SEWAGE TREATMENT USING NEW DEVELOPED TECHNIQUES

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Abstract

Sewage is water-carried wastes, in either solution or suspension that is intended to flow away from a community .It is more than 99.9% pure water and is characterized by its volume or rate of flow, its physical condition, its chemical constituents, and the bacteriological organisms that it contains. Domestic sewage causes a problem to environment so that the treatment and disposal of wastewater is not only desirable but also necessary [(1)]. In this study, we are concerned with the sewage treatment using different techniques. Two major techniques were applied for wastewater treatment, namely biological and chemical treatments. In biological treatment we constructed a pilot and bench scale for applying the two aerobic and anaerobic techniques to reduce some of the studied parameters as BOD, COD, nitrogen and phosphorous at the optimum condition from used time and sludges and compared these results with effluents from plant. In chemical treatment the jar test technique was used where coagulants matter as alum, ferric chloride and polymer are added by a suitable dose of each coagulants.

Introduction

The principal sources of domestic wastewater in a community are the residential areas and commercial districts. Other important sources include institutional and recreational facilities and storm water (runoff) and groundwater (infiltration). Each source produces wastewater with specific characteristics. [(2)]

A wastewater treatment plant is a combination of separate treatment processes or units, designed to produce an effluent of specified quality from a wastewater (influent) of known composition and flow rate. The treatment plant is also, usually, required to process the separated solids to a suitable condition for disposal. By a suitable combination of these unit processes it is possible to produce a specified final effluent quality from virtually any type of influent wastewater (figure 1).

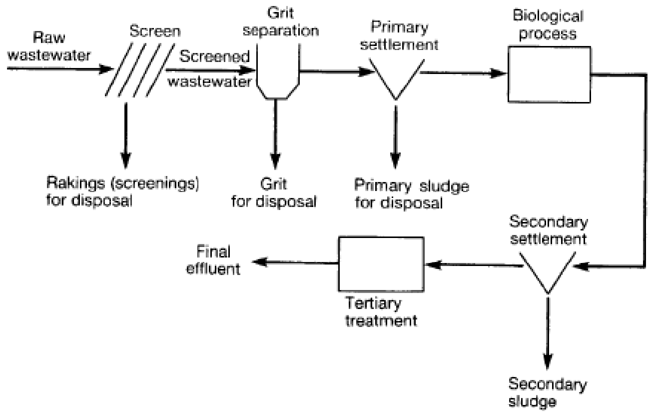

Fig. (1): Typical flow diagram for a wastewater treatment

Sewage treatment is the process that removes the majority of the contaminants from wastewater or sewage and produces both a liquid effluent suitable for disposal to the natural environment and a sludge [3].

Aim of wastewater treatment

(a) To convert the waste materials present in wastewater into stable oxidized end products that can be safely disposed to inland waters without any adverse ecological effects.
(b) To protect public health.
(c) To ensure that wastewater is effectively disposed on a regular and reliable basis without nuisance or offence.
(d) To recycle and recover the valuable components of wastewater.
(e) To provide an economic method of disposal.
(f) To comply with legal standards and consent conditions placed on dischargers.
(g) To treat sewage to be in agreement with the environmental laws.

Wastewater treatment technologies

In terms of treatment plant design, unit processes are classified into four groups or functions:

(i) Preliminary treatment

Preliminary treatment prepares waste-water influent for further treatment by reducing or eliminating non-favourable wastewater characteristics that might otherwise impede operation or excessively increase maintenance of downstream processes and equipments[4].

Preliminary treatment processes consist of physical unit operations, namely screening and shredding for the removal of debris and rags, grit removal for the elimination of coarse suspended matter, and flotation for the removal of oil and grease. Other preliminary treatment operations include flow equalization, septage handling, and odour control methods(5).

(ii) Primary treatment

Primary treatment involves the partial removal of suspended solids and organic matter from wastewater by means of physical operations such as screening and sedimentation. Preaeration or mechanical flocculation with chemical additions can be used to enhance primary treatment. Primary treatment acts as a precursor for secondary treatment. Its is aimed mainly at producing a liquid effluent suitable for downstream biological treatment and separating out solids as a sludge that can be conveniently and economically treated before ultimate disposal. The effluent from primary treatment contains a good deal of organic matter and is characterized by a relatively high BOD (6).

