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Abstract: The phyto-zooplankton composition and some physical and chemical properties of drinking water were investigated in the İvedik water treatment plant. The mean values of phytoplankton abundance were 641±92 and 438±55 ind/ml in the Kurtboğazı and Çamlıdere inlets, respectively. More than 50% of the phytoplankton belonging to the classes Bacillariophyceae, Chlorophyceae, Cryptophyceae and Dinophyceae were removed in the clarifiers. The treatment efficiency of phytoplankton ranged from 89 to 100% after the last chlorination. The mean values of zooplankton abundance were 93±23 and 59±18 ind/l in the Kurtboğazı and Çamlıdere inlets, respectively. The treatment efficiency of zooplankton varied between 97% and 100% in the balancing room. In processed water, phytoplankton (*Tetrachlorella, Cyclotella, Gomphosphaeria, Anabaena, Staurastrum, Aphanizomenon, Botryococcus* and *Rhodomonas*) were recorded. In addition, zooplankton (*Keratella, Ascomorpha, Polyarthra* and *nauplii*) were found in treated water.

Key Words: phytoplankton, zooplankton, treatment efficiency, drinking water, treatment plant

Ankara İvedik İçme Suyu Arıtım Tesisinde Plankton Arıtım Etkinliği

Özet: İvedik arıtım tesisinde içme suyunun bazı fiziksel ve kimyasal özellikleri ile fito-zooplankton kompozisyonu incelenmiştir. Kurtboğazı ve Çamlıdere girişlerinde ortalama fitoplankton sayısı, sırasıyla 641±92 ve 438±55 birey/ml olarak bulunmuştur. Bacillariophyceae, Chlorophyceae, Cryptophyceae ve Dinophyceae sınıflarına ait fitoplanktonun %50'den fazlası durultucularda arıtılmıştır. Fitoplanktonun arıtım etkinliği, son klorlamadan sonra %89 ile 100 arasında değişmiştir. Ortalama zooplankton bolluğu, Kurtboğazı ve Çamlıdere girişlerinde sırasıyla 93±23 ve 59±18 birey/l olarak bulunmuştur. Zooplankton arıtım etkinliği, dengeleme odasında %97 ile 100 arasında değişmiştir. Arıtılmış suda, fitoplankton (*Tetrachlorella, Cyclotella, Gomphosphaeria, Anabaena, Staurastrum, Aphanizomenon, Botryococcus* ve *Rhodomonas*) bulunduğu kaydedilmiştir. Ayrıca, zooplankton (*Keratella, Ascomorpha, Polyarthra* ve *nauplii*) bulunduğu belirlenmiştir.

Anahtar Sözcükler: fitoplankton, zooplankton, arıtım etkinliği, içme suyu, arıtım tesisi

Introduction

One of the most important needs of a society is a clean and secure water supply. Water is used for drinking after treatment to conform to quality parameters. To evaluate the treatment procedures for drinking water and wastewater treatment plants, and to discover reasons for the clogging of pipes and filters, the sampling, identification and enumeration of aquatic organisms is necessary (1). The qualitative and quantitative analysis of phyto-zooplankton in treatment plants is important, not only for treatment efficiency, but also for monitoring changes in water quality (2).

Plankton blooms in drinking water reservoirs lead to taste and odour in the water, and clog the filters (3). Phytoplankton pass from filters, change the colour and turbidity of water, create aesthetic problems and also serve as food for organisms in water pipes (4). Consumption of water in which cyanobacterial blooms occur causes gastro-intestinal problems, tumours, haemorrhaging and even death (5). A cyanobacterial increase as a result of eutrophication is one of the most important water quality problems. Eutrophic water has a high organic matter content and leads to the occurrence of carcinogenic and mutagenic trihalometans after

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chlorination (6). Moreover, eutrophication is an important factor in treatment economics. Associated with algal blooms in dams there was a corresponding increase in treatment costs at the İvedik water treatment plant.

The treatment efficiency of phyto-zooplankton has been investigated by several authors (7-9). Algal rupture during abstraction from reservoirs and the consequences for water treatment have been reported (10); but there has been no study on this subject in Turkey. The aims of this study were to investigate the composition and seasonal succession of plankton, and to determine the efficiency of plankton treatment in the İvedik water treatment plant.

