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The use of diatometes for different water and wastewater treatment

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ABSTRACT

Diatoms are living beings that have the ability to live in different aquatic and wastewater environments, with a shell and a special gel-like fat under this shell, and also can produce and refine oxygen. It is possible to use different kinds of diatoms to decontaminate the pollution in wastewater, dams, and lakes that provide drinking water; and to eliminate moss and intensive algae on sea coasts. This study uses these diatoms which are not harmful to water and human health, to eliminate/decontaminate pollution instead of various chemicals; and also investigates the changes in the aquatic ecosystem. The study examines particularly the decontamination of urban wastewater in Istanbul on a laboratory scale along with the possible cost and efficiency of decontamination of diatoms. However, the most significant part of the study is concerned with applications done for polluting algae and moss which are in the polluted lakes and rivers caused by household wastewater. The field of application is the Pınarbaşı Lake in Elbistan and the Ceyhan River that this lake feeds; we have added solutions that contain the right amount of diatoms for the mass of the lake on certain proportions, continuously for 4 d. We used natural light during the day and a number of lamps that give out 250 W of light at night. The special diatom mix is 1:2,000–1:5,000 ratio for urban wastewater and 1:10,000–1:50,000 dilution ratio for lake water. As a result of the decontamination application, we obtained 14 (94.2%) for suspended solid matter, 25 (93%) for chemical oxygen demand, 1.1 (97.6%) for N, and 0.3 (91.7%) for P. As a result, we have determined that this application can be successfully used in lakes and dams that provide water but with biological or algal contamination; however, even though the decontamination result for urban wastewater is good, the operating cost is relatively high compared to biological wastewater purification systems.

Keywords: Sustainability; Mildly contaminated water; Diatoms; Oxygenation; Sedimentation.

1. Introduction

1.1. General information

The main concern of the present study is represented by the diatoms, which are single-cell algae with silica frustules and which are used in the field practice with regard to the fuel and oil as "Nano-technologic Diatoms" [1].

Diatoms can be also found in studies that were initiated for the improvement of petrol production and genetic transformation of diatoms [2–4]. A wide variety of genomic tools, which were developed for diatoms, prove the continuity of these studies and how necessary they are [5,6]. The reason is that diatoms grow much faster than the other oil crops [7] and that the biomass of some species can reduplicate in size from 5 to 24 h. In other words, a geometrical enhancement between these durations may occur [8,9]. Its increase and reduplication times are 2–10 d in nature and it also contains photosynthesis and photorespiration durations [10,11].

Diatoms are considered as a source of carbon (C) and photosynthesis richness is developed by CO concentration [1]. Diatoms are estimated to consume CO up to 25% on a global basis and then transform it to oxygen [1]. Benthic

diatoms come out under the sun and blossom when there is an abundance of food as well as suitable conditions [12].

It is known that the average density of a diatom depends on mathematical heaviness and volumetric components: this density affects the heaviness, and swimming or sinking in water both depend on this average density (it has to be different from the density of water). Reduction process is carried out under aerobic or anaerobic conditions. The lipids in diatoms are transformed into hydrocarbons.

It is estimated that more light means more productivity for the organisms that make photosynthesis. In addition to this, as diatoms develop in low-level light [13–15], it is important to optimize their growth. This ability may be related to facultative heterotrophy or light level adaptation in nature [16].

Low light may imitate nitrogen deficiency conditions [17], by which it can improve the oil amount per cell. There have been laboratory experiments in marine phytoplankton in order to evaluate and measure their role in non-methane hydrocarbon production [18]. The results show that methane, ethane, propane, and some phytoplankton are probably released to their own culture environments; lipids are produced through oxidation during autolysis; and high ethylene concentrations are produced in environments that have a high primary productivity [19].

1.2. Diatoms in water and wastewater treatment

The water quality, among other possibilities, can be observed also by following and observing the diatom types. While some diatom species have the ability to move, other species cannot. They produce the majority of photosynthetic products. In fact, they contribute approximately to 20%–25% of the world photosynthetic oxygen production, meaning that diatoms play a crucial role for photosynthesis in the world.

