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Phytoplankton Composition Considering the Odor Occurrence in Porsuk River (Eskisehir-Turkey)

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This study was undertaken with the aim of determining phytoplankton composition and its relation to odor occurrence during the summer months in the Porsuk river. Water samples were taken monthly from five sampling points of the Porsuk river within the boundaries of Eskisehir Province between May and October 2006. Water temperature, dissolved oxygen, pH, conductivity and Secchi depth were measured *in situ*. Chlorophyll *a*, ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen and orthophosphate concentrations were analyzed. During the research period, 51 phytoplankton species from Bacillariophyta, Chlorophyta, Cyanophyta, Cryptophyta, Pyrrophyta and Euglenophyta were identified. Phytoplankton composition varied from month to month and from upstream to downstream stations. Phytoplankton abundance started to increase in May and decreased in October. It was observed that the occurrence of unpleasant odors in the Porsuk river increased in the summer months when the water temperatures were over 22 ºC. An occasional bad odor was produced by floating algal mats which were basically made up of *Oscillatoria* sp.

Key Words: Chlorophyll *a*, Nutrients, Odor, Phytoplankton, Pollution, Porsuk river.

INTRODUCTION

Phytoplankton are more important components of productivity in large and slow-flowing rivers. The phytoplankton composition of Turkish rivers is poorly known, although there is some literature on river phytoplankton[1-7]. Whereas the ecology of lacustrine plankton has absorbed the investigative energies of aquatic biologists for more than a century, potamoplankton has received only sporadic attention[8].

Water quality measurements in the rivers of Turkey are concentrated in drainage basins where population and industry and hence pollution, are more. One of these drainage basins is the Sakarya Drainage Basin and the Porsuk river is one of the component causes of pollution in the Sakarya river. This river is used mostly for irrigation and industrial water supply and receives discharges from several domestic and industrial point sources and land-based diffuse pollution[9]. Several studies have been conducted on water quality in the Porsuk river and Porsuk reservoir[10-14].

The channel of the Porsuk river has been modified by the construction of five water level control structures in Eskisehir city center with the recreational aims. After construction, the channel was deeper and wider, with an associated slower flow rate. A part of the river is now suitable for recreational boating and parks have been constructed around the river. However, there are many complaints of unpleasant odor, especially in the summer months. The majority of odor problems in natural waters are caused by naturally-occurring organic matter, especially algae or rotting vegetation. Even though large amounts of some algae are present in reservoirs, this in itself may not cause an odor. However, some algae produce organic by-products such as essential oils and these cause a strong odor. This smell increases especially when the algae die[15].

The odour is caused by four algal groups: blue-green algae (Cyanophyta), diatoms (Bacillariophyta), green algae (Chlorophyta) and golden brown algae (Chrysophyta). Two products of Cyanophyta known as geosmin and 2-methylisoborneol cause odor. Chlorophenic compounds emptied into water sources by industry may also cause an unpleasant odor. These are industrial organic pollutants which cause a taste or smell in the water. In addition, pesticides cause an extremely unpleasant odor[15]. With excessive quantities of nutrients, eutrophication enhances the growth of blue-green algae, which in turn causes odor problems.

This study aimed to determine the phytoplankton composition and whether it was a factor of odor occurrence in the summer months and to evaluate its relations to various water quality parameters and chlorophyll *a* concentration around the recreational areas of the Porsuk river in Eskisehir.

EXPERIMENTAL

Study area and site description: The Porsuk river is the most important tributary of the Sakarya river, which it joins 460 km after passing through the center of Eskisehir[11]. The Porsuk river is mainly sourced from the village of Tokul, 1170 m above sea level. The Porsuk river flows into the lake of the Porsuk Dam 25 km from Eskisehir. The mean flow and annual water flow of the river are 10 $m^3 s^{-1}$ and 300 million m^3, respectively[14,16].