(iii) Secondary treatment

The purpose of secondary treatment is the removal of soluble and colloidal organics and suspended solids that have escaped from the primary treatment. This is typically done through biological processes.

Biological unit processes are used to convert the finely divided and organic matter in wastewater into flocculent settleable organic and inorganic solids. In these processes, microorganisms, particularly bacteria, convert the colloidal and dissolved carbonaceous organic matter into various gases and into cell tissue, which is then removed in sedimentation tanks. Biological processes are usually used in conjunction with physical and chemical processes, with the main objective of reducing the organic content (measured as BOD, TOC or COD) and nutrient content (notably nitrogen and phosphorus) of wastewater as follows (7):

(a) Oxidation:

COHNs + O_2 + Bacteria → CO_2 + NH_3 + Other end
(organic water) products + Energy

(b) Biosynthesis:

COHNs + O_2 + Bacteroa → $C_5H_7NO_2$
(Organic matter) (New cells)

(c) Auto-oxidation:

$C_5H_7NO_2 + 5O2 \rightarrow CO_2 + NH_3 + 2H_2O$ + Energy

(Bacteria)

Biological treatment processes fall into two large categories:

A- Fixed film systems and suspended growth systems. *Fixed film systems* [trickling filters and rotating biological contactors (RBCs)] use biological growth (biomass or slime) that forms on a media. The media provides a large area for slime growth, as well as ventilation. Wastewater passes over and around the slime on the media. With contact between the wastewater and slime, microbial organisms remove and oxidize the organic solids.

B-Suspended growth systems use biological growth that mixes with the wastewater. Typical suspended growth systems are various modifications of the activated sludge process(8).

(ív)Tertiary/advanced waste-water treatment

Tertiary treatment goes beyond the level of conventional secondary treatment to remove significant biological nutrient removal processes; unit operations frequently used for this purpose include chemical coagulation, flocculation and sedimentation, followed by filtration and activated carbon. Less frequently used processes include ion exchange and reverse osmosis for specific ion removal or for dissolved solids reduction(9).

Coagulation and flocculation constitute the backbone processes in most water and advanced wastewater treatment plants. Their objective is to enhance the separation of particulate species in downstream processes such as sedimentation and filtration. Chemical coagulation and flocculation with various salts of aluminum (e.g., alum), iron and other inorganic or organic chemicals are widely used processes to treat water for the removal of colloidal particles (turbidity) and microbes. Although alum and iron salts are the most widely used chemical coagulants for community water treatment(10).

Chemical coagulation-flocculation enhances the removal of colloidal particles by destabilizing them, chemically precipitating them and accumulating the precipitated materials into larger "floc" particles that can be removed by gravity settling or filtering. Flocculation causes aggregation into even larger floc particles that enhances removal by gravity settling or filtration. Coagulation with aluminum or iron salts results in the formation of insoluble, positively charged aluminum or iron hydroxide (or polymeric aluminum- or iron - hydroxo complexes) that efficiently attracts negatively charged colloidal particles, including microbes(11).

Coagulation / Flocculation of wastewater is a highly effective and commonly used process to remove COD (chemical oxygen demand), metals, and suspended solids. Chemical processes are also used to remove ammonia, and other toxic Pollutants e.g. cyanides. organics, pesticides, herbicides(12).

Experimental

Different wastewater samples are collected from different locations in order to be treated biologically and chemically. Three domestic wastewater from El-katamia, El-salam, Qaliube domestic wastewater treatment plants are collected from the initial effluent before the treatment lagoons.

A. Biological treatment:

Advanced or modified biological treatment (anaerobic/ aerobic) device was constructed in the lab of SCDREH and used in this study; the device used in biological treatment processes is a small pilot plant similar to that constructed in any of domestic sewage treatment plant is shown in figure (2).

