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Study of wastewater treatment based on the DAF for the small-scaled industry

Bachelor Thesis

By

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I hereby affirm in lieu of an oath that I provided the submitted bachelor thesis

Study of wastewater treatment based on DAF for the small-scale industry

I did not use any sources other than those stated. In case that the work is additionally submitted on a data medium, I declare that the written and the electronic form are completely identical. The work was not submitted in the same or similar form to any examination authority.

Ulaanbaatar, Mongolia
2020.06.08

Place, Date

Signature

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Abstract

Most of the Mongolia industry scale is small sized industry comparing other country. Therefore, there is an important need of small scale pre-treatment plant of industrial wastewater in Mongolia. As nowadays requirement for protecting environment, all small scale industry have to install WWTP before discharge the wastewater into environment and sewerage network. The wastewater treatment plant at a poultry slaughterhouse comprises a dissolved air flotation (DAF) system. The DAF system at small-scale industries especially poultry wastewater treatment is designed to remove high concentration of organic pollution such as FOG, BOD, COD and TSS. Formulated on the literature, the DAF operation of the system removal efficiency at 300kPa pressure, PAC coagulation and anionic polymer is shown optimal result.

The design of the DAF system surface area is 6.48 m^2, length is 3.6 m, width is 1.8 m and depth is 1.6m based on water consumption and flow rate of the industry. The Ajigana LLC is capacity of producing 1 million chicken in a year and it consumes 42247.5 m^3 water and 115.45m^3 water per hour.

Keywords: DAF, BOD, COD, TSS, poultry wastewater, the efficiency of removal, optimal decision

1 INTRODUCTION

Mongolia is the most sparsely populated country in the world, with a population of over 3.2 million people, and about 31.6 % of all households in our country have lived from breeding livestock (1). Most herders follow the pattern of nomadic or semi-nomadic pastoralism and they have supplied us the 100% of meat. In 2015, Mongolia has 1914 food-related industries and 314 (16%) out of them are the meat production industries (2).

Mongolia has the capability of producing 400,000 tons of meat in a year which of only 10 % of the meat produced by industrial method (3). Therefore 40,000 tons of meat are typically produced in the industrial method. The Statement of the Minister of Environment and Green Development of Mongolia confirms that one meat production is using 21.5 m3 water in the industry process (4). This means, according to the meat tons, the usage of water is about 860,000 m3 in a year and 2356 m3 for daily consumption. Hence, the poultry industry is one of the representatives of industrial method meat production. In abroad, the small-scale industries wastewater treatment plant process decisions limit the number of alternatives possible for subsequent treatment or predicate the need for additional processes such as sludge treatment or dewatering (1). Small scaled industries water usage range is predicted from 500m3/d to 2000 m3/d (1). Mongolia has many food and beverage industries in the city and outside of the city according to 2015 statistical data. Most of them are located in the local area of Mongolia. The most dominant industries are including bakery and meat products which are shown in Chapter 1, Table 1.

The poultry industry is producing an excessive amount of organic pollutants such as COD, BOD, and TSS. According to the literature, the concentration of COD is 7719 mg/l, BOD is 1821 mg/l and TSS is 5462 in the poultry wastewater. The suitable treatment method is dissolved air flotation (DAF) (5) for high organic pollution removal. The technology has been used in many industries such as mineral processing and wastewater clarification. High pollutant wastewater causes many trouble in the water, environment, and workload of central WWTP which reduces the working capacity and speed of treatment.

1.1 Objectives and Limitation of the Study

The broad objective is to study of wastewater treatment design based on a dissolved air flotation (DAF) technology for small-scale industries. Adjusting suitable process procedure which including dosage, rotation speed, tank size, etc. for Mongolian condition that is located in harsh climate regions so wastewater characteristics is going to be different other country's same industry because of fatty concentration.

In Mongolia, the most concerning issue of industries is to build a small-scale WWT plant following meat production capacity which is continuously increasing from time to time.

Therefore, there has to be installed pre-treatment plants of industrial wastewater before discharging into the environment and sewerage networks corresponding to MNS: 4943 and MNS: 6569 standards. The specific objectives of the studies were the following:

- Identification of wastewater characteristics, and
- Study of selected parameters to calculate the design.

Scope study is a ranging meat industry particularly poultry-related small-scaled industry's wastewater treatment. There is also limited information about wastewater characteristics in the Mongolian poultry industry (see chapter methodology). In the mid of the thesis study, the COVID-19 disease arising in worldwide which cause many limitations and problems to the thesis process. Due to the sudden quarantine, the laboratory work is completely impossible to progress and failed to estimate data.

1.2 Hypothesis set to achieve objectives

Hypothesis 1: The BOD, COD, and TSS removal rate of effluents in Mongolian conditions might be different than in other countries due to its harsh climate.

Hypothesis 2: Decrease organic pollution of the poultry wastewater by the DAF system.

2 STATE OF THE ART

As represented in Table 1, the highest number of industries are flour and bakery products industries which are 916 (48%) out of 1916 as well as the meat products is around 314 (16%) out of 1914 in 2015 (2). Since 2015, the development of small-scale industries is increasing fast for human comfort consumptions and the number of industries might change. Under the industries majority, the meat-based industries chosen to treat in this thesis.

Table 1 Mongolian Beverage and food industries type and number, 2015

Types of industry	Numbers
Flour and Bakery products	916
Meat products	314
Fermentation products	243
Dairy products	236
Others	126
Stocked products	79
Total	1914
Location	
Ulaanbaatar city	590
Local	1324

The chosen small-scaled industry is Ajigana LLC which is capable of producing 1 million chicken in a year and according to the data (5), the live weight of the chicken is about 2.8kg (2861.8 g) (4). As a calculation, Ajigana LLC is capable of producing 2,800 tons of chicken in a year and as we predict the industry working capability is 70 %, the number of chicken production is becoming 1960 ton in a year. So as mentioned, the meat production water per meat is 21.5m3 then it becomes 42,140 m3 water in a year and 115.45 m3 water per day, is used by the poultry industry. Due to the development of industries brings a huge amount of water consumption and pollution. Nevertheless, Mongolia has a rare amount of wastewater treatment plant in the small-scale industries and have lack of information related to the treatment plant and industries, to be separate treatment plant, in Mongolia have “Central Wastewater Treatment Plant” which is located in the Ulaanbaatar. WWTP is operated since 1964 and capable of treating 4500 m3 wastewater a day. To being, lack of treatment plants in the industries cause so many problems in the environment such as water, soil pollution, and reduce human health.

Even though, according to the Mongolian effluent wastewater requirement (MNS: 4943) (6) which is a requirement for discharging treated (effluent) water directly into the environment (river or lake). The wastewater (effluent) from the industries has to reduce the concentration of wastewater according to the requirements shown in Table 1. Unfortunately, most of them cannot follow the requirement due to the non-suitable treating technology or lack of treating technology in the industries.

In Table 2, shows the requirements and permissible concentration of the pollutants in the effluent water from industries, according to the MNS: 4943 requirements. The maximum content of the COD is 50 mg/l, BOD is 20 mg/l and SS is 50 mg/l which is a very important concentration for the project.

Table 2 Maximum permissible concentration of pollutants in treated wastewater and other parameters, MNS: 4943

N	Parameters	Unit	Max Content
1	Temperature	C	20
2	pH	-	6.-9
3	Odor	-	-
4	Suspended solids	mg/l	50
5	BOD	mgO/l	20
6	COD	mgO/l	50
7	Permanganate compounds	mg/l	20
8	Suspended salt	mg/l	1000
9	Ammonium nitrogen (NH4)	mg/l	6
10	Total Nitrogen (TN)	mg/l	15
11	Total phosphorus (TP)	mg/l	1.5
12	Organic Phosphor (DOP)	mg/l	0.2
13	Hydrogen Sulfide (H2S)	mg/l	0.5
14	Total iron (Fe)	mg/l	1
15	Manganese (Mn)	mg/l	0.5
16	Aluminum (Al)	mg/l	0.5
17	Total Chrome (Cr)	mg/l	0.3
18	Hexavalent chromium (Cr^{6+})	mg/l	-
19	Total Cyanide (CN)	mg/l	0.05
20	Free Cyanide	mg/l	0.005
21	Copper (Cu)	mg/l	0.3
22	Boron (B)	mg/l	0.3
23	Plumbum (Pb)	mg/l	0.1
24	Zinc (Zn)	mg/l	1
25	Cadmium (Cd)	mg/l	0.03
26	Antimony (Sd)	mg/l	0.05
27	Mercury (Hg)	mg/l	0.001
28	Molybdenum (Mo)	mg/l	0.5
29	Arsenic (As)	mg/l	0.01
30	Nickel (Ni)	mg/l	0.2
31	Selenium (Se)	mg/l	0.02
32	Beryllium (Be)	mg/l	0.001
33	Barium (Ba)	mg/l	1.5
34	Strontium (Sr)	mg/l	2
35	Vanadium (V)	mg/l	0.1
36	Uranium (U)	mg/l	0.05
37	Mineral Oils	mg/l	1
38	FOG	mg/l	5
39	Surfactants	mg/l	2.5

N	Parameters	Unit	Max Content
40	Phenol (C_6H_5OH)	mg/l	0.05
41	Trichloroethylene	mg/l	0.2
42	Tetrachlorethylene	mg/l	0.1
43	Residual chlorine (Cl)	mg/l	1
44	Intestinal pathogens	mg/l	1ml- not found

Despite that depending on the industry regulation, the requirement of the wastewater pollution concentrations is different. There are more requirements for wastewater from industries. As for MNS 65:61 (7) is applied when treated (effluent) water discharges into the central WWTP without discharging into environments. Depending on the different discharging areas, the concentration of permissible pollution is different which is shown in Table 3.

Table 3 represents the requirements of permissible wastewater pollution concentration that discharged to WWTP. According to Table 2, BOD, COD, and SS concentrations are shown 400 mg/l, 800 mg/l, and 400 mg/l respectively. Which are much higher concentration than MNS: 4943.

