DOKUZ EYLÜL UNIVERSITY

GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

A ZERO DISCHARGE APPROACH ON THE MANAGEMENT OF A HOSPITAL WASTE AND WASTEWATER LOCATED IN İZMİR

by

Duygu ARDENİZ ÖREN

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İZMİR

A ZERO DISCHARGE APPROACH ON THE MANAGEMENT OF A HOSPITAL WASTE AND WASTEWATER LOCATED IN İZMİR

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We have read the thesis entitled **"A ZERO DISCHARGE APPROACH ON THE MANAGEMENT OF A HOSPITAL WASTE AND WASTEWATER LOCATED IN İZMİR"** completed by **DUYGU ARDENİZ ÖREN** under supervision of **PROF. DR. DELIA TERESA SPONZA** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ABSTRACT

In this study, the solid and the liquid wastes produced from a hospital and the present waste management procedures was investigated and some novel waste management techniques were determined to treat the solid, liquid waste and wastewaters. The solid wastes should be collected in special coloured bags, they should be labelled and should be stored in special storage area, and should be disposed by the licensed companies according to Waste Management Regulation. The application of the waste separation at the source throughout the hospital decreases the waste disposal fees. The management of hazardous liquid wastes coming from the hospital should be handled as proposed by TÜBİTAK. In Turkey, the hospital wastewaters are not treated and they are released directly to the municipal sewage channel system. Since the hospital wastewater contains some micropollutants such as antibiotics, analgesics, anesthetic chemicals, anti-inflammatories; these organics inhibit the bacteria growth in biologic treatment. Therefore, in this study, some novel-advanced treatment methods to remove the hospital wastewaters were presented. An advanced treatment method contact Anoxic/Aerobic sequential Membrane Bioreactor (AAMBR) system for the treatment of hospital wastewater was suggested and relevant design parameters were calculated. Since the contact AAMBR effluent water quality is very high, therefore, it is considered to use as irrigation purpose. Effluent water characteristics were examined according to irrigation water legislation and the quality of the treated hospital water was considered suitable for use as irrigation water. Reuse of treated water is very important both in terms of protecting natural resources by providing economic benefits.

Keywords: Hospital solid waste management, hospital wastewater management, AAMBR design

İZMİR'DE BULUNAN BİR HASTANENİN ATIKSU VE ATIKLARININ YÖNETİMİNDE SIFIR DEŞARJ YAKLAŞIMI

ÖZ

Bu çalışmada, bir hastaneden üretilen katı ve sıvı atıklar ve mevcut atık yönetimi prosedürleri araştırılmış ve katı, sıvı atık ve atıksuların arıtılması için bazı yeni atık yönetimi teknikleri belirlenmiştir. Katı atıklar özel renkli torbalarda toplanmalı, etiketlenmeli ve özel depolama alanında depolanmalı ve Atık Yönetimi Yönetmeliğine göre lisanslı firmalar tarafından bertaraf edilmelidir. Kaynakta atık ayrıştırmanın hastane genelinde uygulanması atık bertaraf ücretlerini azaltır. Hastaneden gelen tehlikeli sıvı atıkların yönetimi TÜBİTAK tarafından önerildiği şekilde yapılmalıdır. Türkiye'de hastane atık suları arıtılmamaktadır ve doğrudan belediye kanalizasyon sistemine bırakılmaktadır. Hastane atıksuyu antibiyotikler, analjezikler, anestezik kimyasallar, antienflamatuarlar gibi bazı mikrokirleticiler içerdiğinden; bu organikler biyolojik arıtmada bakteri üremesini engeller. Bu nedenle, bu çalışmada, hastane atıklarını gidermek için bazı yeni ileri arıtma yöntemleri sunulmuştur. İleri bir arıtma yöntemi ile hastane atık sularının arıtılması için Anoxic/Aerobik sıralı Membran Biyoreaktör (AAMBR) sistemi önerilmiştir ve ilgili tasarım parametreleri hesaplanmıştır. AAMBR çıkış suyu kalitesi çok yüksek olduğundan, sulama amaçlı olarak kullanılması düşünülmüştür. Çıkış suyu özellikleri sulama suyu mevzuatına göre incelenmiş ve arıtılmış hastane suyunun kalitesi sulama suyu olarak kullanılmaya uygun olarak değerlendirilmiştir. Arıtılmış suyun yeniden kullanılması, hem doğal kaynakları korumak hem de ekonomik fayda sağlamak açısından çok önemlidir.

Anahtar Kelimeler: Hastane katı atık yönetimi, hastane atıksu yönetimi, AAMBR tasarımı

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INTRODUCTION

Hospitals are medical institutions that are present in every country and they are essential for human survival. As they fulfill their duties, hospitals generate dangerous waste materials. While mostly being small in volume, these waste materials may be extremely dangerous for human and environmental well-being. Medical waste has four subcategories; domestic, medical, hazardous and radioactive (Medical Wastes Control Regulation, 2017). Domestic waste is generated in the largest quantity from administrative activities, cooking, etc. This waste type does not require special attention and can be handled the same way as regular municipal waste. However, these should always be kept separate from other waste types in a hospital to prevent the contamination of domestic waste. Waste may be treated physically, chemically, biologically or using advanced methods. Optimal treatment should be used the method that would allow treatment to the required level. However, over-treatment would bring more material, energy and labor costs. Therefore, choosing a correct treatment method is essential. Hospital waste can be solid or liquid. Both these groups require attention specific to their type.

For Turkish hospitals, current regulations impose treatment of wastes by licensed treatment facilities. Hospitals gather their liquid and solid wastes from their units and store them for a limited time. According to waste class, hospital waste is sent directly to licensed treatment centers without any kind of on-site treatment. While it allows wastes to be handled by dedicated professionals, this application brings some burden to hospitals. For example, hospitals need to reserve space for storage and they have to pay fees to treatment companies. From an environmental perspective, mix-ups or spillages can occur due to lack of storage space or during transportation of wastes. Moreover, transportation of wastes means carbon emissions. These all could be solved by incorporating on-site treatment facilities for hospitals and treating hazardous wastes. However, according to the legislation, it is not possible for hospitals to establish their own incineration or sterilization facilities.

In the world, the hospital wastewater was separately treated by advanced treatment process so that the micropollutants and energetic organics can be ultimately removed. In Turkey the hospital wastewaters was discharged directly to the municipal sewage channel system. The conventional treatment processes used in the treatment of municipal wastewater cannot be remove the toxic, energetic, micropollutants and the pharmaceuticals (antibiotics, analgesics, anesthetic chemicals, anti-inflammatories, cytotoxic and cytostatic chemicals, β-Blockers, etc.) used in the hospitals. Therefore, the direct discharges of these chemicals to the municipal treatment reduce the treatment efficiencies of the biological treatment stage in the municipal treatment processes. Therefore; some advanced process should be used in the treatment of hospital wastewaters.

The aim of this study is to characterise the solid and liquid wastes releasing from a hospital located near İzmir in the Aegean Region, to examine the current solid and liquid waste treatment processes present in the hospital, to propose new, advanced solid and liquid waste treatment process/processes to minimize the wastes releasing from the hospital and to design a novel treatment process for the removal the pollutants from the wastewaters for a ‘zero discharge’ approach.

In the framework of this study,

firstly, the characterization of the solid and liquid wastes will be performed in the hospital,

secondly, the solid and liquid waste removal techniques utilised in the hospital will be examined,

thirdly, some new, advanced treatment alternatives will be recommended for the treatment of solid and liquid wastes produced from the hospital,

fourthly, a contact Anoxic Aerobic sequential Membrane Bioreactor (AAMBR) system will be suggested for the treatment of wastewaters of the examined hospital.

Some design parameters was used to propose the biological process volumes and the effluent pollutants parameters.

Current Regulations Relevant to the Disposal of Hospital Wastes and Wastewaters

In Turkey, the hospital wastewaters are treated according to the quides and precautions given by the Ministry of Environment and Urbanisation. The hospital wasterwater is accepted as domestic wastewater according to the Water Pollution Control Regulation numbered 25687 and dated 31.12.2004 (Water Pollution Control Regulation, 2004). According to this regulation the hospital wastewater is defined as domestic and it was discharged to the İzmir municipality sewerage system by taken into consideration the discharge limits given by the regulation namely “Discharge of Wastewater to the Sewerage Network” in İzmir numbered 10 and dated 13.05.2016 (Regulation of Discharge to Sewerage Network in İzmir, 2016) as shown in Table 1.1.

Table 1.1 Wastewater standards for discharge of wastewater to urban wastewater infrastructure facilities (Discharge of Wastewater to Sewerage Network Regulation, 2016)

Parameter	**İzmir Water and Sewage Administration (İZSU) Standards**
Temperature	40
pH	6.5-9
Total Suspended Solids (TSS) (mg/L)	350
Oil and Grease (mg/L)	100
Chemical Oxygen Demand (COD) (mg/L)	800
Sulfate (SO_4) (mg/L)	1000
Sulfur (S) (mg/L)	2
Phenol (mg/L)	10
Free chlorine (F.Cl) (mg/L)	5
Arsenic (As) (mg/L)	3
Total Cyanide (Tot. Cn) (mg/L)	10
Lead (Pb) (mg/L)	3
Cadmium (Cd) (mg/L)	2
Total Chrome (Cr) (mg/L)	5
Mercury (Hg) (mg/L)	0.2
Copper (Cu) (mg/L)	2
Nickel (Ni) (mg/L)	5
Zinc (Zn) (mg/L)	10
Stannous (Sn) (mg/L)	5
Tar and Oil Origin Oils (mg/L)	50
Chloride (Cl^-) (mg/L)	5000
Silver (Ag) (mg/L)	5
Surfactant	It is forbidden to discharge the surfactant which are not biodegredable

The concentrations of the pollutant parameters given in Table 1.1 should be reduced before discharging the hospital wastewaters to the municipality sewerage system. The hospital wastewaters discharged to the sewerage can be treated as is in municipal wastewater according to the limits (Table 1.1) given by the İzmir Water and Sewerage Administration according to the Discharge of Wastewater to Sewerage Network Regulation (Discharge of Wastewater to Sewerage Network Regulation, 2016)

Although hospital wastewater is defined as domestic in the legislation mentioned above, the pollutants present in the hospital wastewater are completely different from than that municipal/domestic wastewater.

Nowadays, in İzmir, a new application procedure is used in the treatment of the hospital wastewaters. In this new application; the authorities from the İzmir water and sewerage administration were investigated the quality of the hospital wastewater. If it is necessary a pre-treatment stage was recomended by this authority before discharging the hospital wastewater to the municipal sewage system. According to this regulation, the hospital wastewaters containing the wastewaters coming from the laboratory devices, dialysis units and laundries should be pre-treated before discharging to the municipal sewage system. In these discharges the wastewater should contains the limits given in Table 1.1.

The wastes produced by the hospitals was managed according to the Waste Management Regulation numbered 29314 and dated 02.04.2015 (Waste Management Regulation, 2015), Medical Wastes Control Regulation numbered 29959 and dated 25.01.2017 (Medical Wastes Control Regulation, 2017), Packaging Wastes Control Regulation numbered 30283 and dated 27.12.2017 (Packaging Wastes Control Regulation, 2017), Waste Electrical and Electronic Equipments Control Regulation numbered 28300 and dated 22.05.2012 (Waste Electrical and Electronic Equipments Control Regulation, 2012), Regulation about Transportation of Dangerous Materials on Highway numbered 30754 and dated 24.04.2019 (Regulation about Transportation of Dangerous Materials on Highway, 2019), while the wastewaters were managed according to the Water Pollution Control Regulation numbered 25687 and dated 31.12.2004 (Water Pollution Control Regulation, 2004).

All the wastes were covered by the Waste Management Regulation and the wastes have 6-digit code number in terms of this regulation. Waste code is determined in accordance with the waste code determination hierarchy in Annex-1 of Waste Management Regulation. Annex-4 of the Waste Management Regulation includes waste code definition. From this part 6-digit code that fits the type of waste is determined. In all studies related to waste, the six-digit waste code corresponding to the definition of waste must be fully used. This management regulation includes; the numbering of the wastes, recovery and disposal methods of the wastes. The management of the electronic wastes, of the packaging wastes and the hazardous wastes in the hospital are also considered in this regulation.

Medical Wastes Control Regulation numbered 29959 and dated 25.01.2017 (Medical Wastes Control Regulation, 2017) is the most commonly used in the management of hospital-acquired wastes. This regulation allows us to classify medical wastes according to their characteristics and explains how to manage the medical wastes produced in hospital. Medical wastes are; infectious wastes, pathological wastes and cutting piercing wastes.

1. Infectious Wastes: Infectious wastes according to Medical Wastes Control Regulation includes the infectious agents containing all kinds of body fluids, especially blood and blood products, human tissues, organs, anatomical parts, autopsy material, placenta, fetus and other pathological material, gloves, drapes, sheets, bandages, patches, tampons, swabs and similar wastes, body excretions of patients under quarantine, bacteria and virus-retaining air filters, laboratory cultures and culture stocks of infectious agents, any material that has come into contact with infected animals and their extracts, waste from veterinary services. (Medical Wastes Control Regulation, 2017).

2. Pathological waste is explained in the Medical Waste Control Regulation and originated from the tissues, organs, body parts, body fluids and fetus that have

been produced by surgical intervention, autopsy, anatomy or pathology study (Medical Wastes Control Regulation, 2017).