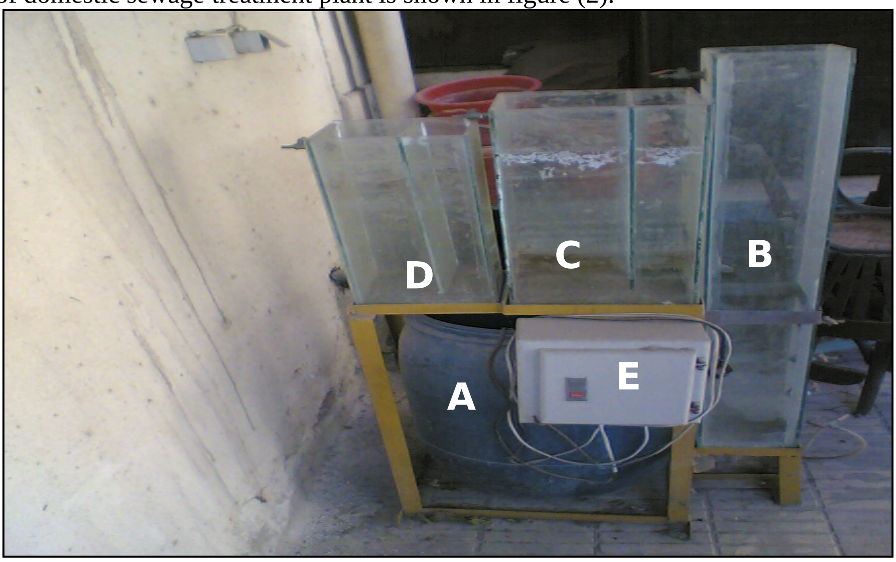

Figure (2): A-Influent container B-Settling container C-Aerated container and D-Anaerobic container E-Electrical motor

The flow rate from the inflow wastewater container passing to the other aerobic and anaerobic containers was adjusted at 60 ml/min and the volume of each container is 1000 ml.

1. Aerobic technique:

- In the aeration tank an air source was adjusted to make the dissolved oxygen (DO) content in range of 2-3 (mg/L).
- This air source acts as a stirrer of the wastewater sample.
- Different amounts of MLSS were used (1500, 2000, 2500, 3000 and 3500 (mg/L))
- Different parameters were determine before and after the addition of MLSS, at different times of 0 (before addition of MLSS), ½,1, 2, 3 and 4 hours.

2. Anaerobic technique:

- This was applied as in case of aerobic technique in the absence of air source. After stirring the wastewater, samples were withdrawn from each part and subjected to the different analysis.
- The results for each stage, aerobic and anaerobic containers, were compared to detect the optimum treatment and compare the optimum condition with the plant; this includes pH, electrical conductance, alkalinity, turbdity, TDS, TSS, COD and BOD.

B. Chemical treatment

The Jar test, as a laboratory procedure, was carried out for evaluating coagulation, flocculation, and sedimentation processes in a series of parallel comparisons (pH 8.5 or 11).Good process control of chemical addition emphasizes application of the proper amounts of chemicals for settling enhancement and ensures that chemicals are well mixed[13].

The coagulants used in this study were prepared as follows:

Stock 1% alum solution**:** 1gm of the (aluminum sulphate) was dissolved in 100 ml distilled water; this represent a concentration of 10 mg alum / ml solution.

***Stock 1% ferric chloride*:** 1gm powdered ferric chloride was dissolved in 100 ml distilled water; this should be mixed by shaking every time (concentration = 10 mg/ml).

Stock 1% polyacrylamide (polymer): 1gm powdered polyacrylamide was dissolved in 100 ml distilled water; this should be mixed by shaking every time (concentration = 10 mg/ml).

To determine the correct chemical dosage, a jar test or coagulation test was performed to study the effect of treatment by using different doses of coagulants on the quality of the treated wastewater.

Results and Discussion

1. Katamia domestic sewage treatment plant

A- Biological treatment

The biological treatment (activated sludge system treatment) was carried out on the domestic sewage influent (this is zero time) by using different amounts of mixed liquor suspended solids (MLSS) of 1500, 2000, 2500, 3000 and 3500 mg/L; this was represented in the tables by the symbols ***A, B, C, D and E,*** respectively, at interval times (1/2, 1, 2, 3, 4 hours) by using a source of air (aerobic process) and in the absence of air source (anaerobic process). This was done by the determination of the studied parameters as pH, conductivity, total dissolved solids, suspended solids, turbidity, salinity, biochemical oxygen demand, chemical oxygen demand, ammonia, some heavy metals, etc. before and after treatment and compared with each amount of MLSS until reaching to the maximum removal of the studied pollutant (100 % removal) at the minimum amount of MLSS and/or minimum time required; this represents the optimum condition for removing of the pollutants.