Materials and Methods

The İvedik water treatment plant (WTP) was planned as four sections, of which two have been operating with a capacity of 1,128,000 m^3/day since 1984. It is a conventional plant with prechlorination, coagulation, flocculation, rapid sand filtration and post-chlorination processes.

The WTP was sampled monthly from June 1995 to May 1996. Samples were obtained with a Ruttner sampler from the inlet pipes of Kurtboğazı and Çamlıdere, the mixing room where the water of two reservoirs are mixed, from rapid filters where the water is prechlorinated and coagulants added, from clarifiers, from the channel after clarifiers, from the sand filters, subsequent to sand filtering, and after the last chlorination from the balancing room (Fig. 1). Plankton samples were also taken with a 55 µm plankton net for qualitative analysis.

Phytoplankton counting followed the standard inverted microscope method after preservation with Lugol solution as described by Lund et al. (11). Zooplankton samples were preserved with 4% formaldehyde solution; 1, 2 or 3 l of water samples were filtered by a 30 µm mesh net and enumerated in a counting chamber (12). Water temperature (Ruttner sampler thermometer), dissolved oxygen (YSI Oxygenmeter), pH (pHmeter) and conductivity (corrected to 25 ºC) were measured *in situ*. Variance analysis (ANOVA) and Duncan's multiple range test were used to evaluate differences in water temperature, dissolved oxygen, pH, conductivity, abundance of phytoplankton and zooplankton between the sampling points. Statistical analyses were performed using Minitab and Mstat for Windows.

Results

The mean values of water temperature, dissolved oxygen, pH and conductivity were 10.4 ºC, 8.6 mg/l, 7.8 and 202.9 µS/cm in the balancing room, respectively. The

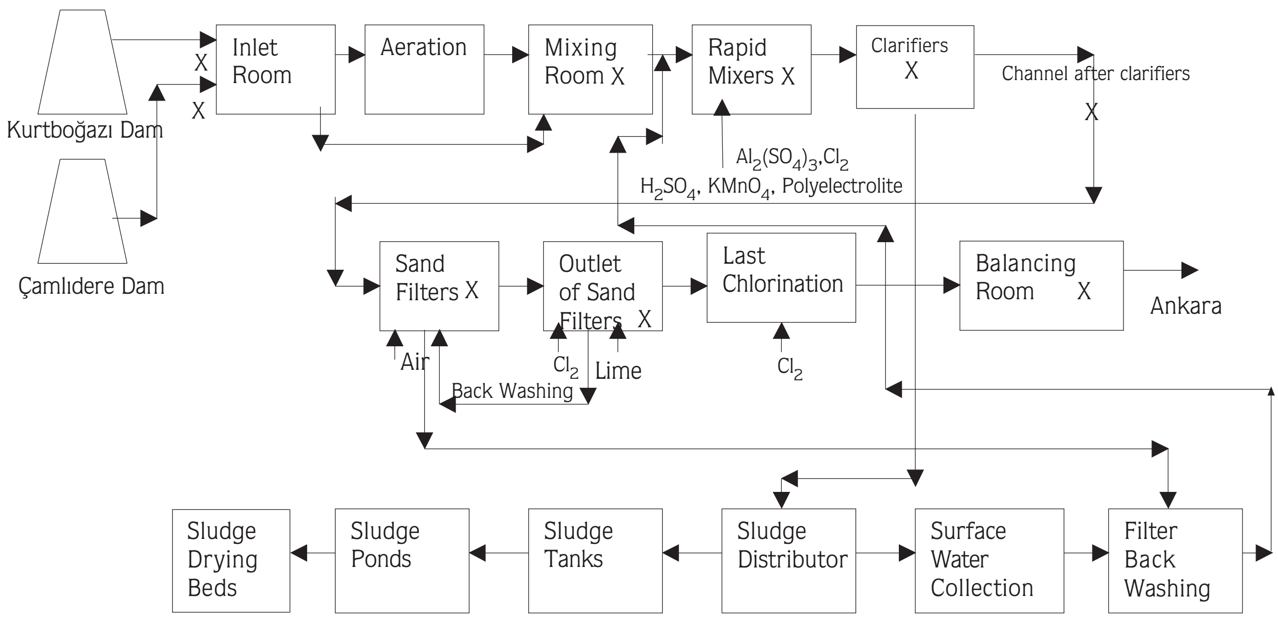

Figure 1. Diagrammatic representation of the İvedik drinking water treatment plant (X shows the sampling points)

changes in water temperature, dissolved oxygen and pH values were statistically insignificant while the changes in conductivity were significant in the sequential treatment processes ($p < 0.05$)(Table 1).