3. Cutting Piercing Wastes: These wastes are identified in Medical Waste Control Regulation as injector and all other medical intervention needles, lancet, capillary tube, scalpel, knife, serum set needle, surgical suture needles, biopsy needles, intraket, broken glass, bulb, lam-coverslip, broken glass tube and petri dishes such as stinging, drilling, wastes that may cause abrasions and injuries (Medical Wastes Control Regulation, 2017).

According to the Medical Wastes Control Regulation (2017), the metropolitan municipalities in metropolitan cities are obliged to provide the sterilization and/or disposal of medical waste, to establish/have a medical waste treatment plant installed for this purpose and to operate it. According to the Medical Wastes Control Regulation (2017); the facilities where medical waste is disposed or sterilized is defined as a "Medical Waste Treatment Plant". According to Article-5 of the aforementioned regulation; health institutions cannot establish and operate individual medical waste treatment plants. Each hospital is responsible for the disposal of medical wastes produced in the hospitals.

The management of packaging wastes produced in hospital can be evaluated according to both Waste Management Regulation, (2015) and Packaging Wastes Control Regulation, (2017). The packaging wastes are weighed and delivered to the company which has an agreement between the İzmir Metropolitan Municipality. Packaging wastes are collected for recycling by licensed companies. These wastes are sent to the licensed companies by special vehicles. "Waste Acceptance" certificate is given as a document that these wastes are taken.

Electronic wastes produced in the hospital are managed according to both Waste Management Regulation, (2015) and Waste Electrical and Electronic Equipments Control Regulation, (2012).

1.1 Hospital Solid Wastes

Table 1.2 exhibited the characterisation of solid wastes produced from the hospitals. Hospital solid wastes contains; office, packaging and food waste as well as domestic waste produced from administrative offices and dining rooms. In addition to these waste types cartridges, toners, batteries, fluorescent lamps are produced from administrative offices are solid wastes. Drug packages, cartridges, toner, batteries fluorescent lamps, packages of hazardous materials or contaminated packages, pharmaceutical wastes are produced in clinics are solid wastes. Amalgam waste produced from the dentistry; X-ray films produced from the radiology, expired drugs from pharmacy and hazardous chemicals from laboratory produced are solid wastes. Contaminated packaging wastes and hepa filters produced from the operating rooms, some machine parts produced from technical workshops are solid wastes.

Table 1.2 Classification of wastes from health organizations (Medical Wastes Control Regulation, 2017)

Domestic Wastes		Medical Wastes			Hazardous Wastes	Radioactive Waste
General Wastes	Packaging Wastes	Infectious Waste	Pathological Waste	Cutting Piercing Wastes	Hazardous Wastes	Radioactive Wastes

The origines of the waste types present in hospital tabulated in Table 1.2 were summarized as follows.

1. General Wastes: General waste is defined as the waste which is not infected such as kitchen waste, garden waste, office waste coming from the administrative offices, kitchens, cafeterias, toilets.

2. Packaging Wastes: Packaging wastes are recyclable and reusable wastes coming from the kitchens, from the warehouses, administrative offices and workshops.
3. Infectious Wastes: Infectious wastes are explained in the introduction part.
4. Pathological Wastes: Pathological wastes are explained in the introduction part.
5. Cutting Piercing Wastes: Cutting piercing wastes are decribed in the introduction part.
6. Hazardous Wastes: According to Waste Management Regulation (Waste Management Regulation, 2015) hazardous wastes bearing one or more of the hazardous properties listed in Annex-3/A (explosive, oxidising, highly flammable, flammable, irritating, harmful, toxic, carcinogenic, corrosive, infectious, toxic to the reproductive system, mutagenic, waste releasing toxic or highly toxic gases from contact with air, water or an acid, sensitizing, ecotoxicity, and other wastes from the wastes giving above after disposal) of this regulation. (Waste Management Regulation, 2015). Also, wastes with an asteriks (*) beside the six-digit waste code in Annex-4 of Waste Management Regulation (2015) are hazardous.
7. Radioactive Waste: Radioactive waste which emits low or high levels of radiation.

1.2 Investigated Hospital Wastewater

Hospital wastewater contains macro and micro pollutants from many units coming from the laboratories, research units, operating rooms, polyclinics, dialysis, emergency room, intensive care and residue of drug. Some of the chemicals used in the hospital such as pharmaceuticals personal care products (PPCPs), solvents, radionuclides, endocrine disrupters, disinfectants and heavy metals are discharged to sewage systems in various ways (Yaşar, Can Doğan & Arslan, 2013).

Hospital wastewater effluents contain pathogenic microorganisms, partially metabolized pharmaceuticals, radioactive elements and other heavy metals and toxic chemical compounds such as Cu, Fe, Cd, Pb, Hg, Ni, Pt, Cyanide and Phenol groups.

Hospitals discharges contained plenty of undesired potential pathogens like antibiotic-resistant bacteria and viruses (Amouei et al., 2015). These hazardous agents which remain in wastewater treatment plants can provoke the pollution in the natural environment by causing biological imbalances (Mahvi et al., 2009)

In many cases, hospital wastewater is considered as an effluent with a similar quality of municipal wastewater, however, due to activities that take place within the hospital it may also contain various potentially hazardous components including microbiological pathogens, hazardous chemical compounds, disinfectants, pharmaceuticals and radioactive isotopes (Amouei et al., 2015).

1.3 Material and Methods

In this study, the wastewater of the investigated hospital is currently discharged into the municipal sewage system. The pollutant parameters in the hospital wastewaters is shown in Table 1.3 and the discharge limits are given in Table 1.1. However, as is known, hospital wastewater contains many macro and micro-pollutant sources and they are discharged into the municipal treatment system without treating the harmfull toxic materials. In addition, some pollutant parameters present in the hospital wastewater is given in Table 1.3 do not meet with the municipal discharge limits is given in Table 1.1. Considering these, hospital wastewater is thought to be treated with a contact Anoxic/Aerobic sequential Membrane Bio Reactor (AAMBR). Therefore in this study, a contact AAMBR will be designed and the the effluent parameters will be discussed. The effluent quality of the contact AAMBR will be compared with the regulation namely Regulation for Treated Wastewater to be Used as Irrigation Water (2010), and Guidelines for Interpretations of Irrigation Water Quality (2010). Improved Table for the Assessment of the Chemical Quality of Irrigation Water and Maximum Permissible Concentrations of Heavy Metals and Toxic Elements in Irrigation Waters are based on this regulation are given in Tables 1.4 and 1.5.

Table 1.3 Raw wastewater characteristics of the investigated hospital

Raw Wastewater Influent Characteristics of the Investigated Hospital	
COD (mg/L)	250
NH_3 (mg/L)	25
NO_3-N (mg/L)	17.93
PO_4-P (mg/L)	12
Total Nitrogen (TN) (mg/L)	33
Total Suspended Solid (TSS) (mg/L)	398
Conductivity (µS/cm)	5
SAR_d (mg/L)	3
Boron (B) (mg/L)	2.3
Sodium (Na) (mg/L)	25
Chlorine (Cl) (mg/L)	1000
Coliform (cfu/mL)	20000
EC (dS/m)	2.1
Total Dissolved Solids (TDS) (mg/L)	500
HCO_3 (mg/L)	12
RSC	3.5
SSP	200
ESP	120
pH	8
Aluminum (Al) (mg/L)	2
Arsenic (As) (mg/L)	1

Table 1.3 continues

Beryllium (Be) (mg/L)	1.2
Cadmium (Cd) (mg/L)	1.6
Chromium (Cr) (mg/L)	2.2
Cobalt (Co) (mg/L)	2.4
Copper (Cu) (mg/L)	3
Flourine (F) (mg/L)	3.6
Iron (Fe) (mg/L)	2.5
Lead (Pb) (mg/L)	2
Lithium (Li) (mg/L)	1.8
Manganese (Mn) (mg/L)	4
Molybdenum (Mo) (mg/L)	1.3
Nickel (Ni) (mg/L)	2.4
Selenium (Se) (mg/L)	1.6
Vanadium (V) (mg/L)	0.9
Zinc (Zn) (mg/L)	3.4

Table 1.4 Limits for the chemical quality of irrigation water (Regulation for Treated Wastewater to be used as Irrigation Water, 2010 and Guidelines for Interpretations of Irrigation Water Quality, 2010)

Potential irrigation problem		*Unit*	*Degree of restriction on use*		
			None	*Slight to moderate*	*Severe*
Salinity (affects crop water availability)					
EC_w		dS/m	< 0.7	0.7-3.0	> 3.0
TDS		mg/L	*< 450*	450-2,000	> 2,000
Infiltration (affects infiltration rate of water-into the soil. Evaluate using EC_w and SAR together)					
SAR	= 0- 3	EC_w	= > 0.7	0.7-0.2	< 0.2
	= 3-6		=> 1.2	1.2-0.3	< 0.3
	= 6- 12		=> 1.9	1.9-0.5	<0.5
	= 12-20		= > 2.9	2.9- 1.3	<1.3
	= 20-40		=> 5.0	5.0- 2.9	<2.9
Specific ion toxicity (affects sensitive crops)					
Sodium (Na)					
Surface irrigation		SAR	< 3	3-9	> 9
Sprinkler-irrigation		me/L	< 3	> 3	
Chloride (Cl)					
Surface irrigation		mg/L	<140	140-350	> 350
Sprinkler-irrigation		mg/L	< 100	> 100	
Boron (B)		mg/L	< 0.7	0.7-3.0	> 3.0
Miscellaneous effects (affects susceptible crops)					
Nitrogen (NO_3-N)		mg/L	< 5	5-30	> 30
Bicarbonate (HCO_3) (overhead sprinkling only)		me/L	< 1.5	1.5-8.5	m > 8.5
Other parameters for sodium toxicity					
RSC			< 0	0- 1	> 1
SSP			< 60	60-80	> 80
ESP			2-10	10-40	> 40
pH			Normal range	6.5-8.4	

Table 1.5 Maximum permissible concentrations of heavy metals and toxic elements in irrigation waters (Regulation for Treated Wastewater to be used as Irrigation Water, 2010 and Guidelines for Interpretations of Irrigation Water Quality, 2010)

Elements	*Maximum total concentration to the unit area (kg/ha)*	***Maximum allowed concentrations***	
		Limit values for irrigation (mg/L)	*In the areas containing aluminium with pH values between 6.0 and 8.5 when the irrigation duration is low than 24 years (mg/L)*
Al	4,600	5.0	20.0
As	90	0.1	2.0
Be	90	0.1	0.5
Boron (B)	680	3	2.0
Cd (Cadmium)	9	0.01	0.05
Chrom (Cr)	90	0.1	1.0
Cobalt (Co)	45	0.05	5.0
Copper (Cu)	190	0.2	5.0
Floroid (F)	920	1.0	15.0
lron (Fe)	4,600	5.0	20.0
Lead (Pb)	4,600	5.0	10.0
Lithium (Li)	-	2.5	2.5
Manganese (Mn)	920	0.2	10.0
Molybdenum (Mo)	9	0.0l	0.052
Nickel(Ni)	920	0.2	2.0
Selenium (Se)	16	0.02	0.02
Vanadium (V)	-	0.1	1.0
Zinc (Zn)	1,840	2.0	10.0

In the treatment of the studied hospital wastewater a contact Anoxic/Aerobic sequential Membran Bio Reactor (AAMBR) was designed. In this design the anoxic reactor was combined with aerobic stage. In the anoxic MBR stage, the organic carbonaceous compounds such as BOD and COD are used to remove the NO_3-N during denitrification with a flow coming from the aerobic MBR stage via heterotrophic bacteria. The PO_4-P present in the cells of the poly-P bacteria are released to the wastewater and the PO_4-P concentration increased in the anoxic stage. A part of the COD was used during PO_4-P release from the bacteria. Then the flow is going to the aerobic MBR in this stage. This stage is used to remove the organic matters such as BOD and COD remaining from the anoxic MBR and the micropollutants (only penicillin as an antibiotic was undertaken). In this stage ammonia is oxidized to nitrate via autotrophic nitrification bacteria. The organic nitrogenous compounds are degraded to ammonia under anoxic conditions. In this stage phosphate bacteria also uptake the PO_4-P to their cells present in the wastewater. The wastewater can be treated by the PO_4-P by separating the sludge from the wastewater. Then, the wastewater is transferred to the anoxic stage to rest NO_3-N generated in the aerobic sludge. NO_3-N in the anoxic stage is transformed to N_2 by heterotrophic bacteria and the rest of the COD was used as electron donor during denitrification take place in the anoxic stage. Table 1.6 shows the microbial metabolism types in bio-treatment of wastewater (Judd, S. & Judd, C., 2015)

Table 1.6 Microbial metabolism types in bio-treatment of wastewater (Judd, S. & Judd, C., 2015)

Component	Process	Electron Acceptor	Type
Organic Carbon	Aerobic Biodegredation	O_2	Aerobic
Ammonia	Nitrification	O_2	Aerobic
Nitrate	Denitrification	NO_3^-	Facultative
Sulfate	Sulfate Reduction	SO_4^{2-}	Anaerobic
Organic Carbon	Methane Formation	CO_2	Anaerobic

1.4 Analytical Procedures

COD, NH_3, NO_3-N, PO_4-P, Total Nitrogen, Total Suspended Solid, Conductivity, SAR_d, Boron, Sodium, Chlorine, Coliform, EC, Total Dissolved Solids, HCO_3, RSC, SSP, ESP, pH, Al, As, Be, B, Cd, Cr, Co, Cu, F, Fe, Pb, Li, Mn, Mo, Ni, Se, V, Zn were analysed according to Standard Methods (2012).