A variety of diatoms can be observed in polluted rivers. In fact, diatoms can live in highly contaminated water types and they both give oxygen to the water and refine the water. However, industrially contaminated water, that is, highly contaminated water types, can rarely accommodate diatoms.

Upon examining the clean water types, such as rivers and streams, concerning the types of diatoms that live in such water bodies, as well as their size and species, we would encounter significant situations. Here, when we compare the diatoms in clean, very clean, contaminated, and highly contaminated water, the differences in amount and variety of diatoms are notable. Diatoms that live in different aquatic environments can co-exist depending on the environmental conditions.

The different and new practices that we carried out constitute an innovative study; the upcoming studies are actually components of a whole which includes a variety of steps. These studies encompass five steps:

- Studies which are performed in spring water, which is considered to be clean and drinkable, or in boiling lakes.
- Refinement studies for the improvement of turbid which that can be used.
- Refinement studies to be conducted in house wastewater.
- Studies on highly contaminated water which involves wastewater of industry.
- Studies on the algae in coastal water and swimming water.

The practices and debate about the outcomes or critical approach will always be open to the analysis of the scientists. In this context, our study attempts to provide alternatives to develop technological products.

1.3. Aim of the study

This study aims to scientifically highlight important remarks on different occasions and application areas, and to obtain various commercial products with the support of the outcomes. In our study, we use instant products (powdered and solution) which include various diatom kinds and which are being commercialized throughout the world as well as produced and used in many countries. These products are applied particularly in drinkable and usable water, house wastewater, and industrial water with standard biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Thus, the areal and problematic examination and application of these industrialized products, which are to be applied in different amounts and ways, are also performed by us in the present study.

The problems which algae, or weed in the sea, causes are obvious during summer months. This study also aims to suggest ways of eliminating these problems by being applied in the Marmara Sea, particularly along the Istanbul–Tekirdag coastline.

1.4. Scope of the study

As it was mentioned with regard to the aim, instant diatom solutions are used in this study. They will continue to be used and later we will also use our own products after we develop diatom based products.

In the laboratory phase of the current study, firstly an aquarium sample and application area have been constructed. Five special systems have been established initially. This system includes dosage pumps, automated measuring tools, and lamps which can provide light for 24 h with a total of 1,000 W.

The system in the study is designed as a more developed version of a jar test in the laboratory (in which the dose of the substance and thinning rate is determined) which is used as a method in wastewater. The pH, soluble oxygen, and daily COD, suspended solid, N, and P analyses have been constantly measured. Different urban and industry water samples have been analyzed by adding them to the system. Diatom accommodation on rocks has also been observed by placing rocks regularly in the system. Later, the system is initiated with different feeding methods and the outcomes are also observed.

Diatoms and their products have a wide application area in Turkey. Diatom based products can be encountered particularly in Ömerli and Terkos dam lakes in Istanbul, where drinkable water is obtained; Sapanca, Küçükçekmece, and other lakes that have been contaminated. The complete removal of algae from contaminated or turbid lakes and

elimination of the algae in water will provide the water with more oxygen.

Dams that have been decommissioned as Alibeyköy Dam in Istanbul and the lake systems which are used for recreation purposes may cause unpleasant view, smell, and other unwanted situations which can be eliminated by the use of diatoms and diatom based products.

2. Methodology, materials, and application in the purification process

In this research, diatom based products and solid or liquid solutions, which have been successfully applied in the world, are used. Together with different climatic conditions, purification options are evaluated.

Our research is to be conducted by considering the effects of day and night zones, since these beings are able to photosynthesize even under low light conditions and according to the researches they produce ten times more oxygen than the Amazon forest which is regarded as the major oxygen source of the world (Amazon forest produces 20%–25% of the world's oxygen).

In order to prevent any interruption within the system – meaning any intermittent operation – for the researches and experiments which are carried out in daylight at nights, different lamplights, in specific light lumens, are used to be reflected on testing apparatuses.