Sampling and analyses: Sampling stations were determined from upstream to downstream as follows: 1st station in the river channel near the inlet of the drinking water treatment plant after the Porsuk Dam; 2nd station after the sand trap structure; 3rd station at Taskopru-Tulomsaj; 4th station at Koprubasi and 5th station at Salhane (Fig. 1). During the course of study the average depths of the sampling stations were 1.06, 1.14, 1.86, 1.60 and 1.09 m for the five stations, respectively. Water samples were collected monthly between May and October 2006 just below the water surface. Measurements were made of water temperature, oxygen (YSI oxygen meter), pH (Consort pH meter) and Secchi depth *in situ*. The ammonia-nitrogen, nitrite-nitrogen, nitrate-nitrogen, orthophosphate were analyzed spectrophotometrically by ESKI drinking water treatment plant laboratory[17]. Chlorophyll *a* concentration was determined on 90 % acetone extracted samples with a spectrophotometer (Shimadzu UV 1201V)[18].

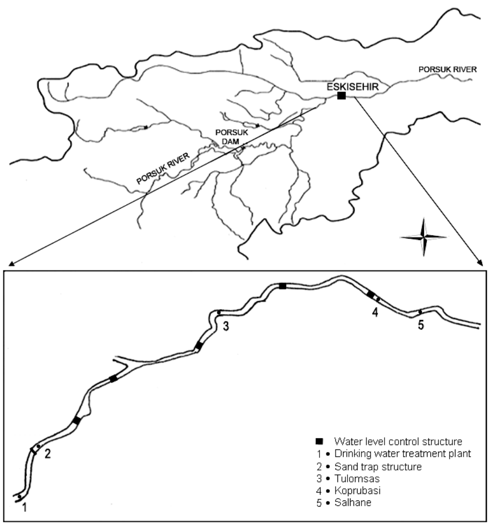

Fig. 1. Map of study area and locations of water level control structures (■) and sampling stations (●)

Plankton samples were collected using a Ruttner sampler. After preservation of water samples with Lugol's solution, phytoplankton was counted by the standard inverted microscope method[19]. Colonies and filaments were counted as one individual. Diatom samples were cleaned with a mixture of HNO_3 and H_2SO_4. The usual taxonomic literature was used to identify the phytoplankton[20-27].

RESULTS AND DISCUSSION

During the course of the investigation conducted in the Porsuk river, water temperature at the stations overall varied between 14 and 25 ºC. The occurrence of unpleasant odors in the Porsuk river was recorded in June when the water temperatures were over 22 ºC. The minimum Secchi depth was found to be 0.2 m (5th station) in August and October whereas the highest value was measured as 1.1 m (1st and 2nd station) in July (Fig. 2). Dissolved oxygen concentrations had the lowest value in the study of 6 mg L^{-1} (4th station) in June and the highest value of 13 mg L^{-1} (2nd station) in May. pH values reached a maximum of 8.43 (2nd station) in June and fell to a minimum of 7.75 (5th station) in July (Fig. 2). The measured water quality parameters were evaluated in this study according to Turkish Environmental Law[28]. While the values of dissolved oxygen and pH indicated clean water conditions and anoxia was not found, this was thought to be the result of flow. The Secchi depths of the stations were found to be in the range of highly polluted water.