1.5 Wastewater Characterisation

1.5.1 Types of Wastewater

1.5.1.1 Industrial Wastewater

Industrial wastewaters produce large amounts of gas, liquid and solid wastes. For this reason, industrial facilities must dispose their waste. Preventive technologies to be chosen should be well defined in order to treat the wastewaters effectively, based on the pollutant partameters. Since the type of wastewaters and the pollutant present in the industries are completely different, the treatment procedures to treat the wastewaters will be different. Therefore, each industry should be considered separately in determining the preventive treatment technologies to be selected. The treatment technologies for each wastewater type are determined by the quantitative and qualitative properties of the wastewater. the pollutants present in each industry wastewater can be as follows: organic matter, dissolved salts, toxic substances, color and turbidity, suspended solids, temperature, pH, nutrients, oil and grease, radioactive materials, surfactants (detergents), phenol and phenol derivatives, bacteriological contaminants, flavor and odor-forming compounds, pesticides, acids and bases, petroleum and petroleum derivatives and other non-perishable (permanent) wastes. Therefore mentioned pollution variables are treated by the conventional treatment processes by taken into consideration the suitable treatment technologies. Nowadays, in order to treat some emergency chemicals new treatment technologies should be taken into consideration since the accumulated organics in the treatment processes bring a lot of risks to the environment and to the people. Therefore, industrial pollution affects negatively the environmental health and therefore the human health. The amount of water used in the industries in Turkey is 102%. This amount is increasing as the industries are developed. The quality and quantity of industrial water discharged into the natural water environment can cause big environmental damages. In order to prevent this, waste water can be controlled inside the factory without leaving the factory and treatment planning can be done. Water sources are not enough and the treated wastewaters should be used again. Recovery and recycling of the treated wastewater with the appropriate treatment technologies will decrease the water consumption in treatment plants (Arceivala, 1998, p. 17).

1.5.1.2 Domestic Wastewater

Domestic wastewater contains suspended substances, colloidal substances and organic and inorganic substances in dissolved form. The density of the wastewater may vary depending on the density of the clean water used prior to soiling and the purpose for which the water is used. The concentration of waste water varies depending on the daily water use per person. This means that the amount of waste water can vary from city to city, from season to season, even from hour to hour.

1.5.1.3 Municipal Wastewater

Urban wastewater is the name of a new mixture of water from a city's municipal wastewater and industrial wastewater and/or rainwater. Urban wastewater is treated with the same method such as in domestic wastewater and industrial wastewater.

1.5.1.4 Hospital Wastewater

The chemical substances used in hospitals for care activities and medical research are generally found in the wastewaters. Even if the high volume of generated wastewaters by these establishments ensures an important dilution of the pollutants, the discharge of these effluents in the urban sewer network or in the natural environment generates risks for human health, and represents a significant contribution to the general contamination of the environment, and more particularly of the aquatic environments. The most important pollutants present in hospital wastewaters are pathogenic microorganism, organohalogen compounds, such as the AOX (halogenated organic compounds adsorbable on activated carbon), radioisotopes, detergents and pharmaceuticals (Alessio, 2010).

Comparison of domestic, municipal and hospital wastewater characteristics are shown in Table 1.7

Table 1.7 Comparison between domestic, urban and hospital wastewaters (Yaşar et al., 2013)

Parameter	Unit	Approximate ranges of domestic and hospital wastewater	Approximate ranges of domestic wastewater	Physicochemical characterization of hospital wastewater	Hospital Wastewater Average Concentration	Urban Wastewater Average Concentration
pH	-	-	-	8.4±0.3	8	7.5
Chloride	mg/L	-	30-100	185±90.4	200	50
TSS	mg/L	60-200	100-350	225±64	160	60
COD	mg/L	150-800	250-1000	638±435	500	170
TOC	mg/L	50-300	80-290	218±78	-	-
BOD_5	mg/L	50-400	110-400	-	200	90
COD/TOC	-	-	-	3.43±0.92	-	-
Redox Potential	Mv	-	-	-	890	100
TKN	mg/L	-	-	-	33	45
TP	mg/L	-	-	-	4	7
Oil and Grease	mg/L	-	-	-	25	75
Total Surfactant	mg/L	-	-	-	45	5
E.Coli	piece/ 100ml	-	-	-	10^4	10^5
Fecal Coliform	piece/ 100ml	-	-	-	10^5	10^7
Total Coliform	piece/ 100ml	-	-	-	10^6	10^8

As shown in Table 1.7 it can be said that the BOD_5, COD and TSS values of the hospital wastewater are 2-3 times higher than the urban wastewater (Yaşar et al., 2013).

The variations of concentrations of pharmaceuticals present in the hospital wastewater are given in Table 1.8.

Table 1.8 Average concentrations of important pharmaceutical compounds in hospital (Yaşar et al., 2013)

Drug Classes	Average Value of Hospital Wastewaters (µg/L)	Average Value of Urban Wastewaters (µg/L)	Avarage HWW / Avarage UWW
Analgesics	100	11.9	8-15
Antibiotics	11	1.17	5-10
Cytostatics	24	2.97	4-10
β-Blockers	5.9	3.21	1-4
Hormones	0.16	0.10	1-3
ICM (Iodinated Contrast Media)	1008	6.99	70-150
AOX (Halogenated Organic Compounds Adsorbable on Activated Carbon)	1371	150	7-15
Gadolinium	32	0.7	35-55
Platinum	13	0.155	60-90

According to the data summarized in Table 1.8 micropollutants such as PPCPs (Pharmaceuticals Personel Care Products) and some heavy metals concentrations present in hospital wastewaters are 2-150 times higher than in urban wastewater (Yaşar et al., 2013).

1.6 Wastewater Treatment Methods

1.6.1 Physical Water Treatment Systems

Grills: The treatment units used for the purpose of preventing large-volume substances from being discharged from the wastewater and damaging the pumps and other equipment and reducing the burden on other treatment units. Different types are present, such as fine or coarse depending on their spacing. They can also be designed with manual or automatic cleaning.

Sieves: Keeping the solids in the wastewater and entering the treatment system are used to reduce the pollution loads.

Balancing Pools: They are used for balancing the flow and pollution loads of wastewater.

Sand Holders: They are used to prevent the deposition of sand and gravel in the settling ponds in order to prevent the erosion of non-decomposing materials from water.

Flotation Systems: The flotation process is the inverse of the precipitation process and is based on the rise of particles having a lower specific gravity than water. Flotation systems are used to hold light materials such as oil, soap, grease, wood parts in waste water.

Precipitation Pools: They are used for the purpose of removing the solids with more density in the water by the effect of gravity under static conditions. Precipitation Pools can be used for pre-precipitation or biological and chemical treatment followed by final precipitation.

1.6.2 Conventional Biological Water Treatment Systems

Biological treatment is the process of removing dissolved organic substances in wastewater by bacteriological activities. In order for bacteria to carry out the purification process, parameters such as pH, temperature, dissolved oxygen; toxic substances must be kept under control.

Applications; activated sludge systems, biofilm systems, stabilization pools, ventilated lagoons and trickling filters (msxlabs.org, 2009).

Activated Sludge System: Classic activated sludge process; it consists of the Inlet Unit, Pumping Station, Sand and Oil Retention Pool, Anaerobic Phosphorus Pool, Ventilation Pool and Final Sedimentation Units. Control of sludge density in excess sludge and pools in the system; recirculation tanks and sludge tanks. The sludge which has grown in mud age is removed from the system by the decanters in the sludge dewatering unit. The microorganisms contained in the activated sludge convert the organic materials in the wastewater into the form they can use in their bodies by breaking down the water and energy required to survive. Microorganisms, which have a great role in the treatment of wastewater in the ventilation pool, need to remove the old microorganisms from the system and keep the number of microorganisms (MLSS) at optimum value in order to better treat the wastewater. Therefore, some of the sludge is sent back from the return unit to the ventilation pools; part of the sludge tank and the sludge dewatering unit is removed from the system.

Biofilm: Wastewater treatment structures consisting of serial circular discs are called biodiscs. Biodiscs consist of materials such as polysterene and polvinylchloride. Biodisc purification method is an example of aerobic treatment. Biodiscs work principle; discs are submerged and turned slowly into wastewater. Microorganisms adhere to these discs to form a biofilm layer. When the microorganisms on the discs get oxygen from the atmosphere by the rotation of the discs and sinks into the wastewater again, the organic materials in the wastewater are removed by air, thus the organic matter in the wastewater is removed from the wastewater.

Stabilization Pools: Stabilization pools are the main purpose of natural treatment without any energy consumption. Stabilization pools are divided into three groups: aerobic, anaerobic and facultative. The main method of treatment is to compensate by balancing, pre-precipitation and organic matter anaerobic digestion and aerobic oxidation.

Ventilated lagoons: These systems are used in the treatment of high quality wastewater with high flow rate and supplied oxygen to the wastewater by means of blowers.

Anaerobic Treatment Systems: Organic and inorganic materials in wastewater are decomposed by microorganisms without using oxygen and converted to CO_2, CH_4, H_2S and NH_3. Continuous mixing reactors, anaerobic filters and fluid bed systems are examples of anaerobic treatment methods.

Continuous Mixed Tank Reactor: This reactor, which is a continuous stirred tank type, is one of the first generation reactors used for anaerobic treatment of wastewater without solid recirculation.

Anaerobic Filter: The filling material used as an anaerobic filter type developed as an adaptation of stationary cell reactors provides the contact surface required for biofilm development.

Fluidized Bed Systems: In this system, the upstream reactor is partially filled with a carrier material (usually sand). In this reactor, biofilm is formed on the sand particles to perform the treatment.

1.6.3 Chemical Water Treatment Systems

Chemical treatment systems are the treatment processes that are applied in order to allow the precipitation of the substances dissolved or suspended in water by changing their physical state. In chemical treatment process, targeted substances are separated from the muddy water by sedimentation as chemical substances (coagulants, polyelectrolytes, etc.) are added to the wastewater at the appropriate pH value. Applications are neutralization, flocculation and coagulation.

Neutralization: It is the process of adding acid or base to adjust the appropriate pH value of wastewaters with acidic and basic character.

Coagulation: It is the process of adding coagulants to the wastewater at the appropriate pH and getting ready to create a flock by combining with the colloidal and suspended solids in the wastewater.

Flocculation: Flocculation is the process of mixing small particles formed by the coagulation process as a result of mixing the wastewater at an appropriate rate and forming the flocks that can easily collapse.

1.6.4 Advanced Treatment

Disinfection: The treatment plant is the process of removing the bacteria and viruses in the water before the leaving water is delivered to the receiving environment.

Nitrogen Removal: The ammonium ions contained in the wastewater are converted to nitrite and then to nitrate in the nitrification stage with the help of nitrogen bacteria. It is then removed from the water as nitrogen gas under anoxic conditions in the denitrification step.

Phosphorus Removal: Chemical and biological methods are used separately or together to remove phosphorus compounds. In chemical treatment, phosphorus is precipitated as phosphate salts at high pH values by using chemicals. Phosphorus treatment with biological methods is achieved by the removal of phosphate by microorganisms during biological treatment.

Filtration: It is applied in order to keep suspended solids and colloides which cannot be removed sufficiently in biological and chemical treatment processes.

Adsorption: The process of collecting dissolved substances in a suitable interface.

Ion Exchange: It is the process of keeping unwanted anions and cations in an appropriate anion and cation type ion exchange column in the waste water used in industrial wastewater treatment.

Reverse Osmosis: In order to ensure the reuse of wastewater, it is a system where high pressure is applied in order to recover or remove the dissolved inorganic and organic substances used in industrial wastewater treatment.

Ultrafiltration: It is a pressure membrane filtration method similar to reverse osmosis process in which semi-permeable membranes are used. In this method, oil droplets dispersed in the oil/water emulsion are separated from the water phase by filtration through a thin membrane. It is useful to pre-treat the emulsion which is intended to be treated before ultrafiltration. This process is carried out by emulsion crackers and the oil water phase is separated (Msxlabs, 2009).

Aerobic Membran Bio Reactor

Membrane Bio Reactor (MBR) technology, which is a combination of biological-activated sludge process and membrane filtration is widely used and is accepted as a treatment process in recent years for the treatment of many types of wastewaters. In this process the conventional activated sludge (CAS) process cannot cope with poor sludge settleability and this does not allow keeping high MLSS concentration in the biological reactors. Complete solids removal, a significant disinfection capability, high rate and high efficiency organic removal and small footprint are common characteristics regardless the wastewater type to be treated (Stephenson et al., 2001). Within one process unit, a high standard of treatment is achieved, replacing the conventional arrangement of aeration tank, settling tank and filtration that generally produces as a tertiary standard effluent. Four main membrane separation processes in which the filtrate is in the form of water are such as; reverse osmosis (RO), nanofiltration (NO), ultrafiltration (UF) and microfiltration (MF). The dependence on disinfection is also reduced, since the membranes with pore openings, generally in the 0.1-0.5 µm range, trap a significant proportion of pathogenic organisms. The more common MBR configuration is to have the membrane immersed in the wastewater, although a side stream configuration is also possible, with the wastewater pumped through the membrane module and then returned to the bioreactor. MBR can be operated at high mixed liquor suspended solids (MLSS) concentration of up to 20000 mg/L and at sludge ages varying between 30 and 60 days; MBRs offer additional advantages over conventional activated sludge plants, including a smaller footprint (Mallia & Till, 2001).