In this context, the study encompasses two different perspectives:

- The condition in the natural state.
- Artificial additions which support the natural state.

The duration between sunrise and sunset in our country, specifically in summer months, is approximately 14–16 h. It is obvious that in summer months, natural purification can be carried out by the addition of the substance, without requiring any additional energy source, and the results can be directly transmitted to the application areas.

By determining the artificial state, which has been prepared as a support to the natural state, it has been attempted to determine the extent of the effects of the artificial state and to identify the changes which emerged.

Depending on the water quality of the lakes, a special solution grout has been applied one to four times a month. Specially prepared liquid formulation, obtained from diatoms, has been effectively applied within the proper hours [20].

In the research, inverse correlation has been established between the existence of diatoms and cyanobacterias. Oxygen is used by aerobic bacteria to disintegrate the organic substance and to consume sediment. It leads to concrete changes such as high dissolved oxygen levels, clearer water, the decrease in BOI, low coliform levels, decrease in mosquito colonies, and healthier aquatic life.

2.1. Different studies and examples of application in Turkey

Data and examples, which have been attained from the studies concerning wastewater systems, conduit type sewers, collectors, and wastewater purification lagoons, have been analyzed. The studies have been conducted in accordance with the quality of the water used.

2.2. Application example of the clean water in Turkey

When the study area, qualities, and composition of the water are examined, it can be understood that it possesses nitrogen, phosphorus, and other pollutants that should not have been existed in the water. Moreover, when biogenic alpine plants and other mosses are analyzed, it can be observed that the water was polluted in different ways.

The reservoir is bean-shaped and the dimensions of this artificial barrage is 700 m × 150 m with a depth of 1.5–3 m and its lake volume varies from 150,000 to 200,000 m^3. According to the statements of the Ministry of Health, more than 35,000 people are affected by epidemic and submissions caused by epidemic are evaluated within the frame of acute enteric disease and submissions related to ICD-10 diagnosis code have been observed [21].

Through environmental researches, it has been seen that drinking and domestic water has been obtained from those three water wells and this water has been fed by River Ceyhan, which is quite polluted, and this situation arises from the infectiousness engendered by the irrigation channel [21].

2.3. Conducting the study

The aim and objectives of the study are determined so as to provide solutions to enhance the quality of water, eliminate the moss, remove the effluvium, carry the water parameters to the acceptable levels, and increase the oxygen level.

This study was carried out between the 30th of July, 2019, and 3rd of August, 2019, with 4 d of practice and 1 d waiting, which is a 5 d study in total. Conmel Blue Ponds is added to the pond. The light system which consists of 250 W bulbs each is constructed in order to make the diatoms photosynthesize whole night (it is opened at 19.00 h and closed at 06.00 h).

The study includes the complete removal of the spirulina/moss which is available in high amounts in clean water.

The amounts of dosages and the result of the progression of the study are presented in Table 2, and the condition before and after the trial is given through the images.

The water in Pınarbaşı headwater lake (150–200 thousands m^3) is emptied, and 30–40 thousands m^3 ground mud is swept and removed. Even the partial recovery as a result of the sweeping could not prevent the reproduction of the algae.

This study is also important because of the existence of the extreme amounts of algae and their reproduction, since the spirulina/moss and different amounts of aquatic plants which cause visual pollution generate a significant problem here.

2.4. Applications/procedure

Before dosing, the dosed substance shows its effects very quickly during dosing hours. The dosed substance consists of Conmel Blue Ponds, a special (EM) substance

composed of useful diatoms. Diatoms which provide controlled and sustainable growth are special types of algae with an outer glass wall, and inside the shell is a photosynthesized single-celled organism that releases pure oxygen microbubbles.

Oxygen is used by aerobic bacteria to break down organic matter and deplete sediment. An increase in high dissolved oxygen (DO) results in a decrease in BOD, a significant decrease in coliform levels, removal of bad smells, a decrease in mosquito colonies in the water, and a healthier aquatic life [22].

