Elimination of Sludge from Water Treatment Process of Petrochemical Industrially Oxidation with Ozone

Abdolreza Ahmahpour*, M. Khashefi Asl*

**Department of Environment, North Tehran Branch, Islamic Azad University, Tehran-Iran*

ABSTRACT- Excess sludge from biological treatment of industrial wastewater is a process that risks to human health and the environment. It must be destroyed by incineration in a special furnace. Sludge incineration has some disadvantages such as large initial investment, high operating cost, energy waste and also produces secondary pollutants such as ash and gas problems. Therefore, any process that reduces costs and secondary pollutants can be effective in the stabilization of biological sludge. This is a good alternative to existing processes. Due to the high oxidation power of ozone, the addition of it accelerates the decay and mineralization of sludge in sludge stabilization process. The purpose of this investigation is to evaluate the effect of different doses of ozone on sludge biological treatment of industrial wastewater. In order to scale the construction, ozone generator and ozone disinfection with volume of 2 litters reactor was used. Parameters such as TSS, VS, and TDS were measured. The results of this study showed that ozone doses with 0.48 - 2.38 O3gr/TSgr in sludge reducing the amount of TSS and VS from 33.67 - 90.78 and 17.5 - 47.48 % respectably. The effect of ozone dosage on the settling of solids in the sludge also tested and it showed that deposition material is improved with increasing ozone dose. So that Sedimentation of solid in the raw sludge decreased from 876 ml/l to 345 ml/l at dosage of 1.46 O3gr/TSgr and to 152 ml/l with increasing dose to 2.38 O3gr/TSgr. Therefore, ozonation can be applied to improve the performance of industrial wastewater treatment and stabilization of the sludge. In addition Pre-ozonation increases decay rate of solid, and therefore reduces the size and area of the wastewater treatment facility.

***Key words**: Biological sludge, Industrial wastewater treatment, Waste burning, Ozonation, Oxidants*

INTRODUCTION

The discovery of huge natural gas reserves and resources in the South Pars Special Economic Energy Zone has caused the rapid growth of oil industries including petrochemicals in Assaloyeh-Iran region. The creation of petrochemical industries and diversification of production has led to a wide range of toxic and hazardous substances such as polycyclic aromatic hydrocarbons, heavy metals and other pollutants in the wastewater of these companies. So the neglect of this topic can create problems for the environment of this region. Observing environmental laws and regulations, particularly industrial waste management can somewhat reduce the risk of pollution arising from companies activities. Petrochemical companies have been built adjacent to each other in Assaloyeh region. In this regard, Mobin Petrochemical Company provides lateral and centralized services such as purification of industrial waste. The company's wastewater treatment process is based on biological sludge, so that the sludge is burnt in the waste incineration unit; however, there are some disadvantages for sludge incineration such as large initial investment, consumption of natural gas for heating, the loss of and valuable and recyclable materials, and production of secondary pollutants such as gas and ash. To solve the mentioned problems, it seems necessary to provide appropriate solutions to remove the excess biological sludge of industrial wastewater treatment plant. In this regard, high oxidizing power of ozone in decomposition and decay of microorganisms and converting organic materials of sludge into minerals was regarded as the topic of graduate thesis titled "Removal of biological sludge obtained from the petrochemical wastewater treatment plant by oxidants with ozone". Biological sludge obtained from wastewater treatment plant of Mobin Petrochemical Company was ozonated and tested as an actual sample in three stages at different time intervals. This study showed that the removal of excess biological sludge by oxidants with ozone is possible as well as using the above process can effectively reduce the initial investment, operating costs, and the production of secondary pollutants.

Biological sludge stabilization process

Activated sludge process is used as a biological technology for wastewater treatment; in fact, it is applied by more than 90 percent of municipal and industrial wastewater treatment plants as the main part of the treatment process [1]. In this process, a large volume of excess sludge (considered as waste and secondary pollutants) is generated and should be stabilized or disposed removed in a safe and affordable way. The stabilization process of sludge is one of the main stages of wastewater treatment.