Table 3 Maximum permissible concentration of pollutants in treated wastewater and other parameters, MNS: 6561

N	Parameters	Unit	Max Content
1	Temperature	C	20
2	pH	-	6.-9
3	Suspended solids	mg/l	400
4	BOD	mg/l	400
5	COD	mg/l	800
6	Ammonium ion	mg/l	15
7	Total Nitrogen	mg/l	30
8	Chloride	mg/l	1000
9	Sulfate	mg/l	700
10	Sulfite	mg/l	5
11	Copper	mg/l	1.0
12	Cadmium (Cd)	mg/l	0.05
13	Cobalt (Co)	mg/l	0.1
14	Mercury (Hg)	mg/l	0.05
15	Nickel (Ni)	mg/l	0.5
16	Selenium (Se)	mg/l	0.1
17	Iron (Fe)	mg/l	3
18	Plumbum (Pb)	mg/l	0.2
19	Aluminum (Al)	mg/l	0.5
20	Total Chrome (Cr)	mg/l	0.5
21	Hexavalent chromium	mg/l	0.001
22	Arsenic (As)	mg/l	0.1
23	Zinc (Zn)	mg/l	5
24	Cyanide (CN)	mg/l	0.1
25	Total phosphorus (TP)	mg/l	5

N	Parameters	Unit	Max Content
26	Phenol (C_6H_5OH)	mg/l	0.5
27	All kinds of solvents	mg/l	10
28	FOG	mg/l	25
29	Mineral Oil	mg/l	5
30	Total hydrogen chloride	mg/l	0.3

2.1 Poultry slaughterhouse process

As for the poultry processing industries has developed and dedicated to large-scaled industries have been built around the world (8) and a major component of the food industry (9). However, in Mongolia, it still dedicated small-scaled industries. Fifty years ago, the maximum line speed was about 2000birds/hr. In comparison, the advanced technology and automation are capable of producing 13500 birds/hr. The modern design of the poultry process flow sheet is including many steps which are only including primary process of poultry where water consumption is demanding (8). As mentioned, a total of 314 meat processing industries located around the Mongolia which are including all types of meat such as chicken, beef, pork, and other meats.

2.1.1 Overview of the slaughtering process

All meats processing steps are much likable with each other. At very first, it starts with the meat holding area. The purpose of these areas temporarily holds animals gently to keep calm. Then, the slaughtering process will begin with stunning and placing the animals on the chain conveyors which means a killing process is executed. The next step is disassembling the carcass into components that means animals are eviscerated and offal is collected and sent to rendering. The eviscerated offal is processed and turned into pet food and other consumer products. Next, the chilling process is taking place as fast as possible to a certain temperature where minimize the risk of spoilage. Moreover, it covers some more steps in the process such as disassembly as the carcass for saleable components, packaging, storing, and shipping. A further process is including unit operations such as freezing, size reduction, heat transfer, and conveying (9).

“Wastes” from the process includes hides, feather, intestines and inedible products. But most of the wastes turned into value-added consumer products, pet foods, and biofuels (9).

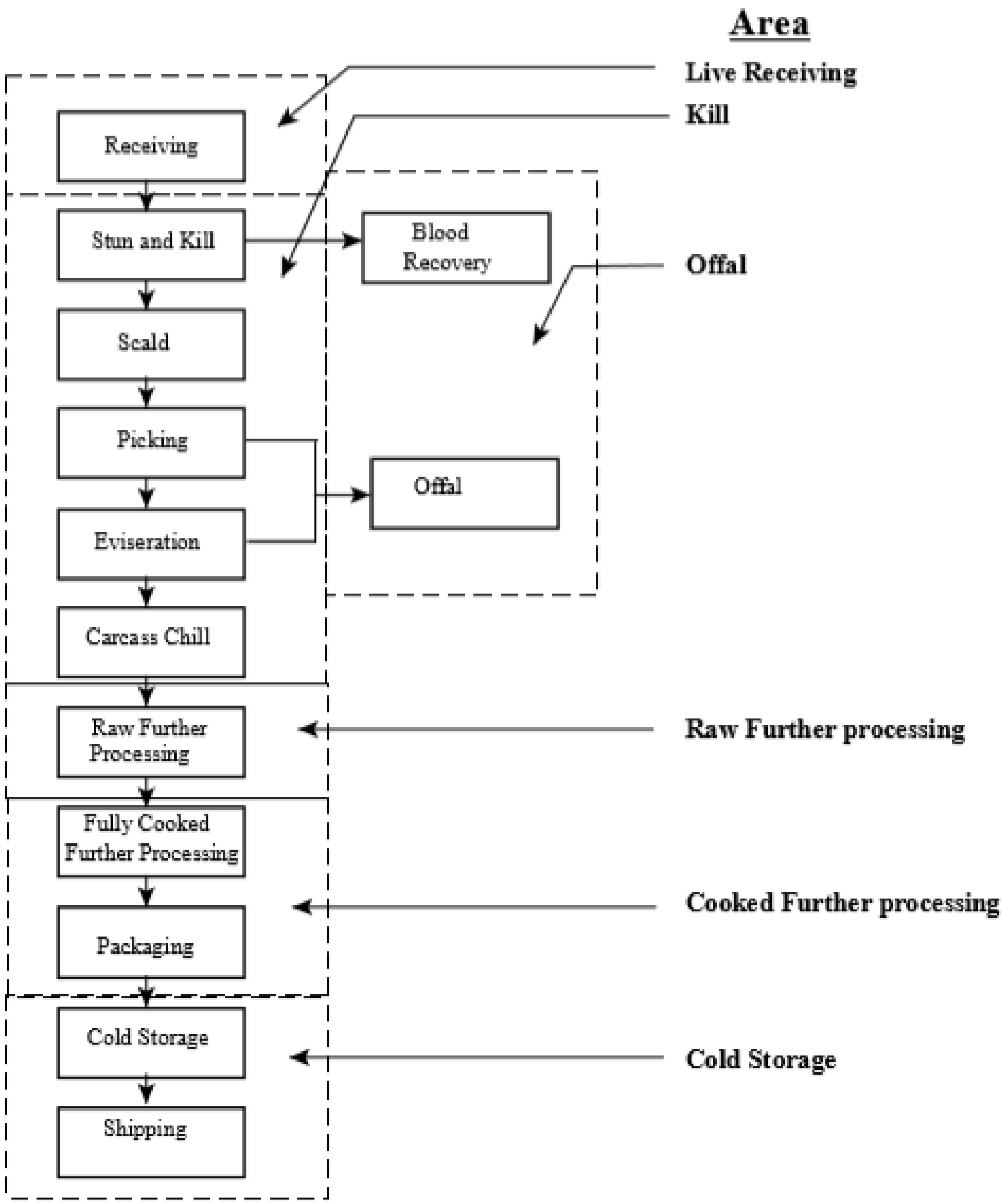


Figure 1 Typical Poultry processing design

2.2 Characteristics of poultry wastewater

The development of the agriculture sector and rapid industrialization has produced a large volume of wastewater and tons of water consumption in the process. To avoid environmental degradation such as spreading water bone disease and eutrophication, the proper and optimal wastewater treatment is needed to protect the water body. Poultry processing wastewater had been characterizing as highly polluted wastewater due to the high concentration of BOD, COD, and TSS, blood, a nutrient from the slaughtering and cleaning activities. Discharged of untreated wastewater into the sewer will decrease the quantity and quality of the water source. The physical characteristics of wastewater effects on the parameter of these wastes due to their role in a biological and chemical reaction. The presence of chemical reactions of organic substances in wastewater is indicated by a high concentration of COD. On the other hand, BOD is an indicator of the biological oxidation of organic compounds. The presence of high concentrations of BOD means available high microbial loads in the wastewater. Furthermore, the high nutrients contain means wastewater refers to nitrogen (organic form including ammonia) and phosphorous (inorganic, nitrate, and nitrite). The parameters tested included BOD, COD, TSS, TN, TP, TOC, temperature, and pH(10).

Table 4 Characteristic of chicken processing (10)
All parameters are expressed as mg/l except for pH, NR=Not reported,

Parameters	This study			EQA 1974	
	Minimum	Maximum	Mean	Standard A	Standard B
pH	7.3±0.42	8.6±0.42	8.02±0.42	6.0-9.0	5.5-9.0
BOD	1341±242.7	1821±242.7	1602±242.7	20	50
COD	3154.19±2282.69	7719.3±2282.69	5422.25±2282.69	50	100
TSS	3776.7±2696.1	5462±2696.1	3438.223±2696.1	50	100
TN	162.6±215	563.8±215	361.25±215	NR	NR
TOC	194.9±222.66	651.5±222.66	419.3±222.66	NR	NR
PO4	7.047±4.25	17.111±4.25	12.256±4.25	NR	NR
F	0.221±0.15	0.642±0.15	0.493±0.15	NR	NR
NO3	1.643±0.58	3.265±0.58	2.241±0.58	NR	NR
Cd	0.000021±0.02	0.034±0.02	0.01234±0.02	0.01	0.02
Cu	0.00351±0.32	0.573±0.32	0.2085±0.32	0.2	1
Hg	0.000421±0.001	0.002513±0.001	0.001454±0.001	0.005	0.05

Table 4 represents the wastewater characteristics of chicken processing in internationally. The maximum amount of pollution in the wastewater is COD which is 7719.3 mg/l. But according to the EQA standard, the amount of pollution should be between 50-100 mg/l. This shows the poultry process wastewater COD pollution concentration is 77 times higher than the standard as well as other pollutants too (10).