In order to eliminate algae in Pınarbaşı Lake and increase the oxygen level in water, experiments were conducted with Conmel Blue Ponds (EM) for a period of 5 d between July 30 and August 2019.

When the condition of the lake was examined before application, the following observations were noticed. The surface of the lake was covered with unwanted algae. It did not look pleasing to the eye and there was a rancid smell in the lower parts of the lake as well as mosquitoes caused by this situation. It was observed especially at night. After application, the odor was largely removed, the algae were completely eliminated, and the water quality was significantly improved. While the dissolved oxygen content increased, BOI, COD and N, P values also decreased considerably.

The dosages used in the application are in the ratio of 1/2,000 to 1/10,000 specified in the specs, and in our application 1/10,000 dilution ratio is used and this ratio has proved sufficient.

2.5. Current situation of water and observations

Fig. 1 shows the current situation of Pınarbaşı Lake (30 July 2019). In this water, numerous blue–green algae exist. It has a strong algae smell. The color of the water is dark blue.

Then, special application was conducted for 4 d. After the application, the blue–green algae came to the surface and formed a brown structure on the water surface (Fig. 2). Then, it was collectively disposed of from the water surface. As a result, the bad smell disappeared and there was an excellent improvement in the color of the water. Figs. 3a and b show the current situation of Pınarbaşı.

Lake (31 July 2019).

Algae have been completely destroyed. While the bottom of the water could not be seen, now the water is completely clean. In Table 1, the parameters of Pınarbaşı Lake are given.

There has been noticed a rapid increase in the fish population which did not appear in the ecosystem. Water quality has considerably improved.

Fig. 1. Pınarbaşı Lake (30.07.2019).

Fig. 2. Pınarbaşı Lake (31.07.2019).

2.6. Applications in wastewater in Turkey: Istanbul Ambarli example

The collection, treatment, and disposal of wastewater in a way that does not harm the environment constitute an important matter today. In the DAMOC master plan, wastewater which is to be poured into Marmara, Bosporus, and Black Sea requires pre-treatment before discharging [23,24]. In the master plan prepared by IMC, advanced biological treatment of wastewater discharged to the Marmara Sea and drinking water basins, and wastewater discharged to the Bosphorus and the Black Sea through the first stage pre-treatment and advanced biological treatment were deemed appropriate [25].

In Istanbul, wastewater, sewerage networks in each basin, pumping station, and carrier collector lines are completely independent of each other [26].

Table 1
Clean water study in Pınarbaşı Lake using diatom

Parameter date	Before dosing	After dosing/total change			(%)
	30.07.2019	31.07.2019	02.08.2019	03.08.2019	
COD	266	106	83	77	**71**
BOD	195	45	34	33	**83**
pH	**7**	**7**	**7**	**7**	

(a) **(b)**

Fig. 3. (a and b) Latest status of Lake Pınarbaşı (1–3 August 2019).

In this study, data collected at different times regarding wastewater treatment plants have been used. The pollution parameters and total amount of pollutants that the plants send to the receiving environment have been determined [27].

- There is a need to improve the efficiency of existing biological wastewater treatment plants in Istanbul. The efficiency factor in the systems is between 0.7 and 0.85.
- Pre-treatment plants consist of structures in which particles with high density are precipitated and coarse and fine particles are retained in the grid and sand trap system. The share of these systems in pollution prevention is very small (2%–3%).
- The wastewater which is cleaned after the treatment in the facilities is poured into Marmara Sea, Bosphorus, and Black Sea. This shows that a very high amount of wastewater is discharged to the sea without being treated sufficiently.

Input and output wastewater values of Istanbul Ambarli advanced biological wastewater treatment plant are discussed in their current status. Then, studies were done by adding diatomic effective microorganisms (EM) used in our study and the results are shown in Tables 2 and 3. Input and output values of Istanbul Ambarlı advanced biological wastewater treatment plant.