In the mixing room, the dominant classes were Chlorophyceae in June, Bacillariophyceae in July, Cyanophyceae in September, Cryptophyceae in winter and Bacillariophyceae in spring. The abundance of phytoplankton was higher in June, September, October and May than in the other months in the mixing room (Fig. 2). Mean values of phytoplankton abundance were 641 ± 92 and 438 ± 55 ind/ml in the Kurtboğazı and Çamlıdere inlets, respectively (Table 1). The mean values of phytoplankton abundance were 531 ± 57 ind/ml in the mixing room and 455 ± 63 ind/ml in the rapid mixers. The difference between these points was statistically insignificant ($p > 0.05$). On the clarifiers, phytoplanktonic organisms sedimented and their abundance decreased approximately 50%. The abundances were 56 and 20 ind/ml after sand filtering and from the balancing room, respectively. This difference was statistically significant ($p < 0.05$).

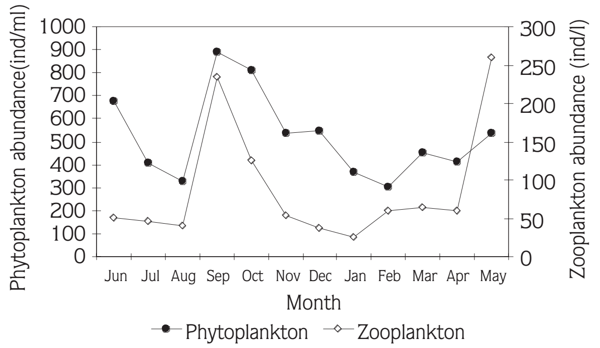

Figure 2. Monthly variations phyto-zooplankton abundance in the mixing room of the WTP

More than 50% of the phytoplankton belonging to the classes Bacillariophyceae, Chlorophyceae, Cryptophyceae and Dinophyceae were removed in the clarifiers except Cyanophyceae (Table 2). The treatment

Table 1. The mean values (± SE) of temperature, dissolved oxygen, pH, EC and the abundance of phyto-zooplankton at sequential treatment steps of the WTP*

Parameter	Mixing room	Kurtboğazı inlet	Çamlıdere inlet	Rapid mixers	Clarifiers	Channel after clarifies	Sand filters	After sand filtering	Balancing room
Water temp., ºC	10.52 ±1.33	9.84 ±1.18	10.85 ±1.40	10.57 ±1.34	10.52 ±1.33	10.54 ±1.32	10.43 ±1.31	10.43 ±1.31	10.37 ±1.27
Dissolved oxygen,mg/l	8.03 ±0.29	7.2 ±0.48	8.13 ±0.29	8.13 ±0.27	8.22 ±0.26	8.25 ±0.24	8.24 ±0.24	8.28 ±0.23	8.59 ±0.27
pH	7.81 ±0.06	7.75 ±0.06	7.92 ±0.10	7.86 ±0.07	7.85 ±0.09	7.86 ±0.10	7.76 ±0.13	7.81 ±0.10	7.78 ±0.12
EC (μS/cm)	180.4^{b} ±4.3	193.9^{ab} ±3.9	161.0^{c} ±4.2	193.5^{ab} ±3.9	193.3^{ab} ±4.4	193.3^{ab} ±4.6	192.6^{ab} ±4.6	195.4^{ab} ±5.4	202.9^{a} ±3.7
Phytoplank. ind/ml	531.1^{a} ±56.7	640.9^{a} ±91.8	438.3^{a} ±54.7	454.8^{a} ±63.2	227.6^{b} ±42.7	166.7^{b} ±33.4	154.1^{b} ±27.9	55.8^{c} ±16.5	19.5^{d} ±7.1
Copepoda ind/l	29.3^{ab} ±9.9	35.5^{a} ±11.6	19.0^{abc} ±3.4	27.6^{ab} ±9.6	21.9^{abc} ±10.0	18.8^{b} ±9.0	15.3^{c} ±7.3	2.6^{d} ±0.8	0.6^{d} ±0.3
Cladocera ind/l	23.8^{ab} ±8.3	30.2^{a} ±10.5	15.2^{abc} ±6.5	21.3^{ab} ±8.4	13.1^{bc} ±5.2	9.6^{c} ±3.7	7.5^{c} ±2.7	0.8^{d} ±0.4	0 ±0.0
Rotifera ind/l	27.9^{ab} ±7.5	27.1^{ab} ±4.8	24.7^{abc} ±10.0	20.9^{abc} ±5.2	14.9^{bc} ±4.1	13.1^{bc} ±3.7	10.6^{c} ±3.3	1.2^{d} ±0.3	0.5^{d} ±0.2
Tot. zoopl. ind/l	81.0^{ab} ±22.9	92.8^{a} ±22.8	58.8^{abcd} ±18.2	69.8^{abc} ±20.8	49.9^{bcd} ±17.6	41.4^{cd} ±14.9	33.4^{d} ±11.1	4.4^{e} ±1.1	1.1^{f} ±0.3