2.3 Treatment process

In the small-scale industries, they usually have the primary treatment process in the plant. The main objective of the primary treatment reduces the concentration of suspended solids from wastewater. The primary treatment process generates primary sludge which mainly contains a biodegradable organic fraction, so that means it reduces BOD. The magnitude of the process depends on the characteristics of water and reagents reaction in the water. Although there are several treatment processes in primary treatment such as filtration, screening, sieving, etc. But the main processes used in sewage treatment plants (9):

- Solid-liquid separation process (physical separation without chemical addition)
    - Primary sedimentation
- Solid-Liquid separation with chemical additions of coagulation and flocculation (physical-chemical separation) and it including several steps:
    - Improved primary sedimentation
    - DAF process
    - Joint process (sedimentation-flotation)

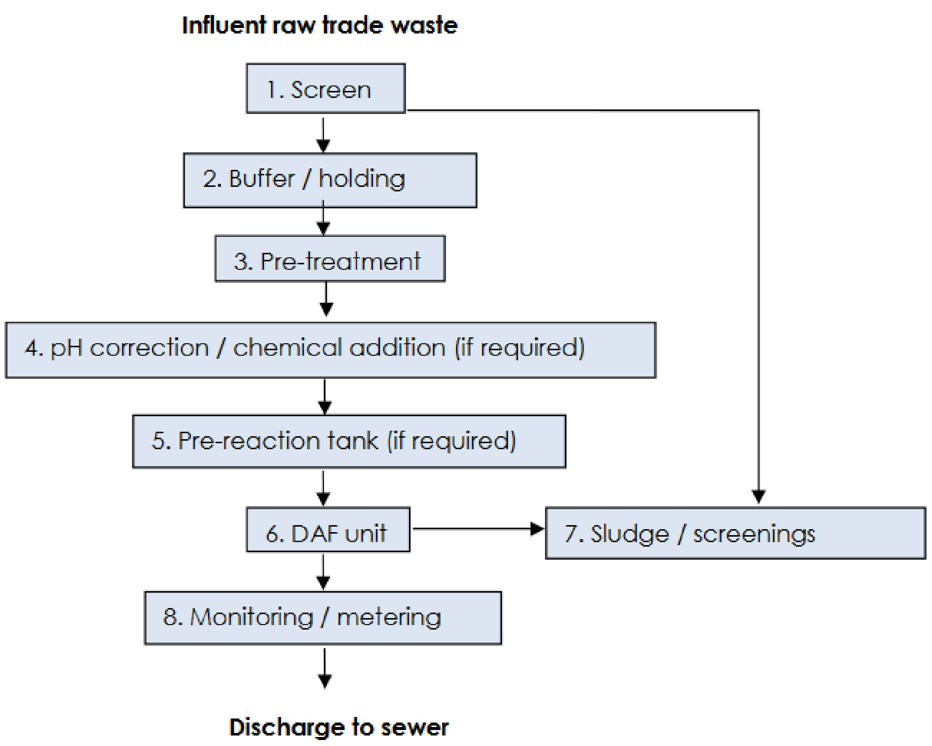


Figure 2 Diagram of the treatment process of Industries

Figure 2 describes the most common treatment system in the industries. But depending on the wastewater type and concentration the small changes occur in the flow sheet (11).

2.3.1 Screening

The screening is to remove gross solids from wastewater which helps to improve the efficiency of the next steps. The main process including;

- Prevents solids from blocking the feed pumps such as recycle and sludge pumps.
- Reduce odor
- Sludge formation is minimized in the DAF units
- Consumption of the coagulant/flocculent id reduced by removing as many solids as possible by simpler means.

For the process, the variety of screens is possible to use and considered matching design and mesh size with typical particle size. The most common screening mechanism with a maximum 2 mm mesh size for processing.

Buffer and holding tank:

The all screened wastewater is collected in the buffer tank for a sufficiently long-time before further treatment. The key parameters in buffer tank including (11):

- Temperature
- pH
- Solids
- Other buffering consideration

2.3.2 Buffering/holding tank

To verifying the influent is accordant to the production period or daily DAF operating cycle is critical for optimum DAF performance. Before further treatment process, the screened wastewater is collected in buffering or holding tank possibly in a long time.

The key parameters are;

- Temperature

The DAF system vessel should maintain the temperature below 40°C because of high temperature or hot ‘slugs’ cause to emulsifying grease and oils through the DAF unit which hinders the supply of dissolved air and promote undesirable biological breakdown in DAF system.

- pH

pH adjustment from 6 to 10 is the most acceptable limit of discharge wastewater and irregularity of pH can cause potential damage to treatment equipment and odor problem.

- Solids

The DAF system manually varies the settings which are coagulants and flocculent dosage and recycle volume as well as air settings for an efficient treatment of contaminants. Buffering reduce wastewater solid concentrations and boost DAF settings by adjusting short-term high contaminant concentration events. The minimum buffering tank capacity is 4 hours at the design peak influent flow rate.

2.3.3 Pre-treatment method

Screening, settling, catch basins and flotation systems are typical options for the pre-treatment process. The treatment process normally starts with screening which is the most typical and simple process for recovery of offal materials (feathers, bones, and proteins) from wastewater as well as catch the biggest particles. The screening process is capable of reducing up to 60% solids and 30% of BOD. However, mechanical failure and blanking can occur from overloading the screen moreover it requires continuous hygiene to getting a high performance. Thereafter, settling tanks and catch basins are used to remove fine particles such as SS and FOG by gravity. Using the principle of particle and water density to settling the particle as a sludge in the bottom of the rise to the surface. According to the Bustillo-Lecompte and Mehrvar, these systems are capable of removing BOD and Solids about 30% and 70% respectively (28).

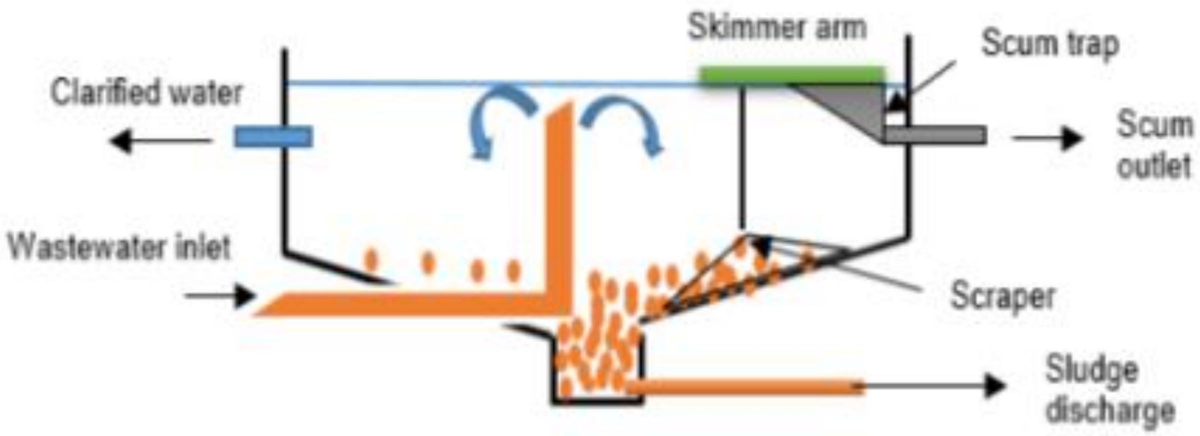


Figure 3 Schematic illustration of the settling tank

Figure 3 represents one of the simple pre-treatment settling tank designs that can use in many industries. As we know, pre-treatment mainly focuses on physical separation from wastewater such as removing big particles (11).

2.3.4 pH correction / chemical addition

All DAF units need to have a pH correction system that supports the DFA unit process by increase pH by alkaline solution or decease pH by the acidic solution. The pH control of DAF treatment systems is important for;

- Guaranteeing pH complies with discharge limits.
- Ensuring pH is within the range for effective removal.

- Minimizing grease/oil emulsions.

The only additive of coagulations or flocculants is shown poor removal efficiency in unsuitable pH conditions. The wastewater cleaning is not only based on chemical addition, but it also requires low temperature and emulsified grease/oil.

2.3.5 Primary Treatment Process

The primary treatment processes area physic-chemical systems that remove TSS, FOG, BOD, and COD from wastewater. Mostly, Dissolved Air Flotation (DAF) systems are used as a primary treatment process for the poultry industry and other small industries. DAF unit process is based on air pressure bubbles, chemicals, and time of settling. DAF removes 30-90% COD and 70-90% BOD, and large amounts of nutrients from wastewater (11).

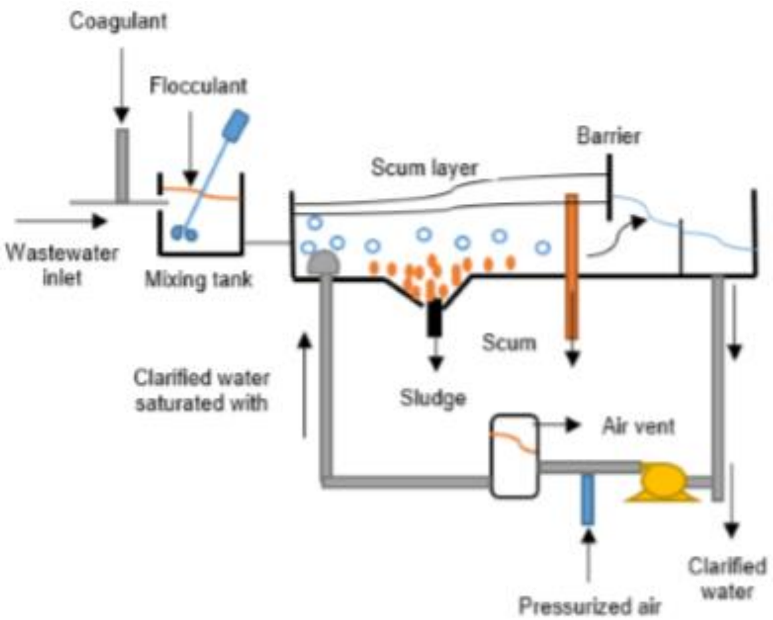


Figure 4 Typical Schematic diagram of a DAF.

The performance of the DAF is improved when coagulants and flocculation are added in the pre-treated wastewater prior to entering the DAF for they promote clattering, precipitation, and FOG flotation (11).

2.4 Dissolved Air Flotation (DAF)

Dissolved Air flotation was patented in 1924 by Niel Peterson and Carl Sveen in Scandinavia. It was initially used to recover fibers and white water in the paper industry. Depending on the different applicants and bubble formation there are various types of the flotation process. The technology has been used in many industries such as in mineral processing, wastewater clarification, artificial recharge, and portable water treatment. In basically, flotation is a process which is separating solid from a body of liquid by using air bubbles (12).

