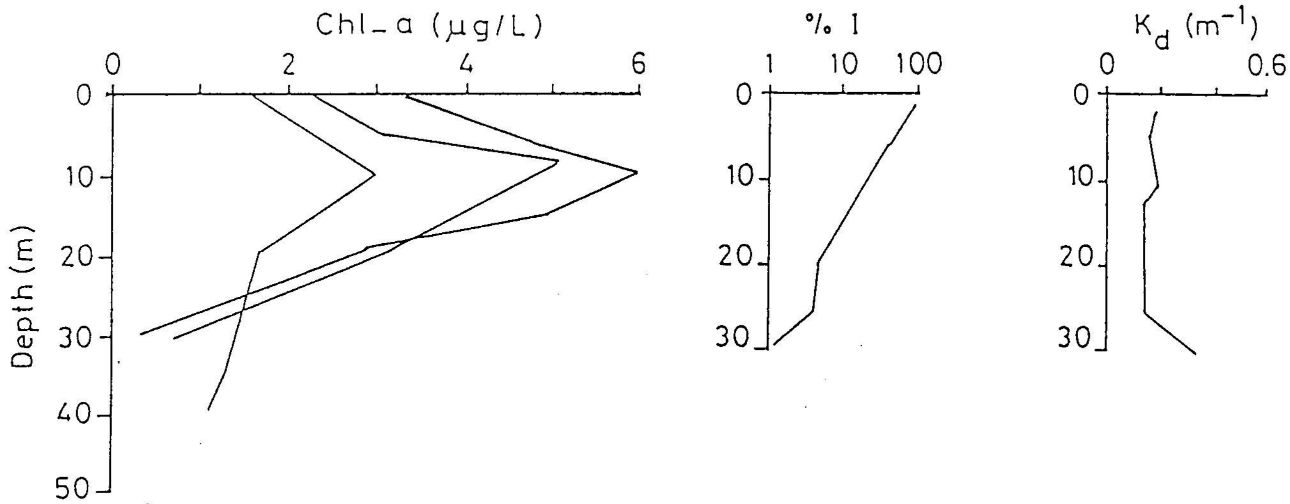

Figure 4. Typical vertical profiles of chlorophyll-a (Chl-a,µg/L), light (% I, percentage of surface value, logarithmic scale) and downward attenuation coefficient (K_d,m^{-1}) in the Sea of Marmara

K_d ranged between 0.070-0.352m^{-1} and the average value was calculated as 0.136m^{-1} for the whole Marmara sea (Table 1). Specific examples of the light as percentage of the surface intensity and the K_d profiles are given in Fig. 4. The average SD was only 9m in the Sea of Marmara and recent observations showed that this depth decreased to ~4m (Table 1). The most striking aspect of the water column transparency in the Sea of Marmara is the coincidence of the depth of 1% of surface light with the depth of permanent stratification. Fig. 5 shows clearly this coincidence; the depth of the 1% light level always falls within the very narrow depth range of 25-30m which is also the range of variability in the depth of the 28.0 Sigma-theta.

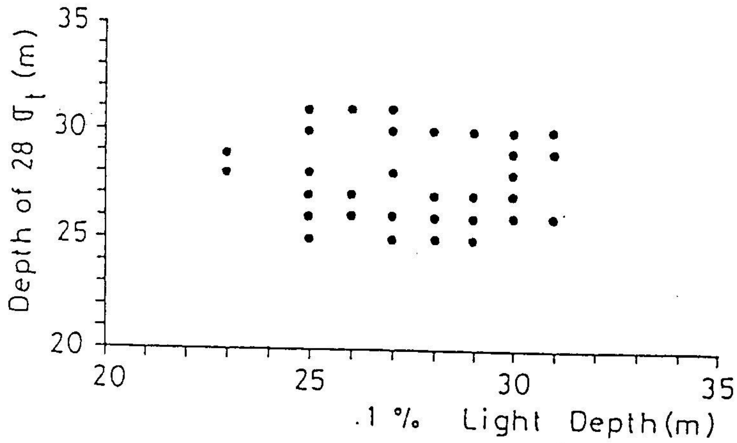

Figure 5. Depth of 28.0 sigma theta vs depth of 1% of the surface light in the Sea of Marmara

This means that the bottom of the euphotic zone is strongly correlated with the depth of the pycnocline (density stratification). Apparently, the sharp halocline (salinity stratification) has an inhibitory effect on the vertical movement of microscopic particles which therefore tend to accumulate at or below the interface. This results in sharp increase in K_d at the interface (Fig.4). Phytoplankton production is consequently limited to the upper layer as indicated by typical Chl-a profiles which show maxima above 30m (Fig.4). Since phytoplankton nutrition is supported by incoming Black Sea waters and the vertical mixing processes in the Sea of Marmara [14,15]; Chl-a concentration is 4-5 times higher here than those of in the NE Mediterranean (Fig.2). In addition to the straightforward effect of relatively high primary production on water column transparency it should be pointed out that both the Black Sea and metropolitan discharges of Istanbul are significant sources of both biogenic and nonbiogenic suspended material which will also absorb and scatter light.