*abcdef; Differences between the means with the same superscripts in each line are not significant ($p>0.05$)

Table 2. Treatment efficiency (as % removal) of phyto-zooplankton communities by group at sequential treatment steps of the WTP

Phytoplankton	Rapid mixers	Clarifiers	Channel after clarifiers	Sand filters	After sand filtering	Balancing room
Bacillariophyceae	14.2	59.2	75.7	79.1	92.0	96.2
Chlorophyceae	24.6	56.2	67.5	75.5	88.0	98.7
Cyanophyceae	22.2	18.7	29.2	62.3	78.6	88.9
Cryptophyceae	33.3	50.3	60.9	75.5	91.2	99.7
Dinophyceae	51.2	76.3	86.9	90.7	100.0	100.0
Euglenophyceae	16.7	21.1	27.7	27.7	88.9	100.0
Zooplankton						
Copepoda	5.8	25.3	81.2	84.7	97.4	99.4
Nauplii	0.4	18.8	30.8	47.4	90.6	97.4
Cladocera	10.3	48.8	59.6	68.4	97.1	100.0
Rotifera	25.1	46.6	53.0	62.0	96.3	98.2

efficiency of phytoplankton ranged from 78.6 to 100% after sand filtering and from 89 to 100% after the last chlorination. In the balancing room, *Tetrachlorella* were recorded in June; *Cyclotella, Tetrachlorella* and *Gomphosphaeria* in July; *Anabaena* in August; *Cyclotella, Staurastrum, Gomphosphaeria, Anabaena* and *Aphanizomenon* in September and October; *Gomphosphaeria* and *Aphanizomenon* in November; *Cyclotella* and *Gomphosphaeria* in December; and *Cyclotella* and *Rhodomonas* in January, February, March, April and May.

It was observed that Cladocera species were destroyed, with the exception of *Bosmina* after prechlorination, and treatment efficiency was 100% in the balancing room. Cyclopoid copepods were observed to be more resistant to chlorination than calanoids. In the balancing room, copepod nauplii and rotifera (*Keratella, Polyarthra* and *Ascomorpha*) were found occasionally. The mean values of zooplankton abundance were 93 ± 23 and 59 ± 18 ind/l in the Kurtboğazı and Çamlıdere inlets, respectively. Zooplankton abundance was higher in September and May than in other months in the mixing room (Fig. 2). The abundance of zooplankton decreased in the treatment steps gradually and these differences were also statistically significant ($p < 0.05$).

Discussion

This study was conducted to determine phyto-zooplankton changes in a drinking WTP throughout the year and it can be concluded that in summer and spring phyto-zooplankton showed peaks compared to winter. Eutrophication occurred gradually due to the increasing blue-green algae. The WTP needs to be improved to meet international standards.