There are different ways of carrying out the flotation process. The difference between them is the generation of bubbles within the water (13). The flotation process is consists of main 4 steps:

1. Bubble generation
2. Gas bubble and suspended particles or oil droplet connection in the water
3. Attachment of particle or oil droplet to the gas bubble
4. Floated in the water surface and skimmed off

Flotation process generates different size of densities of bubbles to the wastewater which improves attachment of small solid particles and oil droplets. There are typically 5 different types of flotation systems, and classification of the method is based on different bubble formation (14);

- Dissolved Air Flotation (DAF)- *The gas is supersaturated with the solution as a result of pressure reduction*
- Induced Air Flotation (IAF) - *Gas and liquid mechanically mixed to induce bubble formation in the liquid.*
- Froth – *Gas is directly released into the liquid*
- Electrolytic – *The electrolysis of water is creating a bubble itself*
- Vacuum – *With the help of negative pressure, the air is released from a saturated solution*

But only the first 4 of them are used in the industrial wastewater treatment process. The most commonly used flotation systems are DAF and IAF. The DAF is applying the capacity of certain solid or liquid particles to get together with air bubbles sizing particle-gas clusters less dense than the liquid phase. DAF process comprised of making air micro bubbles (30-120 microns in diameter) inside wastewater, which get connected to the particles to expel from wastewater. To accomplish microbubble formation, the first pressurization of a volume or water stream is completed, promoting the dissolution of air until oversaturation, and afterward, this stream is depressurized in the flotation tank to atmospheric pressure, where dissolved air excess is released in the form of numerous microbubbles. Microbubble generation tends to be formed in the solid-liquid interface, resulting in the fixation of the air on the particles and thereby facilitating its floatation (13). A DAF system made of the following units as shown in Figure 4 (14):

1. Pressurizing pump
2. Air-injection system
3. Saturation vessel
4. Pressure regulator

5. Flotation vessel
6. Chemical addition system

Depending on the pressurization, the three liquid flow schemes:

The inflow of the wastewater can be pressurized by pump, section of this water flow or water already treated by the process (effluent). In the consequence, the DAF formed in three types of usable process, called full flow, the partial flow of recirculated flow (R-DAF), respectively (see diagrams of figures 5,6, and 7) (13).

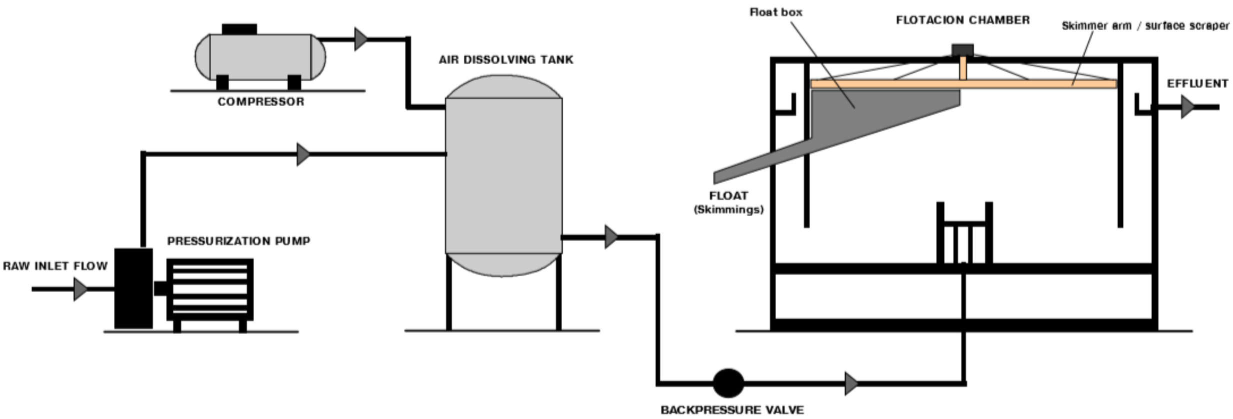


Figure 5 DAF with total inflow pressurization

The total inflow wastewater is pressurized and saturated with air. It provides a maximum gas solution at any pressure cause the most air dissolved and yields the maximum particle-bubble contact, but it results in a larger saturation system. However, it requires high operation and maintenance costs.

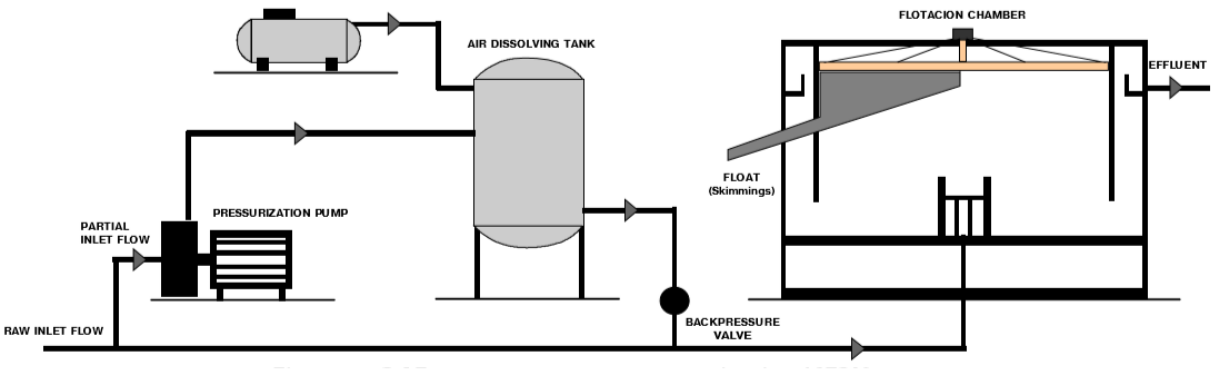


Figure 6 the DAF with half inflow pressurization

Inflow pressurization (total and partial) (13)

In this system, wastewater flows through the pressurization cylinder fully or partially as described in Figures 5 and 6.

Advantages:

- Generates larger bubbles equally over the entire water body and produces maximum dissolution of air,
- Produces an intact formation of microbubbles in the solid-liquid interface

Disadvantages:

- High energy consumption
- Colloids or emulsion formation can happen during the raw water pass in the pumping system
- Equipment erosion and corrosion
- Breakage of pressure tank due to coagulation and flocculation process floc

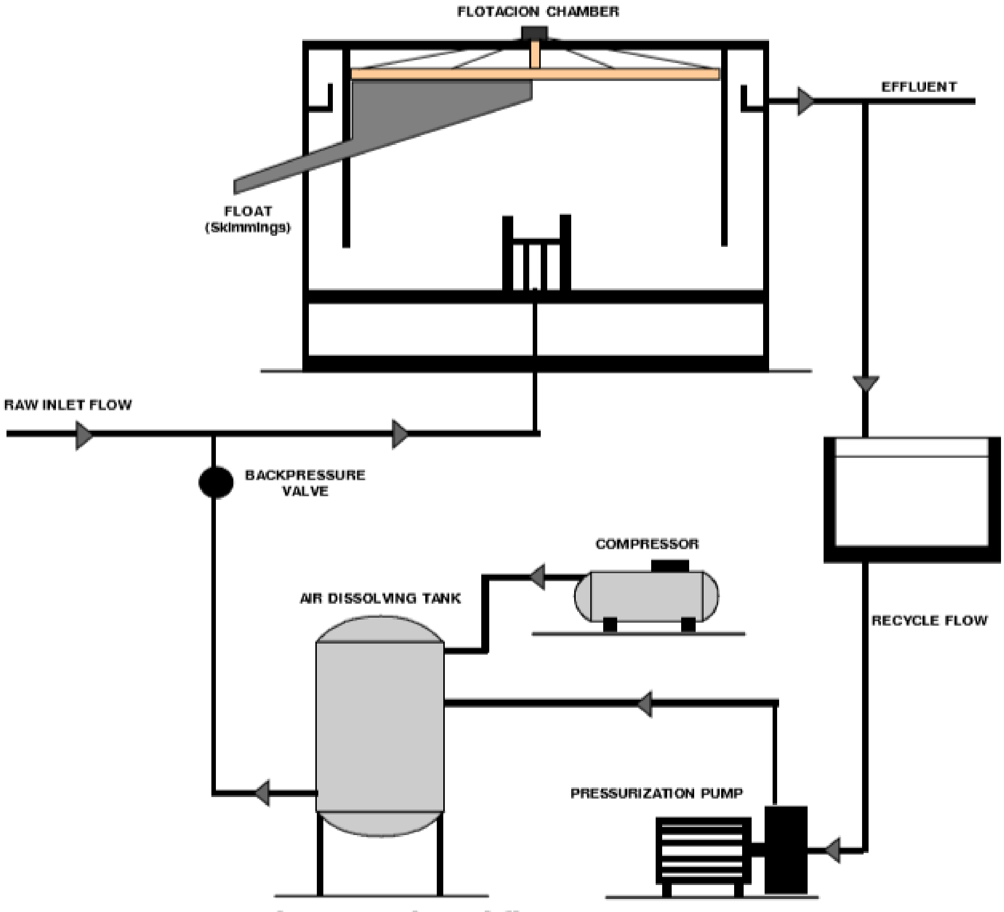


Figure 7 the DAF with recirculated flow pressurization

Outflow recirculation pressurization (13)**:**

The most used treatment diagram design (Figure 7). The part of the effluent is recirculated and initiate into a pressurizing system. Important operating features are:

- Lower energy consumption in the pressurization equipment and recirculation flow rate is lower than the inflow system
- Easily incorporate flow changes

- Less colloid and emulsion
- Fewer abrasion problems in the equipment
- Recirculated water is directly correlated with SS and FOG removal

There are two types of flotation tanks; circular and rectangular tanks. The mostly circular type of tank used to wastewater treatment and sludge thickening process which is implemented in small-sized flotation plants, and require no pre-flocculation prior to the flotation process. However, the rectangular tank which is a simple design that makes easier to remove floated sludge from the water surface and use smaller area than the circular tank, used by larger flotation plants (12). The bubble size is preferred 50-100 Mm and the air is dissolved in a saturator under pressure in a range of 400-600 kPa which are the most suitable size and pressure for the DAF process (12). To achieve a good result using DAF for small-scaled industry influents containing particles and natural color, coagulation or flocculation id necessary prior (12).