The present study was conducted in the natural light environment during the day and at night four lightbulbs, each with 250 W of light were included in the system creating an artificial light environment and the substance was applied and the results observed for 24 h continuously. Firstly, the first state of the existing wastewater was analyzed. Dissolved oxygen level in water (DO), pH, COD, BOD, and suspended solids (SS) in water were measured. Then, the solution containing special diatom was applied to wastewater (Figs. 4–9).

3. Results and discussion

Diatoms, which enhance ecological productivity, have been commercialized for different purposes in many countries and have been used in stagnant water, in the sterilization of polluted lake and dam water, and wastewater treatment.

3.1. Elbistan–Ceyhan River Pınarbaşı application

Pınarbaşı Lake is the origin of the Ceyhan River, and this study is conducted in the dam lake located here. The characteristics of the research field and the water can be listed as following: the amount of dissolved oxygen (DO): 7–8 mg/L,

Table 2
Istanbul Ambarlı Wastewater Treatment Plant of result values

	COD		BOD_5		T–N		T–P		SS	
	Input (mg/L)	Output (mg/L)	Input (mg/L)	Output (mg/L)	Input (mg/L)	Output (mg/L)	Input (mg/L)	Output (mg/L)	Input (mg/L)	Output (mg/L)
Date (2017)										
July	483	50	260	11	49.2	6.7	5.0	0.6	398	41
August	488	42	272	10	45.7	5.0	5.0	1.0	384	22
September	516	66	265	13	54.6	6.0	5.5	1.0	334	67
Average	474	48	267	10	50.0	7.2	5.2	1.0	353	38
Date (2016)										
July	394	32	233	6	57.7	8.0	6.8	1.8	235	16
August	542	38	312	7	63.0	9.5	7.3	1.1	412	19
September	553	35	322	6	63.1	10.6	6.5	1.8	401	17
Average	503	35	284	6	57.2	7.2	6.4	1.2	362	16
Date (2015)										
July	581	41	340	10	65.5	5.5	6.6	0.5	525	21
August	589	55	319	8	61.1	6.1	4.9	1.0	491	50
September	525	43	300	8	61.5	6.6	5.1	2.1	513	39
Average	433	38	241	7	52.1	8.1	4.4	0.8	393	26

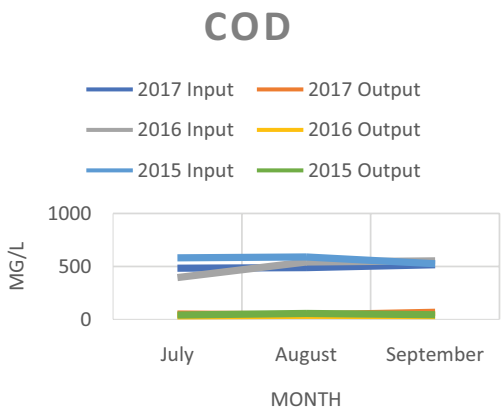

Fig. 4. COD chart.

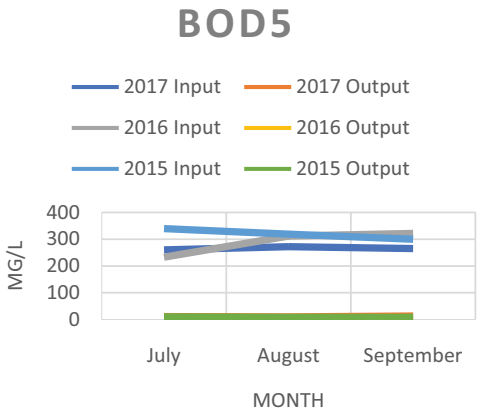

Fig. 5. BOD_5 chart.

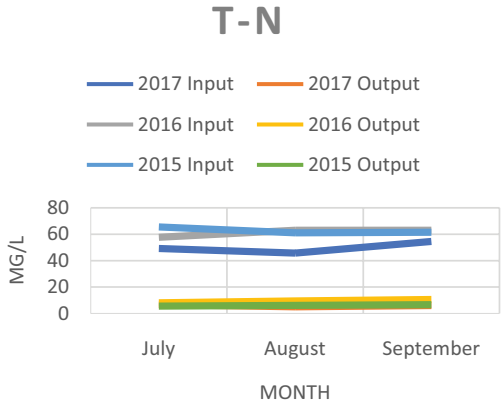

Fig. 6. T–N chart.