Providing appropriate solutions for the stabilization of biological sludge

The present study is aimed at seeking appropriate solutions to remove the excess biological sludge of industrial wastewater treatment plant and replace the anaerobic digestion method with the removal one. It is expected to obtain the following results from the removal method:

1- The reduction of initial investment

2- The reduction of operating costs

3- The efficient use of energy and recovery of materials in the biological sludge.

4- Removing the secondary pollutants.

The need for changes in sludge stabilization process

Far, the issue of industrial wastewater has been taken into consideration from two fundamental**,**aspects. The first aspect is the issue of environmental pollution and its consequences and the second aspect is to prevent waste of resources and increase profitability. Many studies have been conducted on the first aspect in industries, but the second aspect which takes into consideration the waste from the perspective of efficiency and providing appropriate solutions (i.e. for waste reduction, optimization of recycling, and reuse of waste) is less regarded [7]. In this study, both aspects have been taken into account from the perspective of reducing resources consumption, efficiently using energy and materials of sludge, and removing secondary pollutants.

The history of ozone and wastewater disinfection

In the United States, ozonation was firstly used for municipal wastewater disinfection in Jersey City, New Jersey, in 1908 [8]. The first ozonation treatment plant was launched to control taste and odor in Whiting Indiana in 1941, which it still continues to work for this purpose. In addition to Indiana, ozone is used to disinfect drinking water in Pennsylvania and Strasburg. In the United States, the use of ozone for drinking water is less than in Europe. Actually, ozone was firstly used in Europe, France, in the early twentieth century to disinfect the water. Latter, the application of ozone increased and eventually spread to several countries in Europe. Today, there are mainly more than a thousand units for water disinfection with ozone in Europe, which all of them are approximately used to disinfect water. A common application of ozone in these installations is to control factors producing taste, odor, and color.

The water treatment plant of Garmsar-Iran

The project of supplying water to Garmsar (in Semnan province) has been implemented with a credit amounting to 325000$ in a transmission line with a length of 45 km and a capacity of 520 liters per second and the water treatment plant with a capacity of 44930 cubic meters per day. This treatment plant is located adjacent to the water treatment plant in the northern part of Garmsar in Boneh Kooh region. The ozonation equipment of Garmsar water treatment plant (with a capacity of 4.6 kg per hour) includes two working units each with a capacity of 2.3 kg per hour and a machine with a capacity of 2.3 kg per hour as the spare part.

The water and wastewater treatment plant of Kashan-Iran "Kashan Water and Wastewater Company" with supervision of "Utilization Department of Qom Water and Waste Company" has begun the ozonation of Kashan wastewater treatment plant since 2008. The project details are as follows:

The project subject: Installation of ozone-based water disinfection system with the volume of 15 liters per second

The year of project implementation: 2008

Supervisory authority: Utilization Department of Kashan Water and Wastewater Company

The wastewater treatment plant of Isfahan-Iran "Isfahan Water and Wastewater Company" with supervision of Utilization Department has begun the ozonation of Isfahan wastewater treatment plant since 2010. The project details are as follows:

The project subject: the purchase and installation of an ozonation system to aerate the wastewater treatment plant (located in south of Isfahan) to inject ozone into the current wastewater pond at the rate of 0.1ppm.

Capacity: about 200 grams of pure ozone per hour

Municipal water treatment plant of Arak (Saveh)-Iran "Arak Water and Wastewater Company" with supervision of "Utilization Department of Markazi Province Water and Wastewater Company" has begun the ozonation of municipal water treatment plant of Ghaem dam in Saveh since 2013.

The risks of using biological sludge Improper use of sludge will cause risks to public health and the environment; hence, it is necessary to prevent the excess materials whose amounts are non-standard. Among these materials, it can be pointed to heavy metals such as copper, lead, zinc, cadmium, mercury, and nickel (known as trace and heavy metals) and some other metals, which all are of the natural and inevitable ingredients of waste. Despite the fact that some metals are essential for plant growth, the excessive amounts of them can be harmful for plants, animals, and humans. Durability and stability of metals in soil is unlimited, because metals are not destroyed and disintegrated in the soil and their fracture in soil is very low.