For information, there is some air flotation that is widely used to treat wastes from a wide variety of sources; papermaking, refineries, ship bilge and ballast waste, deicing operations, metal plating, meat processing, glass plants, and iron steel plants (15).

2.4.1 Bubble formation

There are 2 processes involved in bubble formation. First is the nucleation process which immediately instigates the pressurized water with air is released through the nozzle. The second process is to appear when the excess air in the saturated water is supplied to the flotation tank. Throughout this step, the bubble size increase in size because of the combination and decreases hydrostatic pressure in the flotation tank. However, the air volume is remaining constant within the process (12).

2.4.2 Bubble particle attachment

The 3 different types of mechanisms that make a bubble particle attachment:

1. Precipitation or collisions
2. Bubbles trapped in a floc structure as they rise through the liquid medium
3. Bubbles absorbed in a floc structure the floc is formed

The sequence of the mechanisms is adhesion or collision, trapping, and absorption in the bubble particle attachment. To making good agglomeration between particles and bubbles, the particles must destabilize. Influent required coagulation process, proper dosing, and pH value resulting in low particle charge (12).

2.4.3 Flotation of bubble particle agglomerate

In the DAF process, the particles float due to bubbles that reduce the density of the bubble–particle agglomerates. As long as bubble–particle agglomerates have lesser density than water (1.00 g/cm3), they will rise and float to the surface. If the particles are small, the process has to generate fewer bubbles to decrease the density of the, on the other hand, the big particles are requiring more bubbles to reduce the density to float the water surface. The bubble particle agglomerates should rise to the surface of the flotation tank unless the clarified water swept out of the tank (12).

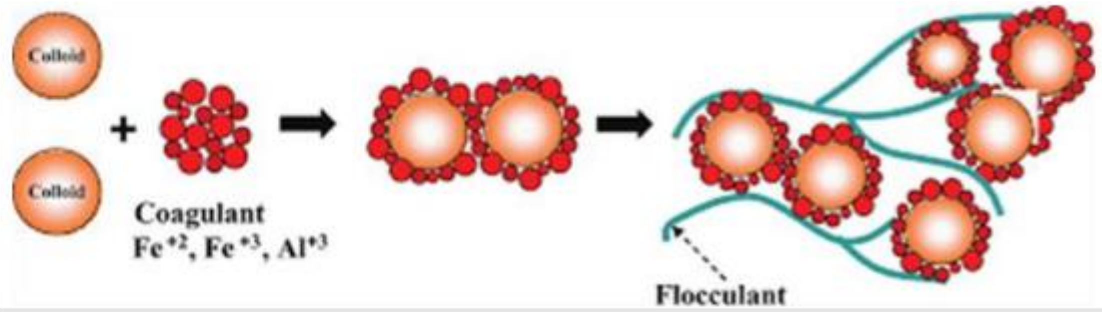
2.4.4 Advantages of DAF Application in wastewater treatment

The flotation technique has many advantages over the conventional gravity settling technique for the removal of low-density particles that tend to float. The flotation technique is based on methods of producing bubbles in the influent water. The advantages of DAF are as follows (12):

- Efficient at removing particles and turbidity of the water, economically efficient by using chemicals and settling down or floating the pollution of water.
- Depending on the coagulation dosages result in smaller chemical and lesser sludge production
- Less sensitive to flow variations.
- Removal of organic matter and inorganic pollutant in the water and work under cold water temperature
- Process flexibility through air loading

2.5 Chemical Usage (Coagulation and Flocculation)

The coagulation and flocculation process is the consequential step which is allowing particle collision and growth of floc. If coagulation is incomplete, the flocculation step will be unsuccessful, and if flocculation is incomplete, sedimentation will be unsuccessful. Coagulation and flocculation are very dependable from each other for the treatment process. Moreover, the coagulation and flocculation process settles down, the microparticles turn into the macroparticles, the bottom of the tank (16).



Picture 1 Coagulation and Flocculation process

2.5.1 Coagulation

In terms of coagulation explains the effect produced when certain sorts of chemicals are added to water containing slowly settling or non-settable particles. The small particles usually negative charges within the wastewater and coagulant chemicals with opposite charges those of the suspended solids are appended to the water to neutralize the negative charges on non-settable particles such as clay and some color-producing organic solids. Once the charge is neutralized by a coagulant, the small suspended particles are capable of sticking together. These slightly larger particles are called microflows and are invisible to the bare eye. The newly formed micro flocs should be clear in the surrounding water. If not, coagulation and few of the particle's charges have not been neutralized which means more coagulant chemicals may have to be added (12). The basic requirements of the coagulation chemical, whether a metallic salt or an organic polymer, is to discharge the theoretically negative charges on the colloids. The most common types of coagulants are including (17):

- **Polymeric coagulants**
  - Cationic
  - Anionic
  - Natural or non-polymeric
- **Metals-based coagulants (inorganic coagulants)**

Table 5 Pros and Cons of inorganic coagulants

Name	Advantages	Disadvantages
Aluminum Sulfate (Alum) Al2(SO4)318H2O	Easy to use, commonly used create less sludge, most efficient pH at 6.5-7.5	Add dissolved solids to water
Sodium aluminate Na2Al2O4	Required small dosage, effective in hard water	High cost and not efficient in soft water
Polyaluminum chloride (PAC) Al13(OH)20(SO)4Cl15	Formed floc more denser and faster to settle	Not commonly used
Ferric sulfate Fe2(SO4)3	Effective pH between 4-6 and 8.8-9.2	Create dissolved solids to water
Ferric chloride FeCl3.6H2O	Effective pH between 4-11	Create dissolved solids to water

Name	Advantages	Disadvantages
Ferrous sulfate FeSO4·7H2O	Not sensitive to the pH value	Create dissolved solids to water
Lime Ca(OH)2	common used and effective	pH dependent, large amount of sludge outcome, over dosage cause poor quality

- **Synthetic Coagulants (organic coagulants)**

Table 6 Organic coagulants

Name	Formula	Typical properties	Uses
Polyaluminium chlorohydrate (ACH) Al2(OH)5Cl	PAC 23	* 23-24% Al2O3 or 40-41% w/w ACH	Used in water with low pH and alkalinity
	MEGAPAC 23		
	ALCHLORAC	* SG 1.33	
		* 83–84% basicity	
	PROFLOC A23	* 8.5% w/w Cl *535 g/l	
Polyaluminium chloride (PACl) Al2(OH)3Cl3	PAAC-10 LB	*10-11% A2O3 or 20-23% w/w PACl	Used in water with low pH and alkalinity, has a greater effect on pH
	MEGAPAC 10		
		* SG 1.18	
		* 50% basicity	
		* 10.5% w/w Cl	
		* 245 g/l	
Polyaluminium silicosulphate Al2(OH)3.24Si0.1(SO4)1.58	PASS®	* 10% Al_2O_3 or 5.3% w/w Al	Forms floc easily and fast
		* SG 1.34	
		* 54% basicity	
Polyferric sulfate Fe2(OH)0.6(SO4)2.7	PASS®	* 12.2% w/w Fe(III) or 43.7% w/w $Fe_2(SO_4)_3$	Mostly used for oil emulsified wastewater
		* SG 1.54	
		* 10% basicity	
		* 673 g	

2.5.2 Flocculation

The flocculation process is part of improving a coagulation process in the wastewater which means primary coagulants and flocculants are coexisting and reduce particle by increasing in size. In the flocculation process, a gentler mixing than the coagulation process, which increases the particle size from micro to visible suspended particles. Microparticles collide, make bond and produce larger particle which called pin flocs. Floc size continues to increase when interaction with added inorganic polymers (coagulant) or organic polymers. Macroflocs are formed and high molecular weight polymers, called coagulant aids, could also be added to assist bridge, bind, and strengthen the floc, add weight, and increase settling rate. Once the floc has reached its optimum size and strength, water is prepared for sedimentation (16).

2.5.3 The reagents were used in the case study with different wastewater;

Depending on the wastewater type and characteristics, the dosage of the chemical additive (coagulation and flocculation) concentration and value is different. To look through the efficiency and removal quality of the DAF system, several industries wastewater is chosen to explain and introduced. Depending on the treatment efficiency, the dosage and chemical coagulation will be decided. The chosen industries include poultry, tannery, automotive and ceramic-tile industries which are most likely to contain a high concentration of FOG and TSS.

Poultry Industry:

As mentioned, the poultry wastewater containing a high concentration of COD, BOD, and TSS. To treating poultry wastewater, DAF technology is used in the case study. The purpose of the experiment to reducing FOG and TSS from the wastewater and some dedicated technology included in the industry treatment process which are rotary and static screen, an equalizing tank, DAF system and, two UASB reactors. The main parameters are mentioned in Table 7 (18).

Table 7 Design and operating parameters of the WWTP.

Parameter	units	Result
Chemical Dosage		
PAC	mg/l	24
Anionic polymer	mg/l	1.5
Air saturator		
Volume	m3	4.8
Saturation pressure	kPa	300
A/S ratio	ml/mg	0.030±0.008
Flotation Tank		
Depth	m	2.5
Diameter	m	6.38
Surface Area	m2	32
Volume	m3	80
Hydraulic loading rate	m/h	2.4±0.2
SS surface load	kg/m2d	22±5
DAF effluent recycling		None
UASB reactor		
Number of units		2
Depth	m	5.8 each
Area	m2	77.6 each
Volume	m3	450 each
Up flow velocity	m/h	0.49±0.04
OLR	kg COD/m3d	1.6±0.3

As a result, the DAF system efficiency removal of COD, TSS and, FOG were 43±9, 43±15, and 49±8, respectively.