CHAPTER TWO

THEORETICAL BACKGROUND OF CONTACT ANOXIC/AEROBIC SEQUENTIAL MEMBRANE BIO REACTOR (AAMBR)

Membrane systems can be defined as systems that combine the physical separation of biomass and the activated sludge process with a filtration process. Biological reaction and water filtration can be processed in the same time in a contact AAMBR system. In conventional systems commonly include an aeration tank, which is used for biological degradation, and a secondary clarifier (sedimentation tank), where the sludge in separated from the treated wastewater system needs a second sedimentation tank. These processes are performed in two separate tanks, while a single tank is sufficient in contact AAMBRs. Sludge sedimentation tank is not required. Effluent water is filtered out from the contact AAMBR tank directly. This saves space.

1. Contact Anoxic/Aerobic Sequential Membrane Bio Reactor (AAMBR)

Figures 2.1 and 2.2 illustrate the conventional activated sludge and the contact AAMBR process (Daigger et al., 2005).

Here, RAS is the return activated sludge; while WAS is the waste activated sludge.

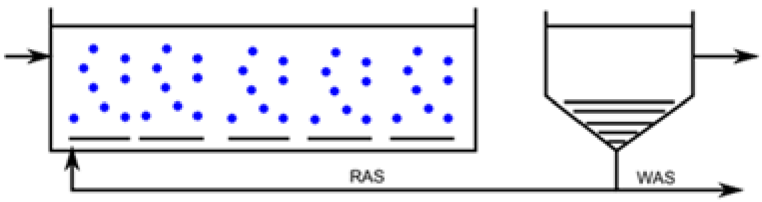


Figure 2.1 Conventional activated sludge process

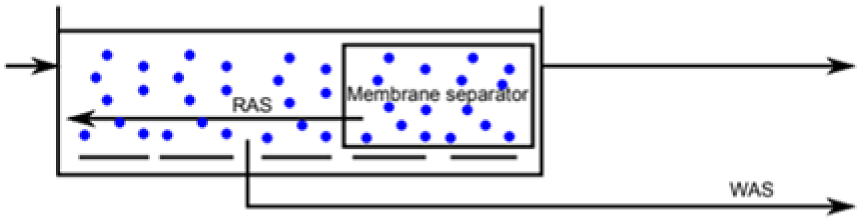


Figure 2.2 Contact AAMBR process

The configurations of the contact AAMBR are shown in Figures 2.3 and 2.4. (Zaerpour, 2014).

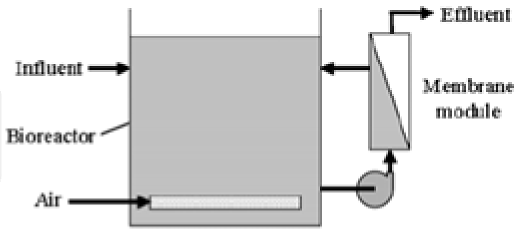


Figure 2.3 Contact AAMBR with external membrane module

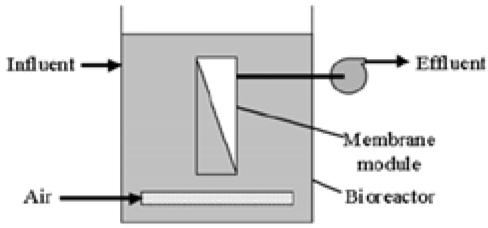


Figure 2.4 Contact AAMBR with immersed membrane module

2. Process Design and Operation in the Biological Treatment

Monod kinetics are used in the design of biological systems for the limiting substrate (S kg/m^3). Organic carbon is provided from BOD, COD or ammonium (NH_4-N). Using known biokinetic coefficients, system kinetics and mass balance can be used to determine substrate degradation, nitrification, biomass growth and slurry production rate (Tchobanoglous et al., 2003).

2.1. Substrate Degradation

The substrate removal rate determines the loading rate (rate of organic matter fed to the reactor, kg BOD/m3) as indicated by the Monod kinetic in Eq. 2.1. (Judd, S. & Judd, C., 2015).

$$\mu = \frac{\mu_m S}{K_s + S} \ , \qquad (2.\ 1)$$

Here,

μ_m : *Maximum Specific Growth Rate (g VSS/g VSS. day),*

μ : *Daily Growth Rate (g VSS/g VSS. day),*

S: Nutrient (BOD or COD) concentration (mg/L)

Ks : Saturation Coefficient (g/m3)

The Maximum Specific substrate utilization rate is given in Eq. 2.2 (Judd, S. & Judd, C., 2015).

$$k = \frac{\mu_m}{Y} \ , \qquad (2.\ 2)$$

The effluent COD concentration in the aerobic reactor is given in Eq. 2.3 (Judd, S. & Judd, C., 2015).

$$S_e = \frac{K_s(1 + k_e \Theta_{x,aer})}{\Theta_{x,aer}(\mu_m - k_e) - 1}, \qquad (2.\ 3)$$

Here,

COD: *Chemical Oxygen Demand*, (mg/L)

S_0: *Influent COD Concentration*, (mg/L)

S_e: $Effluent\ COD\ Concentration, (mg/L)$

$\Theta_{x.aer}$: $Sludge\ Retention\ Time, (d)$

k_e: $Death\ Coefficient, (d^{-1})$

The effluent NH_4-N concentration in the aerobic reactor is given in Eq. 2.4 (Orhon & Artan, 1997).

$$(S_{NH})_e = \frac{K_{NH}(1+k_{e,n}*\Theta_{x.aer})}{\Theta_{x.aer}(\mu_{nm}-k_{e,n})-1}, \qquad (2.4)$$

Here,

$(S_{NH})_e$: $Effluent\ Ammonia\ Concentration, (mg/L)$

K_{NH}: $Half\ Saturation\ Concentration\ of\ NH_4 - N, (mg/L)$

$k_{e,n}$: *Coefficient of Death for Nitrifying Bacteria*, (d^{-1})

μ_{nm}: $Maximum\ Growth\ Rate\ of\ Nitrifying\ Bacteria$, *(g VSS/g VSS. day)*

Total N concentration converted to biomass is calculated by the Eq. 2.5 (Orhon & Artan, 1997).

$$N_x = I_\beta * P_{xVSS}/Q, \qquad (2.5)$$

Here,

I_β: $Constant\ N\imath umber$

$P_{x,VSS}$: $VSS\ Concentration, (g/d)$

Q: $Feed\ Flow\ Rate\ (m^3/d)$

The Effluent NO_3-N Concentration in Aerobic Reactor (NO_3-N in the Influent of Anoxic Reactor) is given in Eq. 2.6 (Orhon & Artan, 1997).

$$NO_3 - N = (S_{NH})_i - ((S_{NH})_e + N_x), \tag{2. 6}$$

The yield and the heterotrophic biomass concentration in the aerobic reactor are given in Eqs. 2.7 and 2.8 (Judd, S. & Judd, C., 2015)

$$Y_{obs} = \frac{Y}{1+k_e\Theta_{x,aer}} + \frac{f_d k_e \Theta_{x,aer}}{1+k_e\Theta_{x,aer}} \ , \tag{2. 7}$$

$$M_{x,het} = Y_{obs} Q(S - S_e) \ , \tag{2. 8}$$

Here,

S_e: *Effluent Substrate Concentration (g/m³)*

$\Theta_{x,aer}$: *Aerobic Sludge Retention Time (d)*

k_e: *Mortality Coefficient (g VSS/g VSS. day)*

f_d:*Fraction of Biomass left over from Dead Cells (g VSS/g substrat)*

2.2 Nitrification Kinetics

During nitrification the relathionship between sludge age of the nitrifiers and the specific growth rate of nifrifier in aerobic reactor is given in Eq. 2.9 (Judd, S. & Judd, C., 2015).

$$\Theta_{x,aer} = \frac{1}{\mu_n} \ , \tag{2.9}$$

The specific growth rate of the nitrifiers in the aerobic reactor is given in Eq. 2.10 (Judd, S. & Judd, C., 2015).

$$\mu_n = \left(\frac{\mu_{n,m} N_e}{K_n + N_e}\right)\left(\frac{DO}{K_0 + DO}\right) - k_{e,n} \quad , \tag{2.10}$$

Here,

μ_n : *Specific Growth Rate of Nitrifying Bacteria (g VSS/gVSS. day)*

K_n: *Half Saturation Coefficient for Nitrification(mg/L)*

$k_{e,n}$: *Mortality Coefficient for Nitrifying Bacteria (g VSS/gVSS. day)*

N_e: *Total Ammonia, Effluent Nitrogen or TKN Concentration (mg/L)*

DO: *Dissolved Oxygen Concentration in Aerobic Tank (mg/L)*

K_0: *Half Saturation Constant for Oxygen (mg/L)*

Equation 2.11 shows the relationship between NO_3 concentration NO_x and sluge production by nitrifiers in aerobic reactor $M_{x,bio}$ (Judd, S. & Judd, C., 2015).

$$M_{x,aut} = \frac{Q Y_n NO_x}{1 + k_{e,n} \Theta_{x,aer}} , \tag{2.11}$$

Here,

$M_{x,aut}$: *Sludge Production for Nitrification (g VSS/day)*

Y_n : $Nitrification\ Sludge\ Yield\ (g\ VSS/g\ NH_4 - N)$

The NO_3-N concentration can be calculated with the Eq. 2.12 (Judd, S. & Judd, C., 2015).

$$NO_x = TKN - N_e - 0.12M_{X,bio}/Q \ , \tag{2.12}$$

Here,

TKN: $Total\ Kjeldahl\ Nitrogen\ (mg/L)$

NO_x: *TKN Concentration Oxidized to Nitrate Form (mg/L)*

$M_{x,bio}$: *Sludge Production for Carbonaceous Organic Degrading Organisms (g VSS/day)*

Influent and Effluent Concentrations of PO_4-P in Aerobic Reactor is given in Eq. 2.13 (Orhon & Artan, 1997).

$$(S_{PO})_e = \frac{K_{PO}*(1+k_e*\Theta_{x,aer})}{\Theta_{x,aer}*(\mu_m - k_e)-1}, \tag{2.13}$$

$(S_{PO})_e$: $Effluent\ Phosphate\ Concentration\ in\ anoxic\ tank$
$= Influent\ Phosphate\ Concentration\ in\ aerobic\ tank\ (mg/L)$

K_{PO}: $Half\ Saturation\ Concentration\ of\ PO_4 - P, (mg/L)$

k_e: $Death\ Coefficient, (d^{-1})$

$\Theta_{x,aer}$: $Aerobic\ Sludge\ Retention\ Time\ (d)$

μ_m: *Maximum Specific Growth Rate*, (d^{-1})

2.3 Sludge Production in the Aerobic Reactor

Wastewater generally contains non-biodegredable volatile suspended solid (nbVSS) and inert total suspended (iTSS) solid fractions that accumulate in the mixed liquid and are not degradable. Both fractions should be considered to find the total sludge conversion rate ($M_{X,TSS}$) (g MLSS/day) as given in Eqs. 2.14 and 2.15 (Judd, S. & Judd, C., 2015).

$$M_{X,TSS} = \frac{M^{X,bio}}{R_{SS}} + Q(nbVSS + iTSS), \tag{2.14}$$

$$M_{X,TSS} = \frac{\frac{QY(S-S_e)}{1+k_{e,}\Theta_{x,aer}} + \frac{f_d k_e QY(S-S_e)\Theta_{x,aer}}{1+k_{e,}\Theta_{x,aer}} + \frac{QY_n NO_x}{1+k_{e,n}\Theta_{x,aer}}}{0.85} + Q(nbVSS + iTSS), \tag{2.15}$$

Using the design MLSS value and aerobic SRT value, as in the Eq. 2.16, the aeration tank volume is calculated by finding the aereted solid mass (Judd, S. & Judd, C., 2015).

$$V_{aer} = \frac{M_{X,TSS}\Theta_{x,aer}}{X_{aer}}, \tag{2.16}$$

Here,

R_{SS}: *VSS / MLSS Ratio in Biomass: 0,85*

$M_{X,TSS}$: *Total Sludge Yield (g MLSS/day)*

$nbVSS$: *Non Biodegredable Volatile Suspended Solid (mg/L)*

$iTSS$: *Inert Total Suspended Solid (mg/L)*

V_{aer}: *Aeration Tank Volume* (m^3)

To determine the effluent COD concentration from Anoxic Reactor, Eq. 2.17 is used (Judd, S. & Judd, C., 2015).

$$S_e = \frac{K_S(1+k_e\Theta_{x,aer})}{\Theta_{x,aer}(\mu_m-k_e)-1}, \tag{2.17}$$

S_i: $Influent\ COD\ Concentration\ to\ Anoxic\ Reactor$
$= Effluent\ COD\ Concentration\ from\ Aerobic\ Reactor, (mg/L)$

S_e: $Effluent\ COD\ Concentration\ from\ Anoxic\ Reactor, (mg/L)$

2.4 Nutrient Removal in the Anoxic Reactor

Nitrate recirculation rate and active biomass in anoxic zone are calculated by the Eqs. 2.18 and 2.19 (Judd, S. & Judd, C., 2015).

$$r_{int} = \frac{NO_x}{NO_e} - 1, \tag{2.18}$$

$$X_{b,anox} = \left(\frac{Q\Theta_{x,aer}}{V_{aer}}\right)\left(\frac{Y(S-S_e)}{1+k_{e,}\Theta_{x,aer}}\right)\left(\frac{r_{int}}{r_{int}+1}\right), \tag{2.19}$$