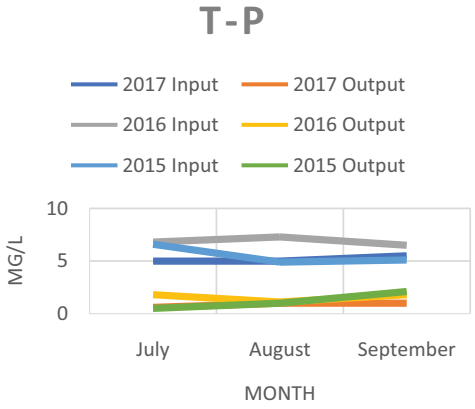

Fig. 7. T–P Chart.

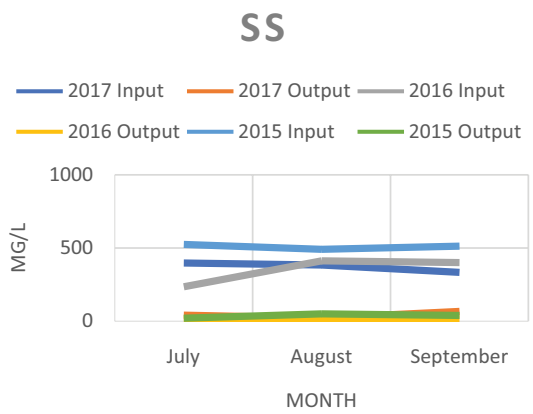

Fig. 8. SS chart.

the flow of Pınarbaşı spring: (Q_{min}): 5.5 m^3/s, the hardness of water of Ceyhan River in Pınarbaşı: 25–26°F (French hardness degree) and pH is >7.8.

The water compound should have consisted of small amounts of nitrogen, phosphor, and other contaminants; however, when the reproducing algae and other moss types are examined, it has been observed that the water is contaminated in different ways.

The existence of high amounts of spirulina in water and their reproduction is significant as well. Since, moss/spirulina and other types of aquatic plants in different amounts that cause visual pollution constitute a significant problem.

The time between 30th of July, 2019 and 3rd of August, 2019 (4 d application and 1 d waiting), in which the algae reach the maximum amount with the effects of the angle of the sunray, is a period of time that sun radiation and day glow reach to 14–15 h.

The light system which consists of 250 W bulbs each, is constructed in order to enhance the quality of water, to eliminate the moss, to remove the effluvium, to increase the oxygen level, and to make the diatoms photosynthesize whole night (between 19.00 and 06.00 h).

The effluvium has been eliminated to a great extent, the algae have been removed completely, an apparent improvement has been provided in water quality, the dissolved oxygen has increased and a significant decrease has been observed in BOI and KOI' and N, P values.

The application rate of this special solution (1:10,000–1:50,000 dilution rate is given) has been applied as 1:2,000–1:5,000 (1 L special solution for 2,000 L wastewater) for the wastewater. The water increases from 1:10,000 toward 1:50,000 as dirty to clean. The substance dosage in clean water is lower than the wastewater; thus, it is more economic.

In this research, the solution consisting of special diatom is injected to 35 L of water with 1:2,000 rate. 1/10,000 dilution rate is used in the dosage of the application out of 1/2,000 and 1/10,000 rates, and this rate has been enough for the research.

3.2. Study of Istanbul wastewater treatment by using diatoms

This study has been conducted in natural daylight and at night under artificial light by using four lamps with 250 W each, during 24 h continuously. The solution consisted of special diatom has been applied to the wastewater (Table 4). The application rate of this special solution has been determined as 1:2,000–1:5,000 (the water increases from 1:10,000 toward 1:50,000 as dirty to clean). At the end of 4 d of research, these results have been obtained [28].