Table 8 Monitoring Parameters of primary treatment system from January 2004 through August 2005

Parameter	N[a]	Industrial effluent			DAF-effluent			Removal efficiency (%)		
		Average	Minimum	Maximum	Average	Minimum	Maximum	Average	Minimum	Maximum
TCOD (mg/l)	20	3124 ± 594	2060	4380	1764 ± 409	1020	2508	43 ± 9	21	58
TBOD (mg/l)	20	2025 ± 352	1559	2683	1094 ± 191	785	1535	45 ± 13	14	64
SS (mg/l)	18	861 ± 204	480	1230	488 ± 155	264	800	43 ± 15	13	64
VSS (mg/l)	18	816 ± 207	426	1150	449 ± 147	232	740	44 ± 14	16	65
O&G (mg/l)	19	182 ± 29	131	261	92 ± 17	71	130	49 ± 8	32	60
pH	20	–	6.3	7.0	–	5.8	7.2	–	–	–

The PAC at 24 mg/l and anionic polymer at 1.5 mg/l with no pH adjustment is leading high remaining turbidity fraction and low SS removal from the wastewater. However, by adjusting the coagulation pH at 7.25 with the same coagulation dosage, the removal rate is increasing at TCOD and SS by 77% and 74% respectively. Under such conditions, the removal of SCOD is 22% and TP is 34%. On the other consideration, the usage of the cationic polymer, between 30 to 50 mg/l, is showing high removal of SS and FOG but for the SCOD and TP, removal presented 14 and 17 % respectively (18).

In the different case studied of poultry process wastewater treatment by DAF system with different coagulation chemicals of Ferric chloride and cationic polymer. The main parameters are including, the pH of coagulation is an adjustment between 4.6 to 7.0, 0.45 to 1.36 iron/phosphorus (Fe/P) molar ration and 1.0 mg/l cationic polymer was used. As a result, the removal efficiency of TCOD is 81±8%, TP is more than 99%, TSS is 65±25% and turbidity is 93±3% obtained. The phosphorus removal is directly correlated to pH adjustment (19).

Textile processing industry: As for textile processing, the wastewater is containing a high color, high COD/BOD, and salt load. Thus, without suitable treatment, discharge of wastewater into the water can affect the aquatic environment and cause huge trouble in the environment by filtration to the soil. The characteristic of textile wastewater is mentioned in Table 9 (20).

Table 9 Characteristic of textile wastewater

S.No	Parameter	Unit	Value
1	pH	-	7.6
2	Color	-	Dark brown
3	Turbidity	NTU	140
4	TSS	mg/l	1040
5	Alkalinity	mg/l	2450
6	BOD	mg/l	1520
7	COD	mg/l	3640
8	Sulfide	mg/l	210
9	Total Nitrogen	mg/l	257
10	Ammoniac Nitrogen	mg/l	85
11	Total Chromium	mg/l	10
12	Total Phosphate	mg/l	16

Thus, the DAF is one of the novel technology for many industries and in the case study, the PAC is used as a coagulant and dosage of 90 mg/l then the removal of COD is 53.45%, BOD is 43.2% and TSS is 79.01% each of them is observed respectively at 10 min flocculation process, the flotation time in the 20s (20).

Oily wastewater: In the study case, the two situations were observed. The first situation is used for the coagulation process were anionic polyacrylamide, cationic, and FeCl3. Sodium oleate (NaOl) was used as a collector. It is a common anionic flotation collector used to enhance the floatability of coagulated solids and emulsion droplets (flotation collector). The DAF system was operated as a batch study using the DAF jar-test with a pressure of 4–5 atm. and recycle ratio of 30%. Results indicated that the use of polyacrylamide and cationic did not offer a good solution. However, using FeCl3 to demulsify and increase the droplet size improved the droplet–bubble adhesion and the overall DAF performance. The best removal rate for oil removal was obtained at 100 mg/L Fe3+ with 50 mg/L NaOl at pH 6 and a recycle ratio of 30% (12).

In the second situation, the alum was used as a coagulant agent at 100 mg/L with pH 8 ad efficiency of removal up to 90% with the pressure of 80psi. the increase of alum concentration is increasing efficiency by destroying the emulsifying agent (a compound in oily wastewater) (12).

Table 10 Oily removal comparison

Parameter Concern	Operating Parameter	Findings
Oil removal	• 100 mg/L Fe^{3+} • 50 mg/L NaOl • pH 6 • Saturator pressure 4–5 atm. • Recycle ratio 30%	Results indicate that the use of polyelectrolyte did not offer favorable results. However, using the $FeCl_3$ to demulsify and increase the size of droplets and improve the droplet–bubble adhesion, the overall DAF performance increased.
Oil removal	• 100 mg/L alum • pH 8 • Saturator pressure (80 psi) • Recycle ratio (20%) • Packed saturator column with 90% efficiency	Increase in alum concentration destroyed the protection action created by the emulsifying agent (compound in oily wastewater). Simultaneously, the repulsive effects of the electrical double layers (zeta potential) were reduced as the concentration of alum increased.

As for the above case study represent the alum coagulation and cationic flocculation is the best performance in oily wastewater treatment like poultry (chicken) industry containing the high oil, COD, and BOD in the wastewater (12).

The automotive process industry: The automotive and electrical and jewelry manufacturing industries are the common source of toxic wastewater which contains a variety of hazardous elements such as chromium, zinc, nickel, and other chemicals. Therefore, the coagulation and flocculation method is used to reduce the heavy metal concentration in water from those industries. The main objective of this case is to compare the effectiveness of three different coagulants like alum, ferric chloride, and PAC, aided by anionic polyacrylamide to reduce the COD, TSS and heavy metal in the automotive wastewater (21).

Table 11 Removal efficiency of COD and TSS

Coagulant	Removal	Dose of anionic polyacrylamide (mg/L)				
		1	2	3	4	5
PAC	COD %	62	71	67	60	55
	TSS %	97	98	98	98	97
$FeCl_3$	COD%	64	59	55	52	51
	TSS%	91	91	91	90	90
Alum	COD%	38	42	47	54	52
	TSS%	92	92	93	94	94

As a result, the PAC coagulation is more efficient than the other two coagulants, FeCl3 and Alum, with the aid of anionic polyacrylamide. At defined optimum dosage condition is PAC at 70mg/l, anionic polyacrylamide at 2mg/l, and pH at 7, it shows the removal of COD is 70% and TSS is 98% respectively. For the FeCl3 and Alum coagulants, the maximum removal is shown 64% and 54% for COD, meanwhile, TSS removal is 91% and 94% respectively for the coagulants. The additive of the anionic polyacrylamide improve the efficiency of removal and decrease the dosage of the coagulant chemicals. For the optimal pH shows 5 to 9. However, the usage of different aids may change the result of the coagulant decision (21).

The ceramic-tile processing industry:

The ceramic–tile industries wastewater contains clays, insoluble ferrites, and silicates, electrolytes, anions such as sulfate and chloride as well as heavy metals like zinc, lead, COD, and BOD.

Table 12 Ceramic-Tile wastewater characteristic

Parameter	Unit	Min	Max	Mean	S.D
PH	–	8.2	8.6	8.3	0.6
Temperature	(°C)	30	32	31 ± 1	1
Conductivity	(µs/cm)	2142	2700	2484	299.57
Turbidity	NTU	9500	13,300	11,100	1969.77
TDS	mg/L	1096	1266	1192	87.1
TSS	mg/L	14,300	34,414	21,638	11,105.05
COD	mg/L	151.2	490	361.3357	183.66
BOD_5	mg/L	100.8	392.5	266.5167	149.58
Color	Pt-Co	219	300	217	41.5

According to the table, the most concerning amount of the parameters are including TSS and turbidity of wastewater. The most used treatment method is filtration, sedimentation, and adsorption for the ceramic-tile industries due to the high concentration of turbidity as well as the recycled water for the process not requiring high purity. However, the coagulation and flocculation method is more suitable because of simple design and operation as well as low energy consumption. So in the case study, the coagulants as Poly-aluminum chloride were used as an anionic (A300), cationic (C270) and non-ionic polymers provided (22).

Table 13 the effect of anionic, cationic and no-polymer (0.5mg/l) at different PAC dosage on the tile wastewater (pH=7)

Polymers	Parameter	Dose of PAC (mg/L)					
		150	200	250	300	350	400
Anionic polymer	Turbidity (%)	99.11	99.31	99.54	99.66	99.66	99.65
	TSS (%)	99.3	99.44	99.61	99.72	99.72	99.72
	COD (%)	67.75	78.12	78.75	85.12	81.15	75.5
	Color (%)	55.42	67.05	79.45	87.2	87.2	87.2
Cationic polymer	Turbidity (%)	99.03	99.23	99.46	99.58	99.55	99.55
	TSS (%)	99.14	99.32	99.52	99.64	99.6	99.6
	COD (%)	37.5	41.25	47.47	52.5	51.5	49.9
	Color (%)	48.83	53.87	59.3	62.4	61.62	61.62
Nonionic polymer	Turbidity (%)	98.85	99.06	99.28	99.41	99.39	99.33
	TSS (%)	99	99.18	99.37	99.48	99.46	99.42
	COD (%)	59.7	64	65	76.25	75.5	65
	Color (%)	43.41	48.44	51.93	55.03	55.03	53.1

As a result, the most efficient and highest removal in compounds of PAC at 300mg/L with anionic polymer (A300) at 0.5mg/L concentration in wastewater. The observed result shows turbidity, TSS, COD, and the color is reduced 99.66%, 99.72%, 85.12%, and 87.2% in respectively. Although a combination of PAC at 300 mg/l with cationic polymer (C270) was a good result in 99.58% for turbidity, 99.64% for TSS, 52.5% for COD, and 62.4% for color observed. For the non-polymeric with PAC at 300 mg/l observed high efficiency for the TSS. Turbidity, COD, and the color was 99.41%, 55.03, 99.48%, and 76.25% respectively. Adding coagulant aids with PAC is decreasing PAC dosage from 400 to 300 mg/l which means coagulants aids can increase efficiency in a small amount of coagulant (22).

2.6 Wastewater measurements

2.6.1 Biological Oxygen Demand (BOD)

The Biological Oxygen demand is one of the widely used criteria for the water quality which contributed to the amount of biodegradable organic matter that is present in wastewater. BOD is defined as the amount of oxygen consumed by different types of microorganisms during aerobic oxidation of organic matter at a given temperature of 20°C for a specified time of 5 to 20 days (23).