Here,

r_{int}: $Recirculation\ Ratio$

NO_x: *TKN Concentration Oxidized to Nitrate, (mg/L)*

NO_e: $Effluent\ Nitrate\ Concetration, (mg/L)$

$X_{b,anox}$: *Active Biomass in Anoxic Zone, (g/m*^{3}*)*

Specific Denitrification Rate (SDNR) is calculated experimentally from the ratio of food to active biomass in the anoxic region as given in Eq. 2.20 (Judd, S. & Judd, C., 2015).

$$F/_{M_b} = \frac{QS}{V_{anox} X_{b,anox}} \ , \qquad (2.20)$$

Here,

$Specific\ Denitrification\ Rate: (SDRN, g\ NO_3 - N/g\ VSS)$

$F/_{M_b}: The\ Ratio\ of\ Food\ to\ Active\ Biomass\ in\ Anoxic\ Region, (g\ BOD/$
$g\ TSS.d)$

$V_{anox}: Anoxic\ Tank\ Volume\ (m3)$

SQ: Q *volumetric feed flow rate* $(m^3\ /day)$

2.5 Sludge Retention Time in Aerobic and Anoxic Reactor

The SRT of the total process is determined by the addition of anoxic and aerobic SRT as given in Eq. 2.21 (Judd, S. & Judd, C., 2015).

$$Q_{x,process} = \Theta_{x,aer} + \Theta_{x,anox} = \frac{V_{aer} X_{aer} + V_{anox} X_{anox}}{Q_W X_{aer}} \ , \qquad (2.21)$$

Q_w is the waste sludge rate and it is considered to be at the same concentration as the solid excreted from the reactor. It is calculated as given in Eq. 2.22 (Judd, S. & Judd, C., 2015).

$$Q_W = \frac{V_{aer}}{\Theta_{x,aer}} , \qquad (2.22)$$

Food to microorganism ratio is a design parameter as given in Eq. 2.23 (Judd, S. & Judd, C., 2015).

$$F/_{M} = \frac{SQ}{VX}, \tag{2.23}$$

The ratio given in Eq. 23 depends on aerobic SRT and it was used to calculate the prosses efficiency as given in Eq. 2.24 (Judd, S. & Judd, C., 2015).

$$\frac{1}{\Theta_{x,aer}} = Y\left(\frac{F}{M}\right)\frac{E}{100} - k_e, \tag{2.24}$$

Here,

Q_W: $Waste\ Sludge\ Rate\ (m^3\ /day)$

SQ: *Q volumetric feed flow rate* $(m^3\ /day)$

This ratio depends on aerobic SRT $\Theta_{x,aer}$ and process efficiency $E(\%)$

Y: *Heterotrophic Conversion Coefficient, (g VSS/BOD)*

1. Aeration

Maintenance of a microorganism population BOD removal can be achieved by mass balance of oxygen demand for ammonia to convert to nitrite and nitrate (Tchobanoglous et al., 2003). It is calculated as given in Eq. 2.25 (Judd, S. & Judd, C., 2015).

$$R_0 = Q(S - S_e) - 1.42P_{X,bio} + 4.33QNO_x - 2.86Q(NO_x - NO_e), \tag{2.25}$$

Here,

R_0: *Total Oxygen Required (kg/day)*

NO_e: Effluent NO_3 concentration (mg/L)

The first term of the equation (24) is the feed oxidation, the second term of this equation is the biomass respiration, the third term gives the nitrification and the last term is denitrification.

To determine the effluent NH_4-N concentration from anoxic reactor, Eq. 2.26 is used (Orhon & Artan, 1997).

$$(S_{NO})_e = \frac{K_{NO} * (1 + k_e * \Theta_{x,aer})}{\Theta_{x,aer} * \left(\mu_{n,m} - k_e\right) - 1}, \tag{2.26}$$

Here,

$(S_{NO})_i$: $Influent\ Nitrate\ Concentration, (mg/L)$

$(S_{NO})_e$: $Effluent\ Nitrate\ Concentration, (mg/L)$

K_{NO}: $Half\ Saturation\ Concentration\ of\ NO_3 - N, (mg/L)$

To determine the effluent PO_4-P concentration from anoxic reactor, Eq. 2.27 is used (Orhon & Artan, 1997).

$$(S_{PO})_e = \frac{K_{PO} * (1 + k_e * \Theta_{x,aer})}{\Theta_{x,aer} * \left(\mu_{n,m} - k_e\right) - 1}, \tag{2.27}$$

Here,

$(S_{PO})_e$: $Effluent\ Phosphate\ Concentration\ in\ anoxic\ tank, (mg/L)$

K_{PO}: $Half\ Saturation\ Concentration\ of\ PO_4 - P, (mg/L)$

2. Types of MBRs

Typical contact AAMBR process flow diagram flow is shown in Figure 2.5 (Wastewaterengineering, n.d.).

Raw wastewater usually pass through coarse screens and fine screens to remove particles that might possibly affect the downstream equipment and process. Membrane module can be immersed in the aeration tank itself or in a separate membrane tank.

Recirculation is utilized if denitrication is required for nitrogen nutrient removal. (Wastewaterengineering, n.d.).

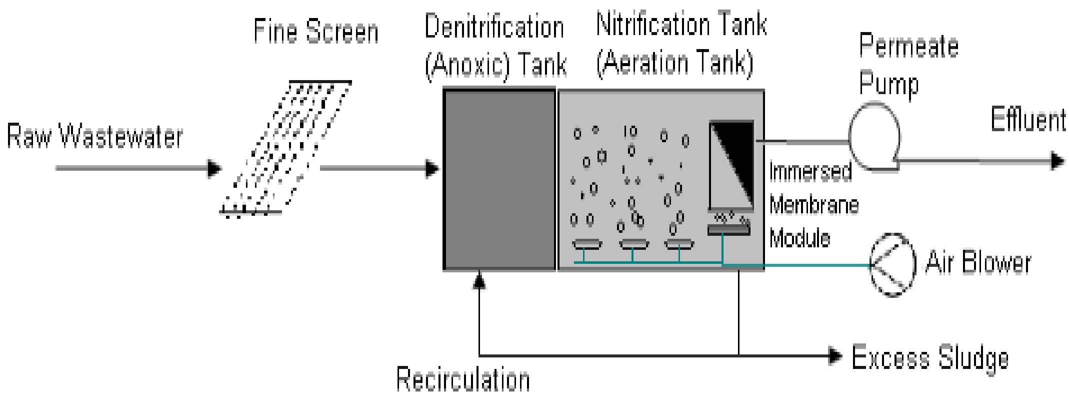


Figure 2.5 Typical contact AAMBR process flow diagram flow

In Table 2.1, internal and external contact AAMBRs are compared.

Table 2.1 Comparison of internal and external contact AAMBRs

Contact AAMBR with immersed membrane module	**Contact AAMBR with external membrane module**
High aeration costs	Low aeration costs
Low pumping costs	High pumping costs
Low flux (large space requirement)	High flux (small space requirement)
Less cleaning frequent requirement	More cleaning frequent requirement
Low operating costs	High operating costs
High initial investment cost	Low initial investment cost
High odor / VOC emission potential	Low odor / VOC emission potential

The advantages and disavantages of contact AAMBR are given in Table 2.2.

Table 2.2 Advantages and disadvantages of contact AAMBR

Advantages	**Disadvantages**
Small space requirement	High energy requirements for aeration, mixing, cleaning of membrane filters
High efficiency of turbidity, suspended solid, nutrient and COD removal	High operational costs
High efficiency COD and BOD removal and low sludge production with extended sludge retention time and high biomass substance	If a steady flow rate cannot be achieved, MBR cannot be operated at full capacity due to increased energy consumption
Membrane bioreactors can treat wastewater both physically and biologically thanks to their special design. Thus aeration, precipitation and disinfection unit used in traditional treatment systems can be eliminated	Over time the membrane becomes clogged, the flux decreases and the resulting water quality decreases. Clogging is a major problem in membrane design and operation. Because clogging requires cleaning and affects performance

CHAPTER THREE
WASTE MANAGEMENT IN HOSPITALS

3.1 Types and Management of Wastes in Hospitals

3.1.1 Domestic Waste

Domestic wastes may be food wastes or packaging wastes. These waste materials do not pose a threat to human health. However, they can be dangerous for environment. These wastes mainly consist of uncontaminated waste produced in the kitchen, toilet, garden or administrative facilities. According to Medical Wastes Control Regulation the wastes are collected in an unit and they are transported as follows; the domestic wastes are collected separately from medical, hazardous and packaging departments in the hospitals and they put to black plastic bags (Medical Wastes Control Regulation, 2017).

Domestic waste bags are transported by specific vehicles and temporarily stored in a storage facility. Domestic waste in the hospitals will always be separated from medical wastes. If there is a mixing domestic or packaging waste with medical wastes, domestic or packaging wastes become medical waste and treat as medical waste. Collected domestic wastes are transported to the disposed points according to the Waste Management Regulation (2015) (Waste Management Regulation, 2015). The waste management autority in the hospital is responsible to prevent the mixing of different typed of wastes, this autority is responsible from the storing and disposing of the collected waste according to the Waste Management Regulation (2015) (Waste Management Regulation, 2015).

3.1.2 Medical Waste

According to Medical Wastes Control Regulation medical wastes consist of infectious wastes, pathological wastes and cutter-piercing wastes (Medical Wastes Control Regulation, 2017). The sign shown in Figure 3.1 exhibited the “international biohazard”. This sign shows that the waste is hazardous medical waste, which is to be handled separately from the other wastes. (Medical Waste Control Regulation, 2017).

Figure 3.1 Medical waste sign (Medical Waste Control Regulation, 2017)

Most prominent type of waste in a healthcare facility is medical waste. These wastes are generated in such quantities and qualities that are harmfull to human life. In healthcare, the goal is to reduce the health problems and eliminate the potential risks to human health. However, some hazardous wastes are unavoidably generated in the process. Compared to other sectors' wastes, healthcare wastes carry larger wounding and infection risks. Wherever waste is generated, it has to be handled safely and reliably. Insufficient and inappropriate treatment of the waste materials may cause serious public health problems and also harmfull effect to environment. Because of this, safe medical waste management is an important part of environmental protection. To carry out short or long terms efficient medical waste management programs multisectoral cooperation and interactions between hospitals administrations are required between all employees of the hospital, municipality and licensed companies on every level. Policies have to be decided on international administrative approaches on the local places. According to the Ministry of Environment and Urbanisation Planning; for better medical waste managements more national policies and regulations should be taken into consideration. The training programmes should be applied to the employess and the sensitivity of the public should be increased (Ministry of Environment and Urbanisation Planning, 2013).

To prevent waste mixing, the utilisation of special waste bins for each waste type is very important. Medical waste boxes are easily reachable in policlinic rooms and in patient services. Patients or their relatives sometimes throw the domestic waste materials to these boxes due to being un-educated or un-informed. This not only risks the human health, but also increases the amount of medical waste and causes to increase the payments to treatment. This issue should be taken into consideration by efficient medical waste management procedures.

The wastes that occur during healthcare can be classified as infectious wastes, pathological wastes, sharp wastes, pharmaceutical wastes, genotoxic wastes, chemical wastes, wastes that contain high amount of heavy metals, pressurized containers and radioactive wastes. 4th article of Medical Wastes Control Regulation classifies the medical wastes as infectious, pathological and sharps that occur in the hospital units. (Medical Wastes Control Regulation, 2017). World Health Organization data shows that medical waste production in countries change according to development level, to income level and to the scale and types of the medical institutes. Medical wastes are rapidly increasing in quantity as the world is developped (Akbolat, Işık, Dede, & Çimen, 2011). In developed countries, 1.1-1.2 kg of medical waste is generated per bed in the hospitals, of which 0.4-0.5 kg of the waste produced is classified as hazardous waste. Annual production of medical waste is 465000 tons in USA, 150000 tons in Italy, 200000 tons in England and 21000 tons in Australia. Such high quantities of waste materials require trained employees that carry out the collection, the storage and the transportation of the wastes (Akbolat, Işık, Dede, & Çimen, 2011).

Medical waste is to be handled separately from the other wastes and they were collected in red plastic bags. Plastic yellow cutter-piercing box is used for cutter-piercing wastes and needles. Medical waste bags are collected by the specific vehicles and temporarily stored in the storage facilities of the hospitals. Collected medical wastes are transported and disposed according to Waste Management Regulation, (2015) (Waste Management Regulation, 2015). Medical wastes are delivered to the licensed companies for disposal as D9. D9 is the physicochemical treatment in a final compound or mixtures of compounds discarded by the any of operations numbered D1 to D12, e.g. evaporation, drying and calcination.