The properties and applications of ozone in industries

Ozone is almost a blue gas with a pungent odor, a triatomic allotrope of oxygen that is unstable and heavier than air at high concentrations. In lower concentrations, it is colorless and has a specific odor; however, in high concentrations, its color is light blue. The maximum amount of ozone in Earth's atmosphere can be found in layers which are 15-50 km above he Earth's surface in a region called the stratosphere. In the stratosphere, ozone is found as the ozone layer protecting the Earth from the excessive radiation of harmful ultraviolet rays [14]. Ozone is a powerful oxidizing disinfectant and has various applications in industry, agriculture, pharmaceuticals, etc. Among many applications of ozone, it can be pointed to disinfection, removing odor and color in water treatment industries, air purification, and disinfection of floor, surfaces, objects, and various materials. Unlike conventional disinfectants such as chlorine, formaldehyde, and other chemicals, oxidation and disinfection with ozone does not leave any toxic or harmful material. Ozone has the capability of removing pathogenic compounds of chlorine and nullifying all chlorineresistant microorganisms. This material unlike chlorine does not produce harmful compounds or create the chlorine-related problems such as eye and nose irritation, dry skin, etc. in pool water. These properties make ozone popular for being used in swimming pools. To eliminate the problems associated with chlorine and provide better services to customers, many pool owners think of ozone as a new approach to solve the existing problems. However, all valid resources including Environmental Protection Agency (EPA) have explicitly emphasized that ozone alone is not sufficient to disinfect the pool water and it is necessary to apply supplemental disinfectants along with it. In many parts of Europe, ozone is mostly used to

Disinfect the water and simultaneously remove the odor, taste, flavor, and color of iron and manganese.

Ozone generators

In equilibrium, the thermodynamic output of an ozone generator is slightly less than 5%. The major part of the energy is lost as heat. The important factors affecting the energy lost are as the reduction of electric field and flow rate, gas composition, and the duration of stay in the discharge area. As mentioned, the discharge method is technically and economically preferred over other methods and is considered as the main method of generating ozone.

Efficiency and Benefits of Ozone Strong oxidizing properties of ozone have been used widely in the industry. Some properties and applications of ozone are as follows:

- High oxidizing power (up to 50 times more powerful than chlorine)
- Higher speed of effectiveness on a wide range of microorganisms compared to chlorine and hypochlorite; the effectiveness on microbes and bacteria is up to 3125 times faster and on viruses 600-100 times faster.
- Broad destruction of algae, fungi, molds, and spores, decolorization, the removal of unpleasant odor and organic materials in various industries.
- Oxidation of minerals such as iron and manganese and the coagulation of dissolved solids to keep the water pure.
- A 70-90% reduction of chemicals in pools and no eye and nose irritation
- Broad-spectrum sterilizing including sterilization of air and removal of pollutants in the air.
- The capability of being used in humid environments.
- It does not change the PH of water.
- Disinfecting the processes of food industries, swimming pools, cooling towers, and so on.
- Oxidation of water impurities and removal of heavy metals from water.

METHODOLOGY

The measurement tools

In experiments, the following tools are used to measure the required parameters: digital scales, ovens, glass fiber filters, Imhoff or Vonhoff funnels, vacuum equipment and pumps, Erlenmeyer flask, filters, pipettes, beakers (glassware), desiccators, electric heaters, furnaces, pH meters, pressure gauges, 2-liter glass reactors, ozone generators, ozonation fittings, mercury thermometers, flow meters, and atomic absorption spectroscopy. In the following, the experiments performed using the above tools are described in detail and separately.

The statistical sample of experiments

The parameters were tested and measured through a three-stage sludge sampling at different time intervals in which each stage was repeated twice and the average values were calculated. Experiments to determine the values of TSS, TS, VS, TDS and SVI were performed according to the methods described in the book "Standards for water testing" [19].