The abundance and composition of phyto-zooplankton in the inlets the of WTP showed similar seasonal variations to of that the depth from which the water was taken from the reservoirs (between 12 and 20 m, and it changed according to water level). In these depths, the abundance of plankton decreased significantly. Mean values of phytoplankton abundance at 12 and 20 m depths were 923 ± 228 ind/ml and 527 ± 90 ind/ml in the Kurtboğazı reservoir and 451 ± 56 ind/ml and 310 ± 51 ind/ml in the Çamlıdere reservoir (13). A possible disadvantage of taking water from the hypolimnion to treatment plants is anoxic water (6). However, in the WTP, water from Kurtboğazı was aerated and anoxic conditions were not observed. Therefore, it is preferable to take the water from deeper layers when the surface water is rich in plankton. The highest abundance of phytoplankton was 1152 ind/ml in the Kurtboğazı inlet but it never exceeded 1000 ind/ml in raw water in the mixing room. Rapid sand filters were clogged rapidly when 1000-3000 ind/ml organisms were found in raw water, and deterioration in water quality may be possible below these numbers (8).

More than 50% of the phytoplankton were removed in the clarifiers. In this step, treatment efficiency was low for Cyanophyceae species. Treatment efficiencies of different classes were 78.6-100% in sand filters and 89-100% after the last chlorination. Treatment efficiencies for Bacillariophyceae, Chlorophyceae, Cyanophyceae and Euglenophyceae were 99.9%, 99.4%, 96.7% and 95% in a treatment plant, respectively (9). The movement and floating mechanisms of phytoplankton affect coagulation, flocculation and filtration processes (8). Most of the Cyanophyceae species have gas vacuoles (3). Because of this, treatment was more difficult when Cyanophyceae species were abundant in raw water.

A detailed list of the phyto-zooplankton species identified in Kurtboğazı and Çamlıdere reservoirs was given in a previous study (13). In this study, *Tetrachlorella, Cyclotella, Gomphosphaeria, Anabaena, Staurastrum, Aphanizomenon* and *Rhodomonas* were found in treated water. Round (14) reported that large diatoms such as *Aulacoseira, Fragilaria* and *Asterionella* may clog the sand filters, and small diatoms such as *Cyclotella* may pass through the filters. It was concluded that increases in the water sources and floating mechanisms of *Anabaena, Aphanizomenon* and *Botryococcus* and small sizes of *Cyclotella, Rhodomonas* and *Tetrachlorella* might be the reasons why they were found in treated water. These organisms may also cause a taste and odour problem (4). Cyanophyceae species such as *Anabaena, Aphanizomenon* and *Gomphosphaeria* are very dangerous for human health (5). Phytoplankton increases affected the washing interval of sand filters; it decreased to 7 h in the WTP.

Keratella, Polyarthra, Ascomorpha and copepod nauplii were found in the treated water. *Cyclops*, which passed through treatment plants, might be found in water distribution systems (4), whereas any algae or other organisms in drinking waters should not be found according to Turkish Standards (15). The WTP must be optimised by the use of dissolved air flotation, a combination of dissolved air flotation and granulated activated carbon filtration, polymers or activated carbon and ozone (16-19). Coagulation and flocculation efficiency are greatly influenced by the selection of the proper type of coagulant and coagulant dosage (20). Filtration must employ filters that are designed, operated and maintained in the proper manner in order to be effective (21).

Both reservoirs were classified as eutrophic according to phytoplankton indices (13,22). Çamlıdere was evaluated as less productive with some increases of desmids, lower phyto-zooplankton abundance, chlorophyll *a* and higher Secchi depth than Kurtboğazı (13). While *Anabaena, Chlorococcus* and *Microcystis incerta* from Cyanophyceae were identified and their numbers were low in Kurtboğazı in 1976-77 (23), phytoplankton reached its maximum with *Anabaena, Aphanizomenon* and *Gomphoshaeria* comprising 64% and 49% of the total in Kurtboğazı and Çamlıdere reservoirs in 1995-1996 (13). The increases in blue-green algae in both reservoirs showed that eutrophication was a problem. According to the findings, some algae and animal organisms pass through the WTP. Because of this, the operations of the WTP must be developed and optimised with chemicals and procedures. Blue-green algal toxins must also be investigated.

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