3.1.3 Hazardous Waste

Hazardous wastes are carcinogenic, caustic, flammable, explosive and irritating-harmful wastes which may be danger to human and to the environment. Hazardous wastes can also harmfull to the other living species. Hazardous wastes from hospitals can be explained under five headings such as genotoxic wastes, pharmaceutical wastes, wastes containing heavy metal, chemical wastes, pressurized containers (Environmental and Urbanisation Ministry, 2008)

1. Pharmaceutical Wastes: Drugs, contaminated pharmaceutical products, vaccines and serums that are expired, un-used or should not be required to be kept for longer time. These have to be disposed by appropriate methods. This category also includes boxes or bottles used in the preparation of pharmaceuticals, gloves, masks, connection tubes and drug vials. (Mollamahmutoğlu & Bekmezci, 2005)
2. Genotoxic wastes: Wastes containing mutant, carcinogenic or abortion in human or animal, cytotoxic (antineoplastic) products used in the treatment of cancer, and radioactive material on the cell DNA. (Mollamahmutoğlu & Bekmezci, 2005)
3. Wastes Containing Heavy Metal: Mercury, cadmium, lead-containing wastes in or in the units, such as thermometers, blood pressure measuring devices and radiation protection panels used in medical fields such as treatment, diagnosis or experimental research. (Mollamahmutoğlu & Bekmezci, 2005)
4. Chemical Wastes: Gaseous, solid or liquid wastes of chemical substances used in medical fields such as treatment, diagnosis or experimental research in units and which may be harmful for human and environmental health. (Mollamahmutoğlu & Bekmezci, 2005)
5. Pressurized containers: Units, cylinders, cartridges and cans containing gases used in medical fields, such as treatment, diagnostic or experimental research. (Mollamahmutoğlu & Bekmezci, 2005)

Hazardous wastes are collected separately from other wastes and stored in yellow plastic bags and in blue containers. Yellow plastic bags are used for solid hazardous wastes and blue containers are used for liquid hazardous wastes. Hazardous waste bags are transported by spesific vehicles and stored in a storage facility in the hospital temporarily. Collected hazardous wastes are transported and disposed or recycled according to Waste Management Regulation. (Waste Management Regulation, 2015)

3.1.4 Radioactive Waste

Radioactive wastes are solid, liquid or gas materials that are contaminated by radionuclides. These are generated by various practices. For example, from the in-vitro analysis of body tissues or liquids, from the in-vivo organ screening, from the tumor localization. Various studies and therapeutic applications are examples for radioactive wastes. Radionuclides that are used in medical applications are stored closely or openly. Openly stored sources are used directly and they do not have a capsule containing them. Closely stored sources are contained a device or apparatus inside and they are protected by unbreakable/water-proof containers. When radioactive waste is produced by an application in the hospital, this waste is received by the people working in Turkey Atomic Energy Authority.

3.1.5 Wastewater

The wastewater of the hospital is discharged to the municipal sewage system without any treatment. As described previously, there are very high differences in some parameters between hospital wastewater and domestic wastewater; however, there is no specific discharge standard for the hospital wastewater in Turkish Environmental legislation. According to Water Pollution Control Regulation, hospital wastewaters are accepted as domestic wastewater (Water Pollution Control Regulation, 2004). However, in the new application, it is desirable to install a pre-treatment system before discharging the hospital wastewater into the sewage system. This may mean that there will be an update to discharge standards from now on the future. The characterization of hospital wastewater will be examined and the hospital wastewater will be subject to a specific legislation.

3.2 Collecting and Storing of Hospital Wastes

In addition to the infection agents and viruses in the contents of medical waste, medical waste must be treated separately from other wastes. Medical waste is more likely to cause infection and injury than any other type of wastes. So, there has been an increase in the hazardous properties of the medical wastes. Since there is a potential risk to human health in the collection, transportation, storage and final disposal of these wastes, there is a problem in the management methods and in the cost for health organizations. Appropriate waste management is provided by the reduction of the desired amount of hazardous wastes. However, the majority of countries today prefer the most economical methods.

Table 3.1 shows the color codes utilised in the hospitals depending to the collected waste types according to Zero Waste Regulation numbered 30829 dated 12.07.2019 (Zero Waste Regulation, 2019).

Table 3.1 Application of color codes in hospitals according to the type of wastes collected (Zero Waste Regulation, 2019)

Color of Bag	Waste Type
Black	Not infectious domestic waste
Brown	Not infectious garden waste
Red	Infectious and pathological waste
Orange	Radioactive waste
Yellow	Hazardous waste
Blue	Packaging waste

According to Zero Waste Regulation, the colours of bags are determined if the paper, the glass, the metal and the plastic wastes are deposited together. Blue is used for these wastes and dark gray is used for other wastes. If separate deposition is made according to the material types, blue is used for paper waste, yellow for plastic waste, green for glass waste, and light gray for metal waste. In the places where biodegradable wastes are densely formed, tea stoves, cafeterias, food preparation or food service and similar places, brown color is used if these wastes are collected separately. Accumulation equipment to be used for collection of waste drugs; made of stainless metal or high-density plastic material, with lid with locked, without sharp edges since these edges may cause damage to collected bags during loading and unloading. They should be easy to load, formed in a way that will not be taken back after the waste is thrown and “Waste Drug” located. The relevant legislation shall be guided in the collection of other types of wastes other than those wastes not specified in the Zero Waste Regulation regulation (Zero Waste Regulation, 2019).

In hospital, black bags are used for collecting the domestic waste, blue bags are used for collecting the recyclable packaging waste, red bags are used for collecting the medical waste and yellow boxes are used for collecting the sharp waste, yellow bags are used for collecting the solid hazardous waste and blue containers are used to collect the liquid hazardous waste.

Figure 3.2 shows the bags used in medical waste collection. In the collection of medical wastes; the tear, puncture, explosion and transport resistant, medium density polyethylene raw material sealed, double bottom seam and without bellows, double layer thickness of 100 microns, at least 10 kilograms lifting capacity were put to the boxes with black colour and they labelling on both sides of the boxes. The bags should contain an “International Biohazard” emblem namely “WARNING! MEDICAL WASTE” in red plastic bags. The bags are filled to a maximum of ¾, their mouths are tightly connected, and if necessary, each bag is put into another bag with the same characteristics and it is sealed. These bags cannot be recovered and reused in any way. The contents of the medical waste bags can not be compacted, not be removed from the other medical waste bags, and should not be transferred to another container (Medical Waste Control Regulation, 2017).

Figure 3.2 Medical waste bag (Ministry of Environment and Urbanisation Planning, 2008)

3.3 Authorities Responsible in Hospital Management

For waste management in the hospitals the institutions have major roles. These institutions and their roles are stated below for a safe medical waste management;

1. Ministry of Environment: It detects the programs and policies related to the management of the medical waste in accordance with the environment. It carries out periodic inspections and control of all activities covering the management of medical waste should to be disposed. It provides the national and international coordination in the implementation of the latest systems and technologies related to the environmental management of medical wastes. It gives pre-license and licenses to the waste disposal and sterilisation facilities.
2. Ministry of Health: It takes the necessary measures to prevent medical waste to threatening the human and the environmental health. It ensures of the health institutions to implement the rules of the regulations in the collection, accumulation, transportation, and disposal of the medical waste separately from other wastes at the source and it implements the necessary sanctions.

3. The local authorities: It conducts periodic inspections of all activities covering the management of medical waste from the formation to the disposal. It provides information to health institutions and municipalities to evaluate the information about the amount of wastes collected and disposed within the provincial borders and send it to the the Ministry of Environment

and Urbanisation in the form of report at the end of the year (Medical Waste Control Regulation, 2017).

4. Municipalities: It prepares and applies the medical waste management plan. It transports the medical waste. It disposes the medical waste. It stores and burns the medical wastes. (Ministry of Environment and Urbanisation Planning, 2008).

5. The head doctor: She/He directs the necessary studies to reduce the formation and quantity of medical waste at the source. She/He carries out the inspection of the application of the regulation on the collection, accumulation of medical wastes and prevents the mixture of hazardous and domestic wastes and applies the necessary sanctions.

6. Medical waste manufacturers: It establishes the system to minimize the wastes production at the source. It prepares and implements medical waste management plan. It ensures separate collection of waste at source, transport of waste in the unit, and provides the temporary storage of waste by financing the disposal cost. (Ministry of Environment and Urbanisation Planning, 2008).

CHAPTER FOUR
LITERATURE REVIEW RELEVANT WITH TREATMENT PROCESSES OF HOSPITAL WASTEWATERS AND WASTES

4.1 Conventional Approaches for the Treatment of Hospital Wastewaters

In this section, alternative treatment methods to treat the hospital wastewaters were reviewed from the recent literatures. Some of these methods may not be currently available in Turkey. As it is stated in previous section, most of the hazardous waste is treated via incineration while only some solvents are able to be recycled.

Treatment processes of different countries vary. In some countries, such as Japan, Chine and Greece, big hospitals treat their hospital wastewaters on-site. They do not discharge the hospital wastewater and they treat it themselves. Some other countries (Switzerland and Italy) take a different approach. In those countries, the hospitals discharged their wastewater to the municipal sewers. Municipal wastewater treatment plants are not so capable of handling the hospital wastewaters. However, directly treatment of hospital wastewaters on-site has advantage because the wastewater was not diluted (Kovalova, Siegrist, Singer, Wittmer, & McArdell, 2012).

In an effort to find how big effect of a hospital wastewater has on the municipal wastewater treatment was performed by Langford and Thomas (2009) on Oslo's wastewater treatment facilities. They have investigated how much load have the hospital-based compounds to the municipal wastewater treatment system. 40 pharmaceutical compounds have been studied during this study. It has been found that 11% of the propranolol in wastewater is hospital-sourced. 2% of the atenolol, carbamazepine, and metaprololand atorvastatin are also hospital sourced. There are also around 20 other compounds that are less than 1% hospital sourced while still being detectable. This study shows that the hospital wastewater can significantly affect the concentration of municipal wastewater.

Therefore, segregation before mixing of hospital wastewater with regular municipal wastewater might be a more efficient way for the treatment of the hospital wastewater. Bencko et al.'s (2003) observed that segregation it is necessary to separated the hazardous wastes from non-hazardous ones. Mixing of hazardous waste with contaminated non-hazardous waste cause health hazards in Czech Republic. Moreover, it has been stated that treatment of hazardous waste is more than three times expensive from the treatment of the domestic waste.

If we look at the developing countries, we can see that hospital waste management techhniques are very poor. Sawalem et al. (2009) mentioned that all of the hazardous waste generated in Libyan hospitals consist of 21% pathogens and 5% sharps. (Abd El-Salam, 2010) stated that regulations which are necessary are not followed in many hospitals. 75% of the hospitals are discharged their wastewater without any pre-treatment or treatment. In most hospitals are incinareted their solid wastes. However, the wastes did not meet with the standards given by the authorities.

4.2 Novel Approaches for the Treatment of Hospital Wastes and Wastewaters

Some new approaches in the literature suggest new ways to incinerate the solid wastes which are cleaner and more efficient. There are also other novel sterilization methods such as electron beam and microwave techniques. Yufeng et al. have presented a new pyrolysis technique which is also applicable to treat the hospital wastes (Yufeng, Na, Jihong, & Changzhong, 2003). Their new pyrolysis device is small and easy to install. It runs automatically. This equipment does not require any separation for the waste to be processed. It does not pollute the environment. Moreover, it generates extra energy. Device runs at 246 ^{o}C, 160-180 Pa pressure.

A study conducted in Italy by Tata and Beone (1995) showed that incineration of the wastes is alternative to the conventional methods. It has been stated that if sterilization or sanitation is used, a good portion of hospital waste may be treated as domestic waste. Study compared electron beam and microwave techniques for sterilization. It has been concluded that electron beam technique is more costly to purchase and less mobile however it is more reliable. The economical analysis showed that the microwave technique is more expensive to operate. After Tata and Beone's study (1995), a new method for the treatment of infectious waste has been found AS Robert Lewis patented steam sterilization in 2003 (Lewis, 2003). This method uses saturated steam at high temperature and in an autoclave and kills off all the bacteria present in the solid wastes.

It has been seen from the literature that most micropollutant treatment processes in industries use membrane bioreactors (MBRs). A review study by Jafrudeen and Ahsan (2012) has stated that MBR is the best method to treat the hospital wastewaters when compared to other methods (activated sludge process, extended aeration, sequential batch reactor, fluidized bed reactor, submerged aeration and fixed film reactor). BOD_5 removal efficiency was 78-85% for all other options while in the MBR the maximum BOD_5 removal efficiency was recorded as 99%. Before MBR treatment the utilization of coagulation-flocculation stages for pretreatment increase the COD and BOD yields together for some micropollutants.

Liu et al. (2010) have studied the treatment of COD, BOD, TSS, and NH_3–N in MBR in 5 different MBR processes (MBR+$NaClO_3$, MBR+NaClO, MBR+ClO_2, MBR+NaClO, MBR+ClO_2) in Chinese hospitals. In the MBR process the membrane areas ranged from 96 to 8000 m^2 while the diameter of membrane pores varied between 0.2 μm to 1.3 μm. Hydraulic retention times (HRT) ranged from 5 to 7.5 hours. The MBR capacity varied from 20 m^3/day and 2000 m^3/day. In the MBR+ClO_2 process (membrane area is 8000 m^2 and membrane pore diameter is 0.4; and at a HRT of 5.4 hours) the COD, BOD, TSS, and NH_3–N removal efficiencies were above 80%. In all MBR applications given, above 80-85% removal yields were obtained for all pollutant parameters. The effluent COD varied from 8 mg/L to 69.3 mg/L while the BOD and TSS in the effluent was detected as 20.6 mg/L and 19 mg/L, respectively.