The experimental variables

Parameters such as volume, mass and pH of the sludge, the reactor pressure and temperature, contact time, and ozone dose are the most important factors which have the highest effect on experiments. In each test, the main variables are the ozone dose and concentration of sludge. Hence, the impact of these variables on the amount of sludge removal was assessed through measuring the indices of TSS, TDS, TS, VS and SVI in the sludge samples taken from the outlet of clarifier pond in wastewater treatment plant of Mobin Petrochemical Company.

Samples preparation and measurement of parameters

In each experiment, the way of preparing the sludge is an effective factor. The results of sludge nalysis depend on operating conditions of the treatment plant, containers used for the experiment, and the place and manner of sampling. Here, it is attempted to keep all environmental conditions uniform in research stages. In each test, the parameters such as the amount of moisture content and organic materials as well as the indices of TSS, TS, TDS, VS and SVI (Sludge Volume Index) were firstly measured and recorded.

Determining the sludge weight percent

The sludge weight percent was determined by gravimetric method and through drying the samples in oven machine at a temperature of C ° 110. The moisture content of the sludge samples was measured at three different time intervals at which the measurement was tools were used: laboratory scales, pipettes, graduated cylinders with a volume of 150 ml, the oven or autoclave, and the desiccator [20].

Calculating the sludge weight percent The weight percent of water in the sample is equal to the difference between the initial weight of the sample (W1) and the weight of dried sample (W2) divided by the initial weight of the sample (W1) multiplied by a hundred. Thus, the weight percent of water is calculated as follows:

$$w = \frac{w1 - w2 \times 100}{w1}$$

In above equation, W, W1, and W2 respectively stand for the weight percent of water in the sample, the initial weight of the sample (sludge + water), and the weight of dried sludge in the sample.

The measurement of iron

Two liters of sludge is stirred well and 50 ml of it is poured into an Erlenmeyer flask. Then, 2ml of concentrated hydrochloric acid and one ml of hydroxylamine is added to the Erlenmeyer flask and the solution is boiled. Heating is continued till the volume is reduced to 20-15 ml, so that the iron sample is completely dissolved. Then, the solution is cooled and transferred to a 50 or 100-ml flask. Later, 10 ml of ammonium acetate buffer solution and 4 ml of phenanthroline solution is reached to equivalence point and put into the atomic absorption device. After 10 minutes, the results should be read. Accordingly, the samples of other elements were measured.

Determining the total suspended solids (TSS) of sludge at a temperature of 103-105 ˚ C

A certain volume of a sample previously well mixed is taken and filtered through a weighed standard glass-fiber filter (about 2 microns). Residual particles on the filter are dried at a temperature of 103-105 ˚ C until reaching a constant weight.

Determine the fixed and volatile solids of sludge (burned at a temperature of 500-550 ˚ C) The remaining particles (or the particles obtained from the TSS measurement method) are burnt at a temperature of 500-550 ˚ C to reach a constant weight. What remains is the total of dissolved and suspended constant solids; in this regard, the weight loss shows the amount of volatile solids. This way of measurement shows the approximate amount of organic matters existed in the solid phase of waste or industrial wastewater. Determining the amount of fixed and volatile solids is an appropriate criterion to identify the proper functioning of wastewater treatment plant.

Determining Settable Solids Volume (SSV) and Sludge Volume Index (SVI)

To determine the volume of settable solids, a liter of sludge sample is poured into Imhoff or Vonhoff funnel and kept constant for 30 min. then, the amount of settled sludge is read using **t**he numbers on the funnel. In this experiment, the amount of settled sludge has been obtained equal to 842ml/l:

SSV_{30}= 842ml/l

Sludge ozonation

A liter of sludge sample well stirred at a temperature of 32 ˚ C is taken and poured into a laboratory cylindrical reactor. Then, it is put inside a container of warm water with a temperature of 32 ˚ C. The ozone generator is turned on and the oxygen inlet valve is adjusted so that the flow of output ozone is fixed on 2 C_3gr/min and a pressure of 1 Barg. Table 1 shows the time (in minute) required for injecting different dosages of ozone. To generate ozone, all experiments are carried out using pure oxygen.