BOD measurement methods (23);

- Modified reference method: improving oxygen
- Photometric methods
- Manometric method
- Biosensor based on bioluminescent bacteria
- Microbial fuel cell
- BOD biosensors with redox-mediators

BOD concentration is one of the important parameters for the design and operation of the water pollution control plant since it is used as a measure of not only the amount of organic pollution in the water body but also the strength of sewage. The BOD_5 in mg/l of O_2 is used as a standard value that is obtained from the BOD test conducted within five days in the wastewater industry. Within the 5 days, the organic matter of the wastewater is assumed about 60 % to 80% (23).

2.6.2 Chemical Oxygen Demand (COD)

Chemical oxygen demand is the standard water quality parameter of wastewater which is an indirect measurement of the organic matter in a sample. It uses a strong chemical oxidant in an acid solution (potassium permanganate [KMnO4], or potassium dichromate [K2Cr2O7]) and heat to oxidize organic compounds to carbon dioxide (CO2) and water (H2O). The measurement of the COD in wastewater, it requires high concentration oxidant chemicals and measured within the 2 to 4 hours (24).

The International Standards ISO 6060-1989 and ISO 15705-2002 are frequently performed standard methods to determine the COD. By the ISO 6060-1989 is used to predict water COD concentration with a determination range of 30 to 700 mg/l. The ISO 15705-2002 is utilized to measure industrial wastewater and domestic sewage COD concentration with a determination range of 6 to 1000 mg/l. In the former method, the open reflux and closed reflux method determine the COD. There are many new technology standard methods to determine COD values to provide (24):

- Modified standard methods
- Digestion methods
- Alternative digestion reagents methods
- Enhanced spectrophotometric methods
- Prevailing over chloride interference method

2.6.3 Total Suspended Solids (TSS)

Solid is a wide range of definitions. In terms of solids generally used when any material suspended or dissolved in water or wastewater that able to isolated by filtrated or through evaporation physically. Solids can also separate as filterable or non-filterable. According to the filterable solids, it can be divided into settleable or non-settle able. Depending on the composition, the solids can divide into organic and non-organic. Moreover, solids in water can be shown in 2 basic ways: particulate size and composition. The formula is shown the particulate size (25);

Total solids = Total Dissolved Solids + Total Suspended Solids

The measurements of TSS in the various process (26);

- Filtration process
- Manage chemical to the removal of solids
- Correlation of process conditions VS solids removal
- Verification of solid removal

Many standards and methods can measure TSS quickly and easily. But in the laboratory, the measurement of the TSS has typically used the filtration method.

2.7 Effects of Poultry industrial wastewater in the environment

Poultry industries have given rise to numerous environmental concerns in the local areas depending on the hygienic outcome of the process and poor sanitation of wastewater (11). These plants consume a huge amount of water to bird carcasses, washing, feather removal, and disinfecting in the poultry operation. Furthermore, intensive poultry production is also responsible for air pollution and gas emission from the process (11). Untreated wastewater from the poultry industry typically contains abnormal turbidity, high electric conductivity, high COD and BOD concentration, and TSS. When discharged into the water body in large quantities and high concentrations, these pollutants cause adverse damage in the water body which including water quality and microbial as well as aquatic flora. For example, in 2004, the EPA estimated that poultry processing plant consume between 580 and 2440 gallons per 1000 pounds of birds processed, the mean is shown 1323 gallons of water used to produce 1000 pounds of birds at slaughterhouses (27).

3 METHOD AND METHODOLOGY

In the experiment, the sample was planned to take from the Nalaikh poultry industry. The primary data of the wastewater characteristics and concentration is problematic to find. The treatment method is based on the DAF technology for high pollution concentration of wastewater. Depending on the laboratory equipment and possibility, we studied to reduce BOD, COD, and TSS of the wastewater. Due to the current situation COVID-19, the laboratory process is completely stopped. Therefore, all experiment methods are based on the literature review.

3.1 Sampling area

The “Orgio” chicken “Ajigana” LLC industry lies in Nalaikh, one of the 9 districts of the Mongolian capital of Ulaanbaatar and built-in 1954-1958, based on the large mining operation. Nalaikh district is located around 36km southeast of the capital of Mongolia, Ulaanbaatar (UB) city, and covers a total area of 68.7 thousand square hectares with a population of 36,426.

The Ajigana LLC is operating since 2013 of April which is the national investment industry and produced 6 different types of products marketed as an “Orgio” chicken. In 2012, the industry acquired Know-how technology for sanitary.

3.2 Biological oxygen demand measurement in the laboratory;

As for the measurement of the BOD is carried out according to a standardized method, so-called closed bottle test, described in the International Standards ISO 5815-2003. Standardized laboratory procedures are used to determine the amount of required oxygen for microorganisms to oxide organic materials in the wastewater. To determine the microbial diversity found in the environment, these measurements based on microbial samples normally taken from the environment. The measurement of the BOD is requiring at least 5 days at a temperature of 20°C. The technology of measurement is Lovibond BOD-System BD 600 which is simple and easy to collecting data or making an experience (23). The Lovibond BOD-System BD 600 is a closed system containing a test bottle and BOD detector. There is a gas

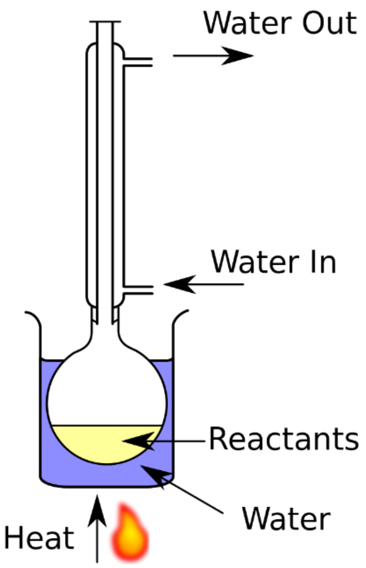
Picture 2 Lovibond BOD -System 600 technology

supplier section within the test bottle for microorganisms to substitute by air oxygen from the gas section of the test bottle. In the parallel time, developing carbon dioxide is chemically connected with potassium hydroxide in the seal cap of the test bottle. While it produces a pressure drop in the system which determines the BOD range and shown in the monitoring display as a graph and table. The BOD value is represented in mg/l O2 and the ability to measure up 4000 mg/l BOD in range (23).

3.3 Chemical Oxygen Demand measurement in the laboratory;

In a COD analysis, two different methods can apply which are including open reflux and closed reflux methods. The open reflux method is used to measure a wide range of wastes where large sample size is preferred. On the other side, the closed reflux is more suitable for smaller quantities of sample and concentration.

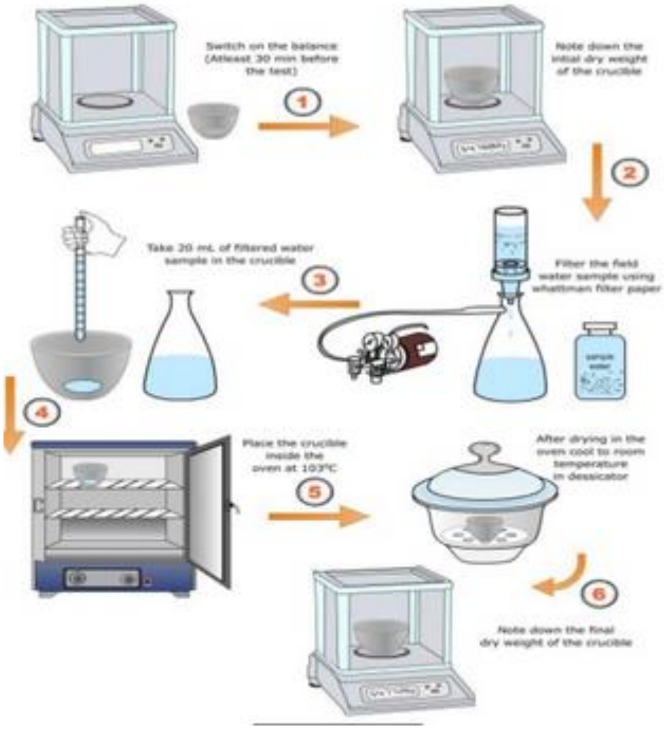
In the COD experiment use the open reflux apparatus and titration method to determine. It requires several reagents in the laboratory process such as standard potassium dichromate solution (K2Cr2O7), sulfuric acid reagent (H2SO4) with silver sulfate (Ag2SO4), standard ferrous ammonium sulfate (Fe(NH4)2(SO4)2*6H2O), mercuric sulfate and ferric sulfate as an indicator solution. The main principle is to heat the reactants to oxidizing organic matter and the unreduced dichromate solution is titrated with ferrous ammonium sulfate to determine consumed dichromate solution and the oxidizable matter is calculated (28).



Picture 3 COD open reflux method

3.4 Total suspended solids measurement in the laboratory;

The total suspended solids are determined by the filtration method in the laboratory which is the simplest method. During the procedure, the high concentration of TSS caused 2 conditions which are particles that are not fully settled or sludge blanket in the clarifier washed out. The experiment is carried out by drying oven, analytical balance, desiccator, glass, and fiber filter as shown in Picture 4 (29). The main principle is filtering fine and suspended solids by glass and fiber filter with the help of a pump and after filtering the remaining solids on the filter will be dried and measured. Then find the dried solids mass by comparison of fiber filter mass difference. For the exact result, all equipment must clean and purge under UV light before measurement.



Picture 4 TSS measurement methods (29)

3.5 Dissolved Air Flotation measurement:

In laboratory measurement of DAF is usually done by jar test to investigate the effect of the coagulation process in the removal efficiency of COD, BOD, and TSS. Therefore, the coagulation of process is PAC and anionic polymer with pH adjustment at 7 to 9. The doses of coagulant are more than 50 mg/l to determine the optimal dosage of the PAC (30) and the most suitable flocculent dosage is 15mg/l or more based on poultry DAF system literature. In Picture 5, the simple laboratory test is shown.

Picture 5 Jar test technology

- Stage 1 flocculation chamber is very high mixing rate to flocs together

- Stage 2 flocculation chamber is much lower mixing speed than stage 1 because the particle size comes much bigger and try not to break down the flocs contact.