3.2.1. Analysis

It took 100 h for water to reach complete clearness. This time period is equal to more than 4 d. The sample taken from the clear water has been analyzed in İSKİ laboratories. It has been revealed that the results are better than the most advanced biological treatment in the world (even better than the membrane supported advanced biological treatment systems).

SS, COD, BOD_5, N–N, and T–P value percentages below have been obtained as a result of the treatment.

4. Conclusion

As a result of our research, it can be concluded that a municipal treatment plant is an expensive option because of the lack of the proper areas to build a treatment facility

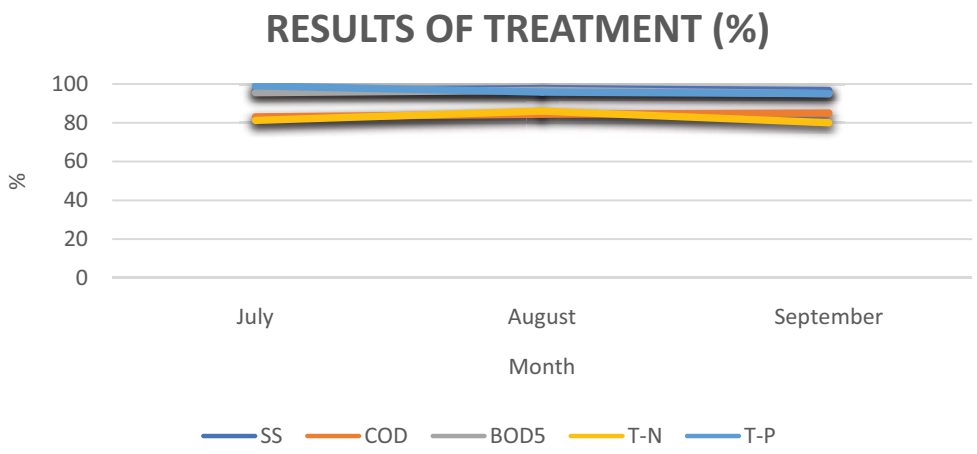

Fig. 9. Result of treatment chart (%), Istanbul Ambarlı wastewater treatment plant (2019).

Table 3
Study on the Treatment of Istanbul Ambarlı Wastewater Using Diatomes (2019)

Date (2019)	SS			COD			BOD_5			T–N		T–P	
	Input (mg/L)	Output I (mg/L)	Output II (mg/L)	Input (mg/L)	Output I (mg/L)	Output II (mg/L)	Input (mg/L)	Output I (mg/L)	Output II (mg/L)	Input (mg/L)	Output (mg/L)	Input (mg/L)	Output (mg/L)
July	518	54	**18**	672	153	**114**	363	27	**16**	61.14	11.45	7.85	**0.45**
August	532	49	**15**	631	139	**98**	311	23	**10**	61.53	8.69	8.25	**0.35**
September	513	67	**17**	689	151	**102**	399	40	**18**	76.89	15.21	10.31	**0.52**

Table 4
Result of treatment chart (%), Istanbul Ambarlı Wastewater Treatment plant (2019)

Date (2019)	SS	COD	BOD_5	T–N	T–P
		(%)			
July	96.5	83	**95.5**	**81.2**	99
August	97.6	84.4	**96.7**	**86**	95.8
September	96.6	85	**95**	**80**	95

(especially for the big cities), ground conditions, and the high amounts of wastewater, as the waiting period is very high in this type of treatment facilities. It can be also been concluded that these treatment facilities are more proper for the large and cheap areas or for the betterment of the available non-manageable lagoon type facilities. It is clear that at least 100 million m^2 area should be reserved for treatment in Istanbul, in which 2.5–3 million m^3 wastewater is produced in a day; however, it is impossible.

This study has revealed that this type of treatment is quite appropriate for the places having enough waiting period, besides the difficulty of its application in rich and dense settlement areas because of the wastewater's long waiting periods.

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