Calculations

After the completion of each stage of ozonation, the amount of ozone remained from the gas phase of the reactor is measured using the absorption technique in potassium iodide, namely iodometry method. In fact, table 1 shows the average results of all tests (conducted in this research so far) in summary. In all experiments, each stage has begun with taking one liter of sludge sample; also the ozonztion has been performed in uniform conditions. To get optimal results, the sampling of sludge (removed from the clarifier) was carried out in three stages at different time intervals. Each parameter was measured twice. TS, TSS, and VS are the parameters measured before and after ozonation. As mentioned, table 1 shows the average results of all tests. According to table 1, ozonation causes the reduction of VS; as a result, sludge ozonation causes the decay and mineralization of organic materials and the reduction of volume and mass of sludge.

Table 2 shows the results obtained from the experiments carried out with different dosages of ozone.

Testing Stages	1	2	3	4	5	6	7
Injection Time (min)	0	0.9614	2.4037	4.8074	7.2111	9.6148	12.0185
The Amount of Injected ozone (gr)	0	1.92295	4.80739	9.61478	14.42217	19.22956	24.03695
The Amount of Gas-phase Ozone	0	0.07614	0.14306	0.27342	0.37821	0.77834	1.10854
The Amount of Consumed Ozone(gr)	0	1.84681	4.66433	9.34166	14.04369	18.45122	22.92841
Ozone Dosage	0	0.19208	0.48512	0.97159	1.46063	1.91905	2.38426
TSS (mg/l)	8532.37	8147.8	5659.1	3457.3	1453.5	1238.8	786.4
TDS (mg/l)	1082.36	1256.12	1758.32	2354.67	2754.61	3157.46	3412.14
TS (mg/l)	9614.78	9403.92	7417.42	5811.97	4208.11	4396.26	4198.54
VS (mg/l)	6434.77	6276.81	5556.18	4689.40	4209.23	3663.71	3537.21

The comparison of results indicates that increasing the dosage of ozone leads to the reduction of volatile solids so that the amount of VS reduction at ozone dosages of 0.97 and 2.38 / is respectively about 30 and 47%.

Table 2: the reduction of volatile solids at different dosages of ozone (mg/l)

TS (*0* $_3$gr/min) (Ozone Dosage)	**VS (mg/l) (Sample)**	**VS (mg/l) (The Amount of Reduction)**	**VS % (The Percentage of Reduction)**
0	6734.77	0	0
0.19208	6276.8256	457.9644	6.8
0.48512	5556.1852	1178.5847	17.5
0.97159	4689.3999	2047.3701	30.4
1.46063	4209.2312	2525.5357	37.5
1.91905	3663.7149	3071.05512	45.6
2.38426	3537.2100	3197.5600	47.48

The impact of sludge concentration on TSS and VS in a constant dosage of ozone

To investigate the impact of sludge concentration on TSS and VS in a constant dosage of ozone, the amount of 1.46 / , as the optimal dose of ozone at various concentrations of diluted sludge (the ratios of 10%, 20%, 50%, 70%, and 100%), was used for testing. The amounts of TSS and VS were measured and the reduction percent was calculated. Table 3 shows in summary the average results of testing TSS of sludge.

Table 3: the impact of sludge concentration on TSS in a constant dosage of ozone

Diluted Concentration	TSS	TSS Ozonation)	TSS	TSS % Reduction)
0.1	853.24	267.92	585.32	68.6
0.2	1706.47	470.99	1235.48	72.4
0.5	4266.18	1040.95	3225.23	75.6
0.7	5972.66	1230.37	4742.29	79.4
0.9	7679.15	1436.02	6243.13	81.3
1	8532.37	1453.5	7078.87	82.96

Due to the high oxidation of ozone causing organic materials to be dissolved in the sludge solution, solution making and sludge volume reduction largely depends on the dose of ozone.