- Stage 3 flocculation chamber is the lower mixing rate which helps to flocs get together and increase the size. As well as it gives time to settle after come together.

For the plant DAF designing and sizing calculation (13)**:**

The ratio of kilograms of removed solids makes a dissolved air flotation system more effective which ration is between 0.005 and 0.09 kg air/ kg solids removed.

The amount of air required is:

$$A = \rho * k \qquad (1)$$

Where:

A= air needs (kg/h)

P= specific needs of air (kg air/ solids separating kg)

K= solids flow to be removed (kg/h)

The suspended solids, FOG concentration, pressure, and temperature of wastewater are most considering parameters as well as the flow of water to treat is important of dimensioning the Recirculation flow of DAF systems. The recirculation flow is estimated by:

$$Qr = \frac{A}{\alpha * Xps} \qquad (2)$$

Where:

Qr = recirculation flow rate (m3 /h)

XS P = air solubility in pure water at work temperature and pressure (kg/m3)

α = the coefficient of the content of impurities in wastewater (0.60 to 0.80).

The solubility of air at atmospheric pressure depends on the water temperature designate by the following table:

Table 14 Solubility of air pressure depending on water temperature

Temperature (°C)	Solubility in pure water of air (ppm)
0	29.2
5	25.7
10	22.8
15	20.6
20	18.7
25	17.1
30	15.6

In the case of high salinity wastewater, thus the net flow design for the flotation tank or chamber will be:

$$Q = Qww + Qr \qquad (3)$$

Where Q present design flow (m3 /h) and QWW is the treatment wastewater that enter the tank flow rate (m3 /h). The floating surface is given by:

$$S = \frac{Q}{H} \quad (4)$$

Where:

S = horizontal surface (m2)

H = hydraulic load (m/h).

The flotation tank volume and depth is calculated as:

$$V = HRT * Q \, , h = \frac{V}{S} \quad (5, 6)$$

Where:

V = volume of the flotation tank (m3)

HRT = hydraulic retention time (h)

h = depth (m)

The depth of the flotation tank is limited between 1 and 3 meters, depending on the flotation tank pressurization distribution device:

The recirculation of the pressure chamber volume is determined by retention time and recirculation flow rate:

$$Vptank = Qr * HRT \quad (7)$$

The pressure tank hydraulic retention time is between 20 to 60 min as shown in Table 15. The recirculation flow rate and required work pressure are to define the pumping equipment for the pressurization of the process.

Table 15 is presenting the design parameters for the calculation.

Table 15 Design parameter value for the DAF system

Parameters	Units	Given
Air/solids ratio	kg/kg	0.03-0.09
Working P	atm	2.5-6
Pressurization rate	%	10.-40
Hydraulic Load	m/h	2.5-10
Hydraulic retention time	min	20.-60
Solids Load	kg/m2/h	4.5-5
Impurities, α	-	0.60-0.80

4 RESULT AND DISCUSSION

4.1 Result

This section is covering the theoretical design of WWTP based on DAF technology calculation for a small-scale industry like Ajigana LLC. According to the statistical data of Mongolian small-scale food-related industries are counted as 1914 in 2015. The highest numbering of industries are including meat and bakery industries, 314 and 916 respectively.

The Ajigana LLC is capable of producing 1 million chicken in a year and as a based on literature, the live weight of the chicken is about 2.8 kg which is requiring 42247.5 m3 water in a year and 115.45m3 water per hour to producing those amount of chicken. The poultry industry wastewater is containing excessive amounts of organic pollutions such as COD, BOD, and TSS. According to the literature, the contamination of COD is 7719.3 mg/l, BOD is 1821mg/l, and TSS is 5462mg/l. The objective is to reduce the high concentration of organic pollution under Mongolian wastewater discharge standards like MNS 49:43 and MNS 65:61 by the DAF system.

Table 16 Standards of wastewater

Parameters	Concentration of wastewater					Removal efficiency	
	Min	Max	Mean	MNS 49:43	MNS 65:61	MNS 49:43	MNS 65:61
COD	1341	1821	1602	50	800	96.8789 %	50.06242197 %
BOD	3154	7719.3	5422.25	20	400	99.63115%	92.62298861 %
TSS	3776	5462	3438.223	50	400	98.54576%	88.36608329 %

Further, the DAF is one of the most common and well known primary treatment systems for many industries as well as high removal efficiency to the treating process. The removal of DAF efficiency shows different results in different coagulation and flocculation reagents as well as different requirements. Under the MNS 49:43 and MNS 65:61 shows the removal efficiency would be maintained within 98% for MNS 49:43 and MNS 65:61 should be more than 50% removal efficiency for COD, other 2 parameters are more than 88% efficiency. But in the literature, the removal efficiency shows 43 % for COD, 43% for TSS, and 49 % for FOG respectively. Which means in Mongolian condition, the process flow diagram must contain other DAF unit system or should place the settling tank.

As a result, the design and calculations of DAF are shown in Table 17.

The surface area of the DAF system is theoretically 6.48 m2 and more realistically 8m2 and the tank is chosen to be rectangular and the width and length ratio is estimated 1:2. Depending on that ratio the width is shown 2m and the length of the DAF is 4m respectively. The depth of the tank is 1.6 m which makes volume in more realistically 10.4 m3 (1.6m X 3.6m X 1.8M). As for the power consumption for only DAF system is estimated to be 1.5-22 KW in an hour (31).

Depending on the flow rate and capacity of the industry, the design calculation is done.

Table 17 DAF design calculation

Parameters	Calculation	unit		Real dimension
Air needs	A	kg/h	0.131372	-
Solid flow removed	k	kg/h	26.2745	-
Recirculation flow rate	Qr	m3 /h	10.62884	-
Flow	Q	m3/h	15.43926	-
The surface area of the float	S	m2	6.175703	6.48
Volume	V	m3	10.3443	10.368
Depth	h	m	1.675	1.6
Width	W	m	1.757228	1.8
Length	L	m	3.514457	3.6
Volume pressure	Vptank	m3	7.121324	-

For the COD, BOD, and TSS measurements, the typical laboratory process is explained. Depending on the wastewater characteristic, the chemical additives and process procedure is changed in the DAF system without change of design or location. Therefore, the suitable process flow of the DAF system also covered in the result depending on the poultry industry process. As mentioned in Chapter 2.1.1, the main process of the poultry industry is producing big particles and organic pollution in water such as offal and blood. However “Wastes” from the process includes hides, feathers, intestines, and inedible products. But most of the wastes turned into value-added consumer products, pet foods, and biofuels.

The design and process flow diagram is simple but little different from other plant designs because of the removal efficiency of wastewater for Mongolian conditions. To reaching the permissible level of concentration for MNS requirements, the removal efficiency should be more than 98%. To achieve that efficiency requires more units in the process as presented in Figure 8.

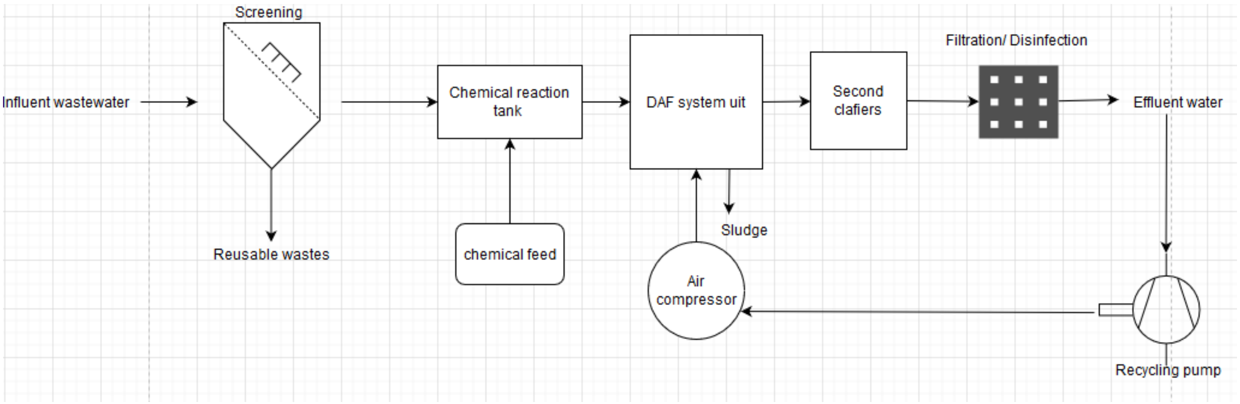


Figure 8 The DAF system process flow diagram

In the first step, the screening is added to remove big particles from wastewater which improves next step efficiency. The next step is to add chemicals to the wastewater for improving the DAF process after the DAF system, the settling tank or another DAF unit system is proceeding to boost the removal efficiency of the system, the filtration or disinfection section is included in the process.

Recently, the developments in sewage treatment have been to improve the reliability and efficiency of a treatment system to treat sewage, to meet standards and reduce the land area occupied by treatment works through increasing technical development. However, despite these developments, sewage water treatment systems are a mainly concerned issue for the environment. For instance; removal of FOG, COD, BOD, organic and nonorganic matters, and some cases of elimination of pathogenic.

The removal efficiency of DAF is typical with in the 45% with chemical reagents. However, to improve the removal efficiency the settling tank or other DAF unit is included in the process which makes better efficiency.

Several uncertainties occur during the thesis work such as due to the privacy of the company, the data and information are hard to find, and all data is taken from literature about the poultry process. Due to the lack of information, the industry process flow is unknown as well as the treatment process. So this study is offering the primary treatment process for the company and it includes the only design of the treatment plant.

5 Conclusion

By using the state of art review approach, I identified issues of the food industry particularly meat production, searched data from previous scientific papers, and estimated the design of the DAF the findings for industrial wastewater pre-treatment plant and, as scope study, analyzed to consider an embodiment of the plant to fit a small scale industry for the sparse population in Mongolia. The analysis and synthesis were followed in the Mongolian standards. I recommended the need to further determine wastewater characteristics in the Mongolian poultry small-scaled industry. It is an important contribution to calculate the design. Another thing, state of art review methodology can make essential to my understanding of research skill.

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