Lee et al. (2014) used a combination of MBR+Ozonation for the treatment of hospital waste waters at pHs 7 and 8.5 at four ozone doses (0.25, 0.50, 1.0 and 1.50) and at room temperature. 70% removal for Iodinated Contrast Media (ICM) namely fluconazole, iopromide, levetiracetam were detected. 93±9% removal efficiencies were obtained for carbamazepine, diclofenac, lidocaine, sulfamethoxazole, venlafaxine, tramadol and atenolol acid. 100% efficiency was detected with an optimum ozone concentration of 0.6 g O_3/g DOC. The maximum removals for oxazepam, pCBA, bezafibrate, valsartan was obtained at Ph=7.0 while gabapentin, iopromide yields was maximum at alkaline pHs (8.5). However, for most compounds 7 pH has been observed to be better for removal.

Kovalova et al. (Kovalova, et al., 2013) have studied post-treatment methods (Powdered Activated Carbon-PAC, Ozone and UV) after an MBR proces. Retention Times are as follows: PAC: 2 days, Ozone: hydraulic residence time of 12−23 minutes, UV: hydraulic residence time: 18-20 seconds. PAC used a flat sheet ultrafiltration membrane with a pore size 0.04 μm and membrane surface 6.2 m^2. Reactor volume is 180 L. Ozone treatment flow rate is 12−23 L/h. During UV treatment at a wavelength of 254 nm and at a power of 220 V and at a energy consumption of 300 W, after 20 seconds of hydraulic residence time and at a up flow rate of 2000 J/m^2 the yield for ICM (Iodinated Contrast Media) micropollutants are as follows: MBR yielded 2% removal, ozonation 50% removal, PAC 61% removal, UV 65% removal, MBR+O_3 51% removal, MBR+PAC 62% removal and MBR+UV 66% removal. For other pharmaceuticals (antibiotics, analgesics, cytotoxic and cytostatic, β-blockers, anti-cancer drugs, etc.) and metabolites (atropine, antibiotics such as erythromycin and bacitracin, citric acid, etc.), MBR yielded 90% removal, ozonation 90% removal, PAC 86% removal, UV 33% removal, MBR+O_3 99% removal, MBR+PAC 99% removal and MBR+UV 93% removal. For industrial chemicals (nitrogen, ethylene, oxygen, etc.). MBR yielded 80% removal, ozonation 98% removal, PAC 91% removal, UV 6% removal, MBR+O_3 100% removal, MBR+PAC 98% removal and MBR+UV 81% removal. Overall, MBR yielded 22% removal, ozonation 52% removal, PAC 62% removal, MBR+O_3 62% removal, MBR+PAC 70% removal and MBR+UV 81% removal for chemicals and micropollutants such as PPCPs, AOXs, radioactive materials, disinfectants, heavy metals, endocrine disruptors.

Radjenovic et al. (2006) have made a study on MBR and Conventional Activated Sludge (CAS) to compare each other efficiency on wastewater treatment. Hydraulic

Retention Time was 12 hours for CAS and 14 hours for MBR. Sludge Retention Time was 3 days for CAS and infinite for MBR with no sludge discharging. MBR volume was 21 L, with two flat sheet membranes had 0.06 m^2 areas and each area was 0.106 m^2 with a pore size of 0.4 μ. Oxygen concentration is 1-2 mg/L while the average flow rate is 22000 m^3/day. Results demonstrate that MBR has significantly better performance than CAS. TSS removal yield was 99% for MBR while 88% for CAS. COD removal yield was 96% for MBR while 88% for CAS. TOC removal was 84% for MBR while 60% for CAS. N-NH_4 removal was 98% for MBR while 1.5% for CAS.

Gültekin (2005) used coagulation-flocculation in the remediation of hospital wastewaters using two coagulants which are alum and $FeCl_3$. Also, clay has been tested with these two chemicals as a secondary coagulant. Two hospitals have been considered which have wastewater flow rates of 127 m^3/day and 660 m^3/day. Two removal parameters are turbidity and COD removals. Optimum values for turbidity removal was 93% for 20 mg/L alum; Optimum values for COD removal was 80% with 20 mg/L alum and 10 mg/L clay.

Morato et al. (2014) have used a fungal bioreactor in the treatment of hospital wastewaters. A 10 L fluidized bed bioreactor has been designed which contained *T. versicolor*. Retention time used was 8 days and the removals of two micropollutants namely pharmaceutical active compounds (PhACs) and some endocrine disruptor compounds (EDCs) were investigated. Out of the 52 compounds present in wastewater, 48 (iethylstilbestrol (the synthetic estrogen DES), dioxin and dioxin-like compounds, polychlorinated biphenyls (PCBs), DDT, and some other pesticides, bisphenol A (BPA), Di(2-ethylhexyl) phthalate (DEHP), phytoestrogens) were at least partially removed. Two different conditions were tested which are sterile and non-sterile conditions inside the reactor. Analgesics/anti-inflammatory compounds were removed 100% with this method and the removal rate was also very fast. Overall removal of antibiotics has been measured as 86.1% for sterile process and 90.8% for non-sterile process while azithromycin antibiotic was removed with a yield of 26%. Except for ciprofloxacin which was only removed 69%, all important antibiotics (penicillins, cephalosporins, fluoroquinolones, aminoglycosides, monobactams, carbapenems, and macrolides) were removed with yields above 80%. Removals of psychiatric drugs were 93.7% for sterile process and 95.4% for non-sterile process. Endocrine disruptor compounds (EDC) were removed with a yield of 81.3% in sterile treatment and 74.4% in non-sterile treatment. ICM (Iodinated Contrast Media) removal was measured as 75.5% for sterile treatment and 34% for non-sterile treatment.

Laber et al. (1999) have used a two-stage constructed wetland in the treatment of hospital wastewaters. The wetland unit consisted of a horizontal flow bed and a vertical flow bed at a flow rate of 20 m^3/d and a bed area of 140 m^2. Horizontal bed was 60 cm and had a pore volume of 39% while vertical bed was 90 cm with a pore volume of 30%. This unit was run without electricity and contained with *Phragmites karka*. Elimination percentage of COD with this method was 95%, while the elimination of BOD_5 was 98%. The elimination of Nitrogen was 92%, of phosphorus was 38% and elimination yield of TSS was recorded as 99%.

CHAPTER FIVE
CHARACTERISATION OF WASTES IN THE INVESTIGATED HOSPITAL IN İZMİR

The hospital wastes can be ranged from completely harmless to highly hazardous wastes. Therefore, a characterization and a classification are essential. First classification is about whether the waste is solid or liquid.

5.1 Solid Waste Groups

The types of these wastes have been stated in the hospital by the interier document prepared every year by the hospital authorities according to requirement of the Ministry of Environment and Urbanisation. There are ten different solid waste sources. The sources of these solid wastes are shortly explained in Table 5.1.

5.1.1 Administrative Offices

These wastes are not carried out directly from healthcare-related processes in the studied hospital. They are mostly the same as any other office. The sources of these solid wastes are the administrative offices and they are coming from the photocopy, fax and printing activities, from the utilisation of the electronics and batteries, and from the utilisation of the lamps during illumination of the hospital. The other wastes generated by the administrative offices in the studied hospital are the cartridges, the toners, the fluorescent lamps and the solid wastes from packaging and papers. Among those solid wastes packaging and papers are classified in the domestic waste category. The cartridges, the toners and their containers, the batteries and the fluorescent lamps produced from the administrative ofifices are hazardous and should be disposed with special treatment processes.

5.1.2 Clinics

In the studied hospitals the wastes originated from the clinics are the same solids produced from the offices such as photocopy, fax, printing products and some solid wastes coming from the utilization of some electronic apparatus and from the batteries, and from the lamps utilised in the lighting of the rooms. Furthermore, some disinfectants and drugs were present in the clinics. Therefore, hazardous solid materials generated in the clinics (cartridges, toner, batteries, fluorescent lamps, and packaging material) were disposed together hazardous substances.

5.1.3 Dentistry

In the studied hospital; in the dentistry section, dental practices are carried out. Amalgam filling wastes is stated as hazardous waste.

5.1.4 Radiology

In the studied hospital radiology is the area which may contain radioactive waste materials. Some solid wastes originated from the X-Ray viewing procedure. The solid waste types produced in the administrative offices are shown in the radiology sections. The wastes are originated from the photocopy, fax, printing activities, from the utilisation of some electronic devices, from the batteries and from the lamps utulized during lighting. Furthermore, the cartridges, the toners and the x-ray films are stated as waste materials.

5.1.5 Laboratories

In the laboratories of the studied hospital, some solid wastes are generated from the some medical devices used. Furthermore, the wastes coming from the photocopy, fax, and printing devices, from the usage of electronics and batteries and of the lighting are solid wastes produced from the laboratories. Some medical devices in the hospital laboratories generate waste in liquid form.

5.1.6 Pharmacy

In the studied hospital the solid wastes produced from the pharmacy are waste drugs, expired drug, drug packaging and medicaments. Cartridges, toners, batteries coming from the administrative affairs, fluorescent lamps wastes of photocopies, of faxes, of printing, of electronics and of batteries and of lighting are the other solid wastes in the pharmacy of hospital. These solid wastes are not hazardous, unless they have been contaminated with some solid and liquid drugs.

5.1.7 Technical Workshop

In the studied hospital the technical section's provides the maintenance of all kinds of devices, as well as in medical devices. The solid wastes are originated from the photocopy, fax and printing facilities, from the utilisation from the electronics and from the batteries. Furthermore the lamps from the lighting devices are some solid wastes. The solid wastes generated by the technical sections also are the excess device parts, the cables, the paint boxes, the cartridges, the toners, the batteries, and the fluorescent lamps. Some of the machine parts also can be considered as solid wastes and these can be classified as hazardous solid wastes. Furthermore, the wastes originating from the photocopy, fax, printing materials, electronics and batteries and lamps are some technical workshop wastes.

5.1.8 Cafeteria

In the studied hospital the cafeteria provides meals for the hospital. These can be eaten by the staffs or by the patients. These wastes have domestic and packaging waste properties. The packages generated from the raw food materials are solid wastes. These wastes are not hazardous.

5.1.9 Pathology

In the studied hospital the wastes produced from the pathology section exhibited similarities with the solid wastes produced from the laboratories section. The solid wastes are coming from the utilisation of medical devices and from the analyses performed in the laboratory. The origin of solid wastes is coming from the photocopy, from the fax, from the printing device, from the utilisation of the electronics from the batteries and from the lighting devices. Furthermore, the most of the hazardous chemicals generated in the pathology section and in the laboratory are liquid.

5.1.10 Operating Room

In the studied hospital there are some special rooms for surgical operations. From these rooms the solid waste sources are electronics, batteries and lighting devices, fluorescent lamps, batteries, hepa filters and contaminated packages. The solid waste materials producing from ten different units in the hospital are summarised in Table 5.1. Domestic and potentially hazardous materials have been categorized. As aforementioned a lot of cartridges, toners, batteries and fluorescent lamps occurred in most units. Therefore, some waste materials coming from the certain units are labelled specifically with dark color.

Table 5.1 Wastes generated in the each unit in the investigated hospital

Unit	Domestic Solid Waste	Hazardous Solid Waste
Administrative Offices	Packaging, paper waste	Cartridges, toner, batteries fluorescent lamps
Clinics	Drug packages	Cartridges, toner, batteries fluorescent lamps, **packages of hazardous materials or contaminated packages, pharmaceutical waste**
Dentistry		**Amalgam Waste**
Radiology		Cartridges, toner, batteries fluorescent lamps, **X-Ray films**
Laboratories		Cartridges, toner, batteries fluorescent lamps,
Pharmacy	Uncontaminated drug packaging	Cartridges, toner, batteries fluorescent lamps, **expired drugs**
Technical Workshop	Paint packages	Cartridges, toner, batteries fluorescent lamps, **some excess machine parts**
Cafeteria	Packaging	

Table 5.1 continues

Pathology		Cartridges, toner, batteries fluorescent lamps, **hazardous chemicals**
Operation Room		Cartridges, toner, batteries fluorescent lamps, **contaminated packaging, hepa filters**

Table 5.2 and Table 5.3 illustrated the total and hazardous wastes and their subgroups produced on years 2012 and 2018. It can be seen that the majority of the wastes originated from the hazardous chemicals and from the cytostatic and cytotoxic drugs.

Table 5.2 Annual production of waste types (year 2012)

Hazardous Waste Types with Specific Codes	**2012 Production (kg)**	**Percentage Production (mass)**
Toners with Hazardous Content (08 03 17*)	168	1.14%
Fluorescent Lamps/Other Mercury Content (20 01 21*)	369	2.51%
Hazardous Chemicals (18 01 06*)	9189	62.44%
Cytotoxic/Cytostatic Drugs (18 01 08*)	4651	31.60%
Amalgam Waste (18 01 10*)	0.250	0%
Water Based Offset Plate Developer Solution (09 01 01*)	280	1.9%
Batteries (16 06 01*)	60	0.41%
Total	14717	100%

Table 5.3 Annual production of waste types (year 2018)

Hazardous Waste Types with Specific Codes	2018 Production (kg)	Percentage Production (mass)
Toners (08 03 17*)	408.12	2.01%
Contaminated Packaging (15 01 10*)	1000	4.91%
Discarded Electronics (16 02 13*)	3140	1.54%
Contaminated filters, rags, clothing (15 02 02*)	69	0.34%
Hazardous chemicals (18 01 06*)	9997.18	49.13%
Cytostatic/Cytotoxic Drugs (18 01 08*)	4940	24.28%
Mercury Containing Waste (20 01 21*)	209.68	1.03%
Paraffin (12 01 12*)	582.46	2.86%
Total	20346.44	100%

5.2 Liquid Waste Groups

In the studied hospital; it has been observed that, majority of hospital wastes are hazardous and are in liquid form. The liquid wastes are originated from the clinics, from the radiology sections, from the laboratories, from the pharmacy and cafeteria, from the pathology rooms and from the operating rooms. Furthermore, the waste liquid toners are hazardous. The all units emitting liquid wastes in the studied hospital will summarized below as follows.