Table 4: the impact of sludge concentration on VS in a constant dosage of ozone

Diluted Sludge Concentration	VS(Initial)	VS (After Ozonation)	VS (Reduction Amount)	VS % (Percentage Reduction)
0.1	643.48	152.5	490.98	76.3
0.2	1286.95	456.87	830.08	64.5
0.5	3217.35	1557.2	1660.15	51.6
0.7	4504.34	2463.87	2040.47	45.3
0.9	5791.29	3741.17	2050.12	35.4
1	6434.77	4343.47	2091.30	32.5

The experimental results show that the amount of volatile solids in the sludge changes at different doses of ozone. In other words, the increase in ozone dosage causes the volatile solids of sludge to be converted into minerals, water, and carbon dioxide more. As previously mentioned, here, an actual sample has been used to measure ingredients and parameters of the biological sludge. In this regard, a three-stage sampling was carried out in the wastewater treatment plant of Mobin Petrochemical Company at a time interval of one month. In each stage, all experiments were performed twice. Although the human error or equipment failure never becomes zero, the numbers obtained from several experiments are the average results of these tests at different times; hence, this can increase the reliability of results. It should be noted that all experiments were carried out according to the methods described in the book "Standards for water testing" [23].

Investigating the reduction of sludge volume by increasing the ozone dose

In the process of sludge ozonation, due to the permeability of the bacterial cell wall, ozone firstly causes the lysis and release of organic materials within the cell through degradation of cell wall, and then the materials are pulled into the liquid, namely water. In fact, since a part of TSS is converted into TDS, the mass of sludge is decreased [25]. The comparison of the two samples of sludge before and after ozonation showed that the amount of settable solids has declined substantially. Also, the results showed that the ozone concentration is inversely related to the mass of suspended solids and the amount of suspended solids decreases with increasing ozone dose.

The impact of sludge concentration on TSS and VS in a constant dosage of ozone

The results of experiments showed that the increase in sludge concentration causes the solution and settling materials to increase slightly in a constant dose of ozone due to the higher initial mass of solids. In other words, the consumption of ozone and the reduction of its concentration in the solution cause the availability of organic materials (for ozone oxidation reaction) to decrease and result in the reduction of organic materials mineralization. Therefore, the reason for reduction of volume and mass of the residual solids (remained from the sludge ozonation) is the consumption of ozone by solids and their decay [26].

CONCLUSIONS

The anaerobic digestion is one of the methods for stabilization of the excess biological sludge of municipal or industrial wastewater treatment plant. Due to the long aeration time in the anaerobic digestion method, the size of facilities used for implementation of the method is so large, which it imposes a large initial investment to the system. Thus, any process that can reduce aeration time is effective in reducing the size and cost of wastewater treatment plants. The present study investigated the ozonation process and the impact of ozone dose on the reduction of mass and volume of sludge. The experiments conducted on biological sludge ozonation showed that increasing the dosage of ozone leads to the increase of solution making and mineralization of organic materials and subsequently the reduction of the volume and mass of sludge [29]. Reviewing the results obtained from the study indicate that the best dose in terms of estimating the minimum conditions required for biological sludge stabilization and improving the performance of wastewater treatment plant is reported equal to 1.46-1.92 / . In other words, this optimal dose of ozone leads to higher reduction of volatile solids in comparison to what is recommended by EPA (38%) as the minimum amount. Also, the sludge ozonation greatly enhances the settling ability of sludge and reduces the final disposal of sludge. On the other hand, due to the decay of sludge and increasing the concentration of biodegradable materials, and the easy access of microorganisms to them, it is concluded that pretreatment of wastewater with ozone and then applying the process of anaerobic digestion result in the reduction of time needed for digestion and ground facilities. Thus, the ozonation process can be technically recommended for stabilization of biological sludge and increasing the efficiency of industrial wastewater treatment plant. The main advantages of using ozone in municipal and industrial wastewater treatment process can be summarized as follows:

- ✓ The sludge ozonation enhances the settling ability of sludge and reduces the final disposal of sludge.
- ✓ Sludge pre-ozonation decreases the aeration time and greatly increases the efficiency of anaerobic digestion process due to the decay of solids and organic materials.
- ✓ The ozonation process can dramatically enhance the operating conditions of wastewater treatment plants.
- ✓ It can reduce initial investment, the size of facilities, and operating costs.
- ✓ Since biological sludge ozonation leads to the decay and mineralization of organic materials in sludge, the optimal use of materials and elements existed in biological sludge becomes possible.