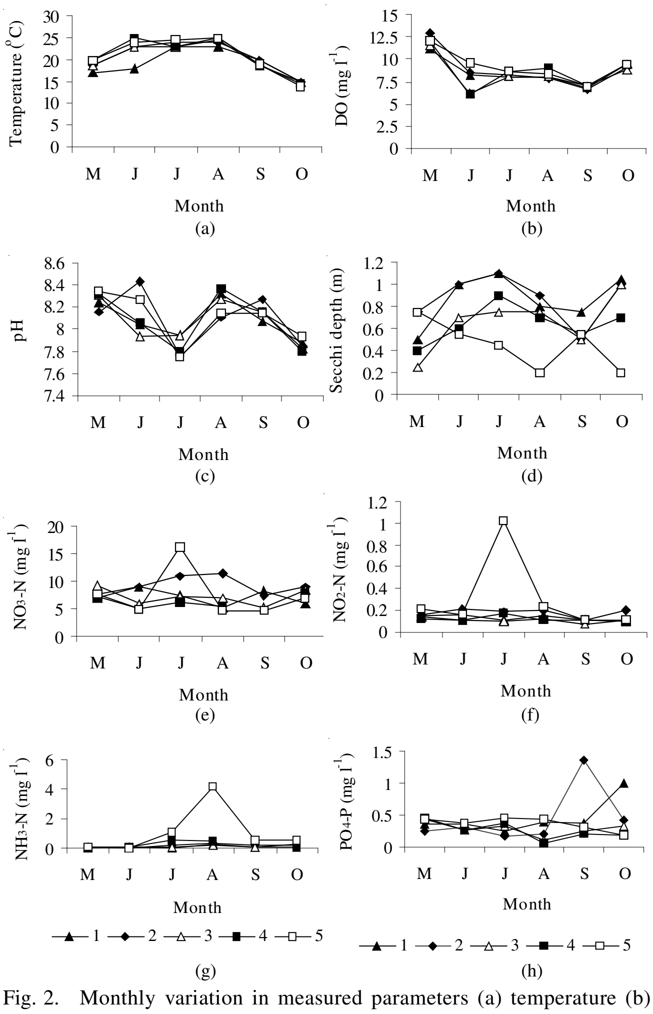

Fig. 2. Monthly variation in measured parameters (a) temperature (b) dissolved oxygen (c) pH (d) Secchi depth (e) nitrate-nitrogen (f) nitrite-nitrogen (g) ammonia-nitrogen (h) orthophosphate concentration

Among the measured ammonia-nitrogen the lowest value was found to be 0.03 mg L^{-1} whereas the highest concentration was 4.14 mg L^{-1} (5th station) in August (Fig. 2). The lowest value of nitrite-nitrogen was measured as 0.08 mg L^{-1} at 3rd station in September and the highest value was 1.02 mg L^{-1} at 5th station in July. During the study period, the nitrate-nitrogen concentration varied between 4.84 and 16.35 mg L^{-1}. Orthophosphate concentrations fluctuated between 0.07 and 1.36

mg L^{-1}. All stations were classified as moderately polluted during the research period according to the concentrations of ammonia and nitrates in the water and highly polluted when the amounts of nitrites were taken into account according to Turkish Environmental Law[28]. When the orthophosphate values at the stations were taken as a basis, all the stations were classified as either moderately polluted or polluted. The Porsuk river and Porsuk dam lake have been classified as highly polluted/ hypertrophic in the previous studies[12-14,29]. The 1st station (located in a water-intake at drinking water treatment plant) had the lowest levels of chlorophyll *a* and the highest Secchi depth during the research period was found. The phytoplankton abundance was also low in this point. At this station too, no species known to cause odors were identified.

During the research period, 51 phytoplankton species from Bacillariophyta, Chlorophyta, Cyanophyta, Cryptophyta, Pyrrophyta and Euglenophyta were identified in the Porsuk river (Table-1). Bacillariophyta had the highest number of species. Pennate diatoms were dominant and together with centric diatoms composed more than 80 % of phytoplankton in June and July (Fig. 3). Epiphytic and epilitic diatom species were recorded in the phytoplankton in this study. According to Descy's[30] classification for European rivers, pennate diatoms are dominant in fast-flowing river conditions and green algae are characteristically poorly developed. In present study however, centric diatoms dominated in August at 1st, 4th and 5th stations. In the medium sized river Ter, centric diatoms were scarce and a great influence of benthic species was observed[31]. Because the Porsuk dam lake is located in the upper part of the sampling area, lacustrine species were also found in this study. The increase of water depth for recreation in the river channel has resulted in the development of phytoplankton. Phytoplankton abundance showed an increasing trend from upstream to downstream (Fig. 4a). During the study period, the lowest phytoplankton abundance was measured at the 1st station and the highest value was recorded in August at the 3rd station. Phytoplankton abundance increased starting in May and decreased in October. Chlorophyll *a* concentration was lower than 20 mg m^{-3} between May and June, but it increased in August to 108 mg m^{-3} at 3rd station (Fig. 4b).