In the biological treatment, the pH value was adjusted at about 6.5 - 7.5 and the sample was good mixed and then taking a time to settle in the sedimentation tank[(14)]. The flow rate was adjusted to pass to the aerobic tank and to the anaerobic tank. At the optimum condition the sample was passed by aerobic tank to anaerobic tank then to aerobic tank again to give the complete removal for all of the studied pollutants, if needed to this sequence of the treatment techniques.

Example (1): Removal of ammonia

The removal of nitrogen was effected through the biological oxidation of nitrogen from ammonia (nitrification) to nitrate, followed by denitrification, the reduction of nitrate to nitrogen gas. Nitrogen gas was released to the atmosphere and thus removed from the water[(15)].

The data obtained for the removal of ammonia concentration is recorded in Table (1) and represented graphically in Figures (3 & 4) for aerobic and anaerobic treatment techniques, respectively.

Table (1) Ammonia concentration (mg/L) after aerobic and anaerobic treatment processes

.h	Ammonia concentration(mg/l) in Aerobic process						Ammonia concentration(mg/l) in anaerobic process				
	A	B	C	D	E		A	B	C	D	E
0	54.5	54.5	54.5	54.5	54.5		54.5	54.5	54.5	54.5	54.5
1/2	46.5	43	42	39	34		53.5	52.1	59.6	48.6	46.5
1	36.7	32.4	28	2.6	13		48.9	46	43	40.5	36.5
2	16.5	12	8.7	6.5	3.5		42.6	40.1	37.5	34.7	29.2
3	4.3	0	0	0	0		36.5	32.3	29	26.3	20.1
4	0	0	0	0	0		24.6	22.9	18.6	13.8	9.5

On the other hand, during anaerobic treatment techniques the concentration of ammonia decreases by its accumulation or its adsorption by bacteria or organisms and this does not lead to 100% removal.

The maximum removal of ammonia is obtained by the amounts of MLSS 1500, 2000 to 3500 mg/l at times of 4, 3, 3, 3 and 3 hours and the optimum condition for 100% removal (zero concentration) of ammonia was found at 3 hours using 2000 MLSS content under biological aerobic treatment techniques.

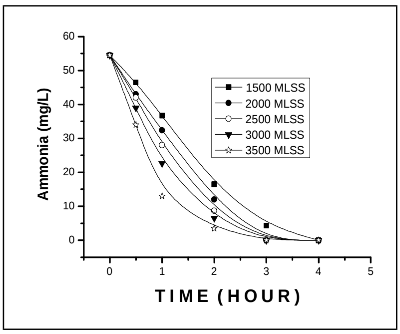

Fig. (3): Ammonia (mg/L) in aerobic treatment techniques

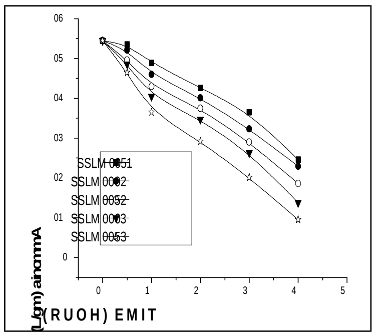

Fig. (4): Ammonia (mg/L) in anaerobic treatment techniques

Example (2): *Biochemical oxygen demand (BOD):*

Biochemical oxygen demand (BOD) is the amount of oxygen consumed by the organism in the process of stabilizing waste. As such, it can be used to quantify the amount or concentration of oxygen-consuming substances that a wastewater may contain. Analytically, it is measured by incubating a sample in a refrigerator for five days at a temperature of 20 ºC and measuring the amount of oxygen consumed during that time [16].

The measurement of BOD_5 is a significant parameter and provides an important basis for determining plant loading and design considerations. As designed, the BOD_5 test typically measures the amount of oxygen required to oxidize the organic matter in the sample.

The extent of oxidation of nitrogenous compounds during the 5-day incubation period depends upon the type and concentration of microorganisms that carried out biooxidation. The nitrifying bacteria are usually not present in raw or settleable primary sewage [(17)].