აღმოფხვრის წყლის პროცესი ნავთობქიმიური ინდუსტრიაში დაჟანგვის ჭარბი ნარჩენების ბიოლოგიური სამრეწველო ჩამდინარე არის პროცესი, რომელიც ადამიანის

ჯანმრთელობაზე და გარემოზე. უნდა განადგურდეს დაწვა სპეციალური ღუმელი. ნარჩენების დაწვა აქვს გარკვეული ნაკლოვანებები, როგორიცაა დიდი საწყისი ინვესტიცია, მაღალი საოპერაციო ხარჯების, ენერგეტიკის ნარჩენები და ასევე აწარმოებს საშუალო ნივთიერებები, მაგალითად ნაცარი და გაზის პრობლემა. აქედან გამომდინარე, ნებისმიერი პროცესი, რომელიც ამცირებს ხარჯებს და საშუალო დამაბინძურებლების შეიძლება იყოს ეფექტური სტაბილიზაციის ბიოლოგიური ნარჩენების. ეს არის კარგი ალტერნატივა არსებულ პროცესებში. იმის გამო, რომ მაღალი დაჟანგვის ძალა ოზონის, გარდა ამისა, რომ ეს აჩქარებს და მინერალიზაცია ნარჩენების ნარჩენების სტაბილიზაციის პროცესში. მიზნით ამ ფაქტთან დაკავშირებით შეაფასოს ეფექტი სხვადასხვა დოზით ოზონის ნარჩენების ბიოლოგიური სამრეწველო ჩამდინარე. რათა მასშტაბის მშენებლობა, ოზონის გენერატორი და ოზონის სადეზინფექციო მოცულობის 2 ლიტრი იყო გამოყენებული. პარამეტრების როგორიცაა, და იყო იზომება. შედეგები ამ კვლევამ აჩვენა, რომ ოზონის დოზა ნარჩენების შემცირების ოდენობა და დოზა .