TABLE-1
LIST OF PHYTOPLANKTON IN PORSUK RIVER

Bacillariophyta	Chlorophyta
Achnanthes lanceolata Breb.	*Coelastrum microporum* Naeg.
Amphora ovalis Kütz.	*Closterium ehrenbergii* Meneghini ex. Ralfs
Aulacoseira italica (Ehr.) Simonsen	*C. littorale* F. Gay
Caloneis schumanniana (Grun.) Cleve	*Monoraphidium komarkovae* Nygaard
Cocconeis placentula Ehr.	*M. minutum* (Naeg.) Komarkova-Legnerova
Cyclotella meneghiniana Kütz.	*Pandorina morum* (O.F.Müll.) Bory
Cyclotella stelligera Cleve & Grun.	*Planktosphaeria gelatinosa* G.M.Smith
Cymbella affinis Kütz.	*Scenedesmus arcuatus* (Lemm.) Lemm.
C. aspera (Ehr.) Cleve	*S. quadricauda* (Turpin) Breb.
Cymatopleura eliptica (Breb.) W. Smith	*Staurastrum cingulum* (West & West) G.M. Smith
C. solea (Breb.) W. Smith	*Tetraedron minimum* (A. Braun) Hansg.
Fragilaria virescens Ralfs	Cyanophyta
Gomphonema olivaceum (Lyngbye) Kütz.	*Anabaena aequalis* Borge
Gyrosigma acuminatum (Kütz.) Rahb.	*Chroococcus minutus* (Kütz.) Naeg.
G. spencerii (Quekett) Griffith & Henfrey	*Gomphosphaeria aponina* Kütz.
Melosira varians C. Agardh	*Planktothrix agardhii* (Gomont) Anagnostidis *et* Komarek
Navicula cryptocephala Kütz.	*Oscillatoria* sp.
N. radiosa Kütz.	Cryptophyta
Nitzschia linearis W. Smith	*Cryptomonas erosa* Ehr.
N. palea (Kütz.) W. Smith	*Rhodomonas lacustris* Pascher et Ruttner
N. sigmoidea (Ehr.) W. Smith	Pyrrophyta
N. scalaris (Her.) W. Smith	*Peridinium cinctum* (O.F. Müll) Ehr.
N. vermicularis (Kütz.) Hantzsch	Euglenophyta
Rhicosphaenia curvata (Kütz.) Grun.	*Euglena oxyuris* Schmarda
Rhopalodia gibba (Ehr.) O. Müll.	*Phacus caudatus* K. Hübner
Surirella ovata Kütz.	*Trachelomonas hispida* (Perty) F. Stein
S. robusta Ehr.	
Synedra acus Kütz.	
S. ulna (Nitzsch.) Ehr.	

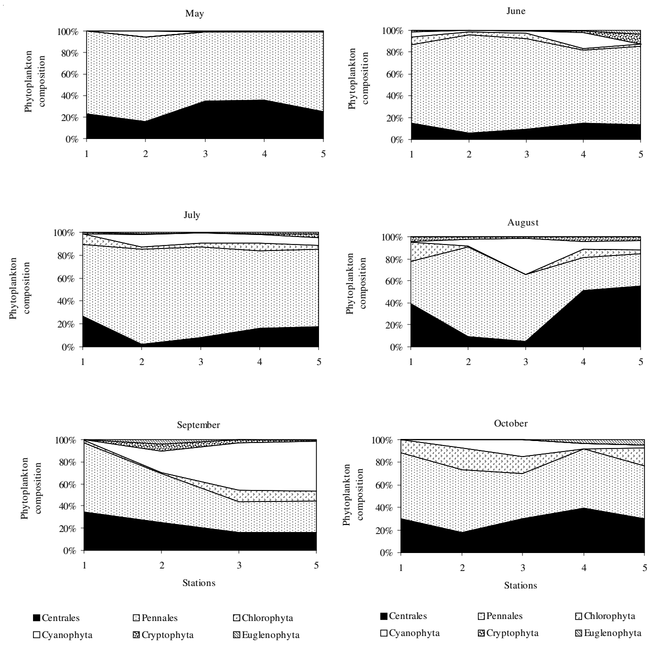

Fig. 3. Per cent variation of phytoplankton composition in sampling stations by months

Green algae were found in the sampling stations in low abundance. The ratio of Cyanobacteria increased at the 4th station in June and at the 3rd station in August and September with filamentous species. At the 2nd station, filament-based algae formations formed by *Oscillatoria* sp. were observed on dead pools in the river-bed and in time, these formations reached the surface of the water, forming green-gray and blue-green floating mats, some of which broke away due to the current. It was observed that the occurrence of unpleasant odors in the Porsuk river increased in June with a parallel increase of the water temperature and pH and a sharp decrease of dissolved oxygen. Most odor problems in natural waters start at 25 ºC and at temperatures under 16 ºC fewer complaints are received regarding smell. The by-products of some algae, such as essential oils, cause a strong odour. This odour increases especially when the algae die[15]. It has been reported that there are four algal groups which may cause the odor and among these, blue-green algae and diatoms were found to be the dominant groups in the Porsuk river. The species reported by Gray[15] as giving the water a mossy/grassy odor, *Anabeana*, *Gomphosphaeria* and