Table (2): BOD_5 concentration (mgO_2/L) using aerobic and anaerobic processes

.h	BOD concentration in Aerobic process						BOD concentration in anaerobic process				
	A	B	C	D	E		A	B	C	D	E
0	352	352	352	352	352		352	352	352	352	352
1/2	320	300	290	281	264		322	304	291	283	265
1	290	225	212	188	174		293	230	215	190	175
2	195	113	95	86	71		197	115	96	87	72
3	90	0	0	0	0		92	0	0	0	0
4	0	0	0	0	0		0	0	0	0	0

The optimum condition was recorded using 2000 to 3500 MLSS content at 3 hours for aerobic and anaerobic processes for 100 % removal. The best condition for treatment of the studied pollutants was found to be 2000 MLSS after 3 hours.

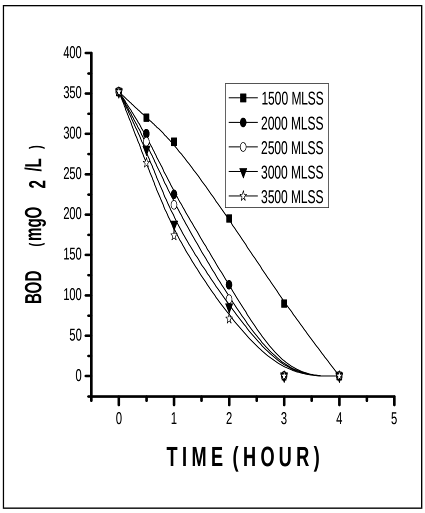

Fig. (5): BOD (mgO_2/L) in aerobic treatment techniques

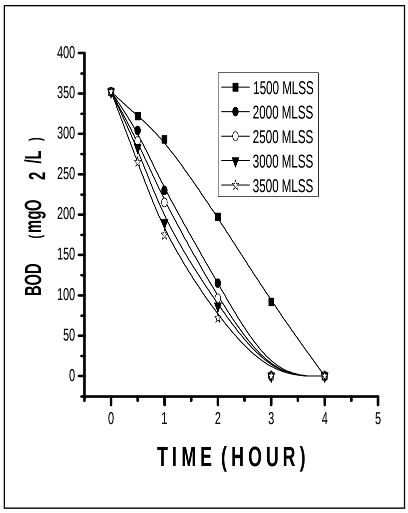

Fig. (6): BOD (mgO_2/L) in anaerobic treatment techniques

Table (3): Comparison between effluent characteristics in katamia plant and in pilot plant (Biological treatment)

Parameter	Out in katamia plant	Out in lab
pH	7.5	7.65
Conductivity (μs/cms)	398	18 (aerobic), 25 (anaerobic)
Total dissolved solids (mg/L)	252	12 (aerobic), 16 (anaerobic)
Turbidity(NTU)	2	2
Total suspended solid(mg/L)	9	7 (aerobic), 13 (anaerobic)
Total hardness(mgCaCO3/L)	70	0
Calcium ion(mg/L)	16	0
Magnesium ion(mg/L)	8	0
Biochemical oxygen demand(mgO2/L)	10	0
Chemical oxygen demand(mgO2/L)	16	0
Oil and Grease(mg/L)	0.7	0
Total organic carbon(mg/L)	43	0
Total Alkalinity(mgCaCO3/L)	55	0
Ammonia(mg/L)	3.4	0 (aerobic), 9.5 (anaerobic)
Total phosphorus (mg/L)	0	0
Sulphide(mg/L)	0.3	1.2 (aerobic), 0 (anaerobic)
Sulphate(mg/L)	50	91(aerobic), 0 (anaerobic)
Chloride(mg/L)	30	0
Fluoride(mg/L)	0	0
Nitrite(mg/L)	0	0
Nitrate(mg/L)	1.8	14 (aerobic), 0 (anaerobic
Acetate(mg/L)	0.02	0
Cupper(mg/L)	0	0
Zinc(mg/L)	0.05	0
cadmium(mg/L)	0	0
lead(mg/L)	0	0
Nickel(mg/L)	0.05	0
Iron(mg/L)	0.09	0
Aluminum(mg/L)	0	0

The results obtained in the pilot plant indicated higher maximum removals than those in katamia plant due to the following:

(i)Heterogeneity of the microbial population.

(ii) Increased metabolic activity; this leads to increase in respiration and substrate use, hence higher removal rates.

(iii) Better resistance to toxicity.

(iv) Increased persistence in reactor; this leads to increase in biomass of organisms, reduction of hydraulic retention time and thus smaller reactor volumes.