REFERENCES

1- Barnabé, S. K. Brar, R.D. Tyagi, I. Beauchesne and R.Y. Surampalli, (2009), Pretreatment and bioconversion of wastewater sludge to value-added products Fate of endocrine disrupting ompounds, Science of The Total Environment.
2- Michael H., Gerardi, (2006), Wastewater Bacteria.
3- Carballa M., Manterola G., Larrea L., Ternes T., Omil F., Lema J.M., (2005),. Influence of ozone pre-treatment on sludge anaerobic digestion: Removal of pharmaceutical and personal care products.
4- Bougrier C., Albasi C., Delgenes J. P., and Carrere H., (2002), Effect of ultrasonic, thermal and ozone pre-treatments on waste activated sludge solubilisation and anaerobic biodegradability.
5- Christiane G., Judy A. L., Adrian S., (2000), Ozonation of Water and Waste Water.
6- Mobin Petrochemical Co, (2006) Wastewater Treatments Plant Manual Operation.
7- Muller, J., A., (2001), "Pretreatment Processes for the recycle and reuse of sewage sludge," Water Science Technology, 42, pp 167-174.
8- Nafari, M., (2003), “Investigating the methods for disinfection of hygienic and industrial drinking water”, Tehran, pub. Sarsabz
9- Habibinejad, M., (2010), “Practical guide to industrial waste management”, Tehran, pub. Aram
10- Jouzi, A., (2010), “Environmental Law”, Tehran, pub. Agricultural Sciences
11- http://www.pseez.ir/fa/database/petrochemicalunit
12- Mobin Petrochemical Co, (2006), Power Plant Manual Operation, Vol. 1 & 2.
13- Mobin Petrochemical Co, (2006) Wastewater Treatments Plant Manual Operation
14- Egemen E., Corpening J., Nirmalakhandan N., (2001) Evaluation of an ozonation system for reduced waste slugde generation.
15- Mothakaf Vadi, (2010), “Wastewater engineering”, trans. M., Nafari, Journal of Iranian Corrosion Association, vol. 4
16- Lin, Y., (2003), Chemically Reduced Excess Sludge Production in the Activated Sludge
Process, Chemosphere, 50, pp 1-7.
17- Park, K., Y., Ahn, K., Maeng, S., K., (2003), Feasibility of Sludge Ozonation for Stabilization and Conditioning, Ozone Science Eng., 25, pp73-80.
18- Bohler M, Siegrist H., (2005), Partial ozonation of activated sludge to reduce excess sludge, improve denitrification and control scumming and bulking.
19- APHA. (2005), STANDARD METHODS for the examination of water & wastewater, 21th Edition, American Public Health Association, Washington, DC
20- ASTM, (2007), Annual Book of Standards.
21- Institute of Standards and Industrial Research of Iran, “Sampling and testing of waste”, the first edition, No. 1779
22- Management and Planning Organization of Iran, ““Sampling and testing of waste”
23- Mousavi, G., Jamal, A., (2009), “Investigating the impact of ozone dose and the initial concentration of sludge on the reduction of the mass and volume of the removal sludge resulted from municipal wastewater treatment”, Shiraz University, Eighth International Congress on Civil Engineering
24- Park KY., Ahn KH. Maeng SK., Hwang JH. Kwon JH, (2007), Feasibility of Sludge Ozonation for Stabilization and Conditioning
25- Carballa, M., Manterola, G., Larrea, L., Ternes, T., Omil, F., and Lema, J., M., (2007), Influence of Ozone Pre-treatment on Sludge anaerobic Digestion, Chemosphere, 67, pp 1444- 1452.
26- Tomonori M., Kelisuke H., Satoshi T., Hiroyasu S., (2006), Advances In Water And Wastewater Treatment Technology.
27- William M., Susumu K., (2008), Cost Estimating Manual for Water Treatment Facilities.
28- Metcalf & Eddy, Inc (2003), Wastewater Engineering: Treatment, Disposal and Reuse, 4th Edition.4
29- Izrail S., Turovskiy and P. K. Mathai, (2006), Wastewater Sludge Processing
30- Hwang, S., Jang, H., Lee, M., Song, J., and Kim, S., (2006), “Characteristic of Sludge Redaction in an Integrated Pretreatment and aerobic Process”
31- Keshavarzi, M., (2012), “Using the sludge of industrial wastewater treatment plant in manufacturing concrete”, Master’s thesis, Islamic Azad University, Shahrood
32- Cogger C. D. Sullivan, 1987, "Recycling municipal wastewater sludge in Washington" Washington State University.
33- Water Science Technology, 53, pp 235-242
34- Lavric, E.D H., Weyten, J.D., Ruyck, V., Plesu, V. Lavric, (2001), "Supercritical waste oxidation improvements through chemical reactors energy integration."
35- Muller, J., A., Schwedes, J., (1996), "Dewatering of disintegrated excess sewage sludge," Water Science Technology, 26, pp289-292.
36- Woodard, Frank, (2001), "Industrial Waste Treatment Handbook",
37- Wunjer, NG. (2006)," Industrial Waste Treatment"
38- Hwang S, Jang H. ristics of sludge reduction in an integrated pretreatment and aerobic digestion process. Water Sci Technol
39- Kopp J, Muller J, Dichtl N, Schwedes J. Anaerobic digestion and dewatering characteristics of mechanically excess sludge Michael H. Gerardi, Mel C. Zimmerman, (2005), Wastewater Pathogens.