The Black Sea: The Black Sea is one of the largest anoxic basins in the world. The circulation and hydrographic characteristics of the southern Black Sea have been reviewed by [16], and the biochemistry by [17]. The average depth of euphotic zone was calculated as 40m and mean K_d was calculated as 0.10 m^{-1} (Table 1). SD ranged from 12 to 28m (Table 1), and recent observations showed that the mean Secchi transparency in the Black Sea <12m [18]. A typical examples of Chl-a and light penetration relative to surface light are given in Fig. 6.

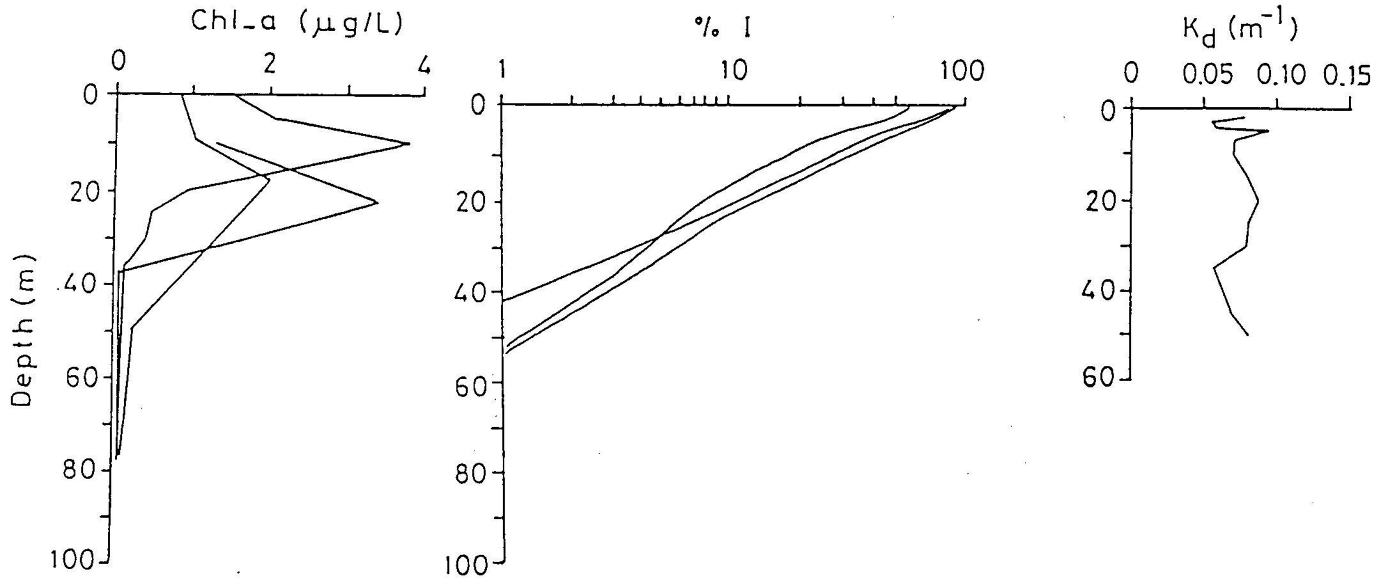

Figure 6. Typical vertical profiles of chlorophyll-a (Chl-a, µg/L), light (% I, logarithmic scale) as the percentage of surface light and downward attenuation coefficient (K_d, m^{-1}) in the Black Sea

The euphotic zone is located much above the interface in the Black Sea and its thickness is approximately half of the thickness of the euphotic zone in the NE Mediterranean. The maximum Chl-a usually occurs at first 30m of the euphotic zone (Fig.6). The Chl-a level is five times higher in the Black Sea when compared with the NE Mediterranean values (Fig. 2) because of the relatively high freshwater input, effective regeneration in the upper layer and the transport of nutrients from the nutrient rich deeper layers (which could be considered as nutrient trap) by vertical mixing processes [17,18] which causes a relatively high primary production.

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