The influent in plant may be too much and affect negatively on the quality of the effluent as well as some troubleshooting which happen in mechanic operator; each operator has a great effect on the efficiency of treatment but the pilot plant is easy to control.

B-Chemical treatmena-

a- Effect of treatment by using alum on the quality of the treated wastewater:

Several jar tests containing different doses of 1% alum of 1, 3, 5, 7, 10 and 30, 50 and 70 mg/L to the wastewater sample were carried out to determine the best dose of alum addition. The results obtained from this study indicated variations in pH, **Total** suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total dissolved solids (TDS), nitrate, nitrite, sulphate, fluoride, sulphide and conductivity as compared with their values before treatment.

The results showed that the addition of alum leads to general decrease in the values of the above studied parameters except those obtained for DO which show some increase. The best dose of alum required in affecting conductivity, TDS, TSS, turbidity, BOD, COD, chloride, sulphate, nitrate, total alkalinity, sulphide, copper, zinc and nickel was 30 mg/L and the dose required for removal of T-P, ammonia, fluoride, nitrite, aluminum and O&G was 10 mg/L and and the dose required for removal iron was 50 mg/L

Generally, the best dose of alum which affects the measured parameters was 30 mg/L. Also, the floc size formation increases with increasing the dose till the dose of 50 mg/L sample and so the settlement rate becomes more faster, then flocs formation started to get smaller with higher alum doses; which recorded at 70 mg/L; and it gets numerous and lighter. So, it was noticed that the levels of the studied pollutants such as total suspended solids, biochemical oxygen demand and chemical oxygen demand tend to higher values again and dissolved oxygen begin to decrease than that before the lighter flock formation doses.

b- Effect of treatment by using ferric chloride on the quality of the treated wastewater:

To determine the effect of increasing ferric chloride dose on water quality, different doses of 1, 3, 5, 7, 10, 30, 50 and 70 mg/L were added. The results revealed a major advantage of ferric chloride coagulant for improving floc characteristics.

The obtained results showed that addition of ferric chloride leads to a general decrease in the levels of the above studied parameters except those obtained for DO which show some increase. The best dose of ferric chloride required in affecting the values of conductivity, TDS, TSS, turbidity, BOD, COD, ammonia, chloride, sulphate, nitrate, total alkalinity, sulphide, copper and nickel was 10 mg/L and the dose required for removal T-P, fluoride, nitrite, aluminum and O&G was 7 mg/L and the dose required for removal iron and zinc was 30 mg/L Generally, the best dose of ferric chloride which strongly affects the levels of the measured parameters was 10 mg/L.

The flocs are large, dense and heavy until reached the dose of 10 mg/L, then the formation of flocs become started to get smaller and lighter with increasing the doses of ferric chloride than 10 mg/L, and so some of these parameters tend to increase again.

c- Effect of treatment by using polymer on the quality of the treated wastewater:

The effect of increasing of polymer (polyacrylamide-low molecular weight) doses on the water quality was studied; the doses of 1, 3, 5, 7, 10, 30, 50 and 70 mg/L were used. The best effective dose was found to be 10 mg/L.

The results show the addition of polymer leads to a general decrease in the above studied parameters except those obtained for DO which show some increase. The best dose of polymer affecting the levels of conductivity, TDS, TSS, turbidity, BOD, COD, ammonia, chloride, sulphate, nitrate, total alkalinity, sulphide, copper. iron, zinc and nickel was 10 mg/L and the dose obtained for removal of T-P, fluoride, nitrite, aluminum and O & G was 7 mg/L. Higher concentration of polyacrylamide becomes less effective.

2. El-Salam domestic sewage treatment plant

A. Biological treatment

The best condition for treatment of the studied pollutants was found to be 2500 mg/L MLSS after 3 hours.

B. Chemical treatment

The best amounts of the used coagulants were found to be 30, 10 and 10 mg/L for alum, $FeCl_3$ and polymer, respectively.

3. Qaliube domestic sewage treatment plant

A. Biological treatment

The best condition for treatment of the studied pollutants was found to be 3000 mg/L MLSS after 4 hours

B. Chemical treatment

The best amounts of the used coagulants were found to be 90, 70 and 70 mg/L for alum, FeCl3 and polymer, respectively.

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