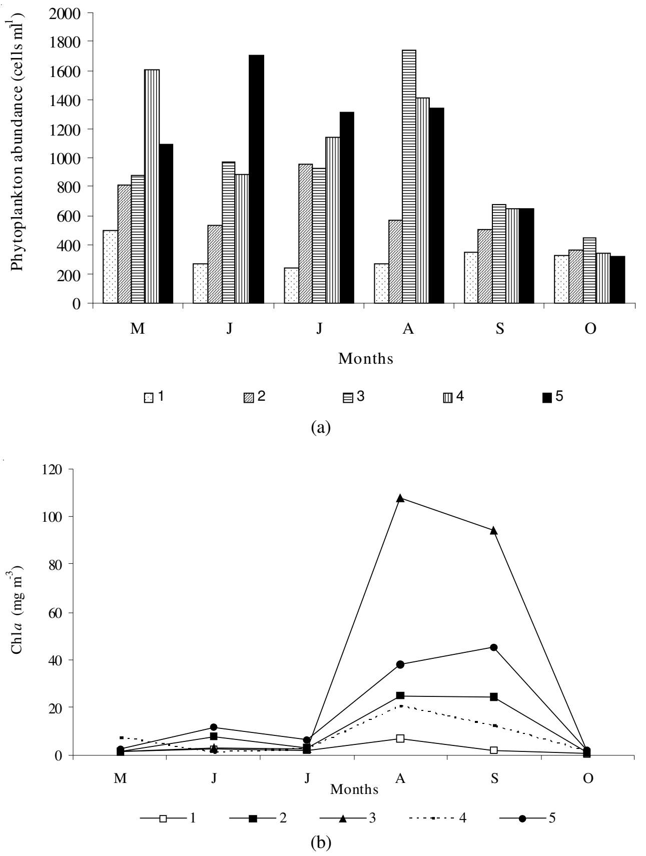

Fig. 4. (a) Phytoplankton abundance (b) Monthly variation in chlorophyll *a* concentrations in the five sampling stations

Oscillatoria, were identified in this study. Some species of diatom, such as *Fragilaria*, *Aulacoseira* and *Synedra* were identified and Gray[15] reported that these produce oils that cause a fishy or aromatic odor.

Of the blue-green algae found, it was shown that, downstream from the 2nd station, *Oscillatoria* grew in filament-based mats which broke away and were carried with the current. Samples taken from these mats showed a population mostly comprised of *Oscillatoria* sp. Even when these samples were preserved in formaldehyde, their containers had a strong muddy, swampy odor. Hoson *et al.*[32] identified two odor seasons caused by blue-green algae such as *Oscillatoria* and *Phormidium* in the Yodo river where it joins the outlet of Lake Biwa. Blue-green algae grew in dense masses to form benthic mats on rivers that produce geosmin and it was reported that these benthic mats broke off and spread in the direction of the current[33]. Cyanobacteria represent only a small proportion of all algal groups present in the Vaal river, but they are one of the most problematic because of their toxin-producing, filter-clogging, scum-forming, unaesthetic properties[34]. Eutrophication resulting from organic pollution increases the growth of blue-green algae and the secondary metabolytes produced by these algae, such as 2-methylisoborneol and geosmin, cause an odor. It is known that bacteria from the Actinomycetes group especially, such as blue-green algae, release odor-causing compounds. Large amounts of industrial organic pollutants and pesticides and industrial dumping of chlorophenic compounds into water sources have been shown to be a cause of unpleasant odours[15]. Because the lack of knowledge of the bacteria population, pesticides and organic pollutants other then algae which cause the odor. Further studies must be conducted in the modified Porsuk river channel.

In conclusion, it was found that an important source of the odor problem in the Porsuk river resulted from the mats of filament-based algae on the surface of the water. If the source of pollution is taken under control in the Porsuk river, odor and other recreational problems will not develop and the public will not have health problems.

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