5.2.1 Clinics

In the studied hospital; liquid drugs are generated from the clinics, which are disposed from various reasons. Some cytotoxic drugs, cytostatic drugs and pharmaceutical wastes are liquid hazardous waste materials generated in the clinics.

5.2.2 Radiology

In the studied hospital, from the radiology sections, some liquid contrast media and Iodinated X-Ray Contrast Media (ICM) are produced. The ICM materials are micropollutants such as diatrizoate, ioxaglate, iopromide, iohexol, iopamidol and metrizoate.

5.2.3 Laboratories

In the studied hospital, the medical devices used in the laboratories generate wastewater. Sometimes, some wastewaters contain hazardous chemicals. The hazardous chemicals also generated from the medical devices and from the expired reactants. Depending on laboratory type, the medical wastes are some cultures, some bacteria media stocks, some infected body fluids, some serological chemicals, blood and some contaminated materials.

5.2.4 Pharmacy

In the studied hospital, the pharmacy distributes liquid drugs in the hospital to the patients. Some of these drugs are expired and they can not be used. As shown in Table 5.4, the origin of the liquid wastes is expired drugs and vaccines in the pharmacy.

5.2.5 Cafeteria

In the studied hospital, cafeteria is the unit producing food. Waste oil is the liquid waste produced from the cafeteria.

5.2.6 Pathology

In the studied hospital, pathology is similar to the laboratories section as they use medical devices and they do analyses. There are various chemical wastes that come from pathology. In the pathology, these hazardous chemicals are generated: xylol, formaldehyde, methyl alcohol, tissue tracking device waste, paraffin and stain wastes such as gram giemza and may green volt. There are also these medical wastes generated: anatomic waste tissues, organs and body parts and various bodily fluids resulting from operations.

5.2.7 Operating Room

In the studied hospital some mercury products are produced as liquid waste material in the operating room, due to the utilisation of some special lamps. The majority of all the liquid wastes mentioned above are hazardous and can be classified in seven subgroups. Table 5.4 exhibited these groups and relevant samples.

Table 5.4 Liquid waste types for hospital units

Unit	**Hazardous Liquid Waste**
Clinics	Cytotoxic drugs, cytostatic drugs, pharmaceutical waste
Radiology	Radiology wastewater (Bathing liquids containing silver salts)
Laboratories	Medical device wastewaters (such as tissue tracking device waste), cultures and stocks, infectious body fluids, serological wastes, blood and related products, contaminated liquids by these
Pharmacy	Expired drugs (liquid drugs and vaccines)
Pathology	Chemical Waste (xylol, formaldehyde, methyl alcohol, tissue tracking device waste, paraffin and stain wastes), bodily fluids
Operating Room	Mercury

CHAPTER SIX
CURRENT APPLICATIONS IN THE INVESTIGATED HOSPITAL FOR WASTEWATERS AND WASTES

The studied hospital has not any treatment plant itself for every type of waste generated. The hospital only stores its wastes until they are treated according to R1-12, which is done in licensed treatment facilities not at the hospital. On-site treatment does not exist in any way or form in this hospital. The code for hospital's procedure is "R13", according to Waste Management Regulation (Waste Management Regulation, 2015). Eventually, waste is sent to the treatment facilities at which R1-12 procedures are carried out by licenced firm. Some hospital waste materials are not suitable for recycling. In that case, licensed treatment facilities carry out D1-14 procedures. "D" stands for "Disposal". "R" stands for "Recycle" All of the procedures available according to Turkish regulations are given below.

(R1): Usage for fuel for energy generation: Many organic materials such as alcohols, oils and hydrocarbons can be burned for energy generation or heating. However, direct burning is almost never environmentally safe because of impurities. They can be used as fuel in a safe environment or after processing.

(R2): Reclamation or reproduction of solvent: Solvent reclamation is an important practice to cut down costs. To remove residues and make solvents usable again, filtration is used.

(R3): Reclamation or recycle of non-solvent organic material (includes compost and other biologic recycling): uncontaminated biologic materials such as paper products are available for recycling.

(R4): Reclamation or recycle of metals and metal compounds: uncontaminated waste metals can be processed again, melted and reshaped.

(R5): Reclamation or recycle of other inorganic substances: R5 stands for the recycling of materials inorganic materials except for metals, such as glass.

(R6): Reproduction of alkalis or acids: alkali and acid solutions that have lost their function can be reproduced instead of disposal.

(R7): Reclamation of used components for pollution reduction: salvaging of old components such as machine parts.

(R8): Reclamation of catalyst components: catalysts can consist of valuable components such as gold, silver, platinum, nickel, etc. When they complete their lifetime, producers most of the time take them back for reproduction.

(R9): Re-refining or otherwise reusing of used oils: used oils contain unwanted impurities however they still contain valuable organic content. They are very commonly converted to biodiesels.

(R10): Land reclamation for ecological improvement or for the good of agriculture: land that has been used for industry or other purposes can be rehabilitated to be used again.

(R11): Usage of (R1)-(R10) products: usage of materials produced by above-mentioned methods.

(R12): Exchanging of wastes for one of (R1)-(R11) procedures: waste from one industry can be a raw material input for another.

(R13): Storing of waste until it is treated by (R1)-(R12) (excluding waste collection and temporary storage in waste generation site): facilities that generate waste are supposed to store them until it is ready to be treated.

Since none of these are used in the hospital, the hazardous wastes are taken by licensed firm. Reclycle method of the company is R13, namely storing the hazardous wastes until it is treated. When waste material is not going to be recycled, it will be disposed of. According to Waste Management Reulation disposal methods are listed from D1 to D15 (Waste Management Reulation, 2015). The hospital considered does not carry out any of D1-15, as it is stated in their documents. These are carried out in licensed treatment facilities. D1-15 procedures are as follows.

(D1): Orderly storage under or above the ground.

(D2): Land reclamation (such as biological decomposition of liquid or sludge waste).

(D3): Deep injection (such as pumping into wells, salt rocks or naturally occurring cavities).

(D4): Surface filling (such as the filling of liquid waste into cavities, pools, lagoons).

(D5): Orderly storage that requires specific engineering (such as isolated cellular storage).

(D6): Discharging to a water mass except for seas/oceans.

(D7): Discharging to seas/oceans (including sea beds).

(D8): Biological procedures that generate compounds of mixtures that is to undergo D1-D7 or D9-D12.

(D9): Physical or chemical procedures that generate compounds of mixtures that are to undergo D1-D8 or D10-D12 (such as evaporation, drying, calcination, etc.).

(D10): Incineration (on land).

(D11): Incineration (over sea).

(D12): Permanent storage (such as placing in containers in a mine).

(D13): Blending or mixing prior to undergoing procedures D1-D12.

(D14): Repackaging prior to undergoing procedures D1-D13.

(D15): Storing of waste until it is treated by (D1)-(D14) (excluding waste collection and temporary storage in waste generation site).

According to hospital documents, for hazardous wastes, R13 procedure is followed. Waste is safely stored until it is sent to treatment facilities. For medical wastes, D9 procedure is followed in licensed firm. This procedure means physical or chemical procedures that generate compounds of mixtures that are to undergo D1-D8 or D10-D12 (such as evaporation, drying, calcination, etc.).

6.1 Solid Waste Treatment

In the studied hospital the solid waste management is examined under five subheadings such as nonhazardous waste, batteries, amalgam waste, fluorescent lamps and hazardous wastes.

6.1.1 Nonhazardous Waste

The nonhazardous wastes are the waste that does not require any special treatment. In the studied hospital, the nonhazardous wastes are classified to two subgroups namely domestic wastes and packaging wastes which are regular wastes such as generated in homes or in other places. They are nonhazardous and are specific to the hospital units.

6.1.1.1 Domestic Waste

In the studied hospital, the domestic wastes are collected in plastic black bags and they are labeled to show the waste properties. They are sent to the domestic waste depots by using specialized trucks. These wastes are handled by the municipality according to Waste Management Regulation, (2015) (Waste Management Regulation, 2015).

6.1.1.2 Packaging Waste

In the studied hospital, the main types of non-hazardous hospital packaging wastes are the papers, the cardboards, the packaging materials, the plastic packaging materials, the mixed packaging and glass packaging materials. These non-hazardous packaging wastes in the hospital are collected in blue plastic bags. These bags are labelled to have all the properties, their sources, their weigths and the current day. These bags are stored and were kept in a packaging depot. These bags are taking by the licensed firms for recycling (Waste Management Regulation, 2015). Sometimes these wastes can be mixed-up with hazardous waste. When a mix-up occurs, packaging waste becomes hazardous waste and the amount of hazardous waste is increased.

6.1.2 Batteries (16 06 01)*

In the studied hospital, the utilised waste batteries are hazardous. The total annual weight of the batteries used in the hospitals is 60 kg. These batteries are collected in different units of the hospitals and they stored in the specialized storage containers and sent to MBMIA-(Mobile Battery Manufacturers and Importers Association-MBMIA). For the collection and the transportation of the batteries the hospital has some agreements with public entities with some public collector firms and cargo companies (tap.org.tr, 2018). MBMIA takes back waste batteries free of charge. This does not incur additional costs to the hospital.

6.1.3 Amalgam Waste (18 01 10)*

In the studied hospital, as a result of utilisation of the tooth pastes amalgam and mercury produced as waste material. Since the mercury is liquid under room temperature and is volatile in the absence of the metals. Amalgam waste is recyclable. 250 grams of amalgam waste per year is generated in the hospital. According to Waste Management Regulation, (2015), amalgam waste is coded by (A), which means that it is hazardous waste. (Waste Management Regulation, 2015)

6.1.4 Fluorescent Lamps/Other Mercury Containing Wastes (20 01 21)*

In the studied hospital the wastes produced from the fluorescent lamps and their mercury contents are handled by licensed firms such as YA-SE. Code for this waste type is (A), which means that they are hazardous wastes. The total annual production of the fluorescent lamps is 369 kg in the studied hospital in the year 2012. The disposals of the lamps are performed by the licensed companies.

6.1.5 Hazardous Waste

In the studied hospital the generated pharmaceutical, genotoxic, chemical wastes, wastes coming from the pressurized containers, from the cartridges, from the toners, from the contaminated packaging, and from the contaminated filters are solid hazardous wastes. These wastes are handled by the licensed firms such as YA-SE according to Waste Management Regulation (2015) (Waste Management Regulation, 2015).

6.1.6 Medical Waste

In the studied hospital the infectious wastes, pathological wastes and cutter-piercing wastes are medical wastes generated from the laboratory, operating room, clinics, dialysis unit, emergency room, intensive care units. These wastes can be infectious, pathological or sharp waste. Therfore, they are weigthed and they are labelled and they are recorded as medical waste. These medical wastes are collected by the licensed companies for disposal according to Medical Waste Control Regulation (2017) (Medical Wastes Control Regulation, 2017).

6.2 Liquid Waste Treatment

97.08% (mass) of wastes produced in the studied hospital is liquid. 180000 m^3/year of wastewater is discharged into municipal sewer system without any treatment or pre-treatment. The sources of the liquid wastes produced in hospital are classified as follows.

6.2.1 Toners with Hazardous Content (08 03 17)*

In the studied hospital the toners mass is 1.14% of the wastewater. The total annual production of toners is 168 kg. The toners were handled by the licensed company for disposal according to Waste Management Regulation (2015) (Waste Management Regulation, 2015).

6.2.2 Water Based Offset Plate Developer Solution (19 01 02)*

In the studied hospital the annual total 150 kg water based on offset plate developer is generated according to the hospital data by year 2012. The code for disposal this solution is (A). (A) Means that this solution is hazardous in any quantity (Waste Management Regulation, 2015).

6.2.3 Hazardous Chemicals (18 01 06)*

In the studied hospital, the hazardous chemical groups are largest generated waste section. The percentages of these chemicals are 62.44% of all hospital wastes. They have many subgroups and all of these labelled with the same code "18 01 06*" (Waste Management Regulation, 2015)

1. Bouin's Solution: Bouin's solution consists of 5% acetic acid, 9% formaldehyde and 0.9% picric acid. It is highly toxic (sigmaaldrich.com, 2018a). Bouin's solution is a waste occurring in the pathology section as a product of staining process. It is a fixative staining agent. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for Bouin's solution waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

2. Wastes coming from the Tissue Tracking Devices: These wastes are coming from the pathology section. Example chemicals to these wastes are

formaldehyde and xylene. These are solved in high concentration in ethanol. These materials cause high health hazard. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for wastes coming from the tissue tracking devices is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

3. Eosin Alcoholic: This type of waste comes from the pathology section after staining process. This chemical is corrosive and has an ecological risk, therefore it cannot be discharged. It can be recycled. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for Eosin Alcoholic waste is R2- reclamation or reproduction of this solvent incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

4. Phenol: Phenol is produced in the microbiology laboratories. It is used in tissue protection. Phenol shows acute toxicity for humans, and it is hazard to the environment and is also corrosive (sigmaaldrich.com, 2018b). In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for phenol waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

5. Formaldehyde: Formaldehyde is coming from the pathology section. It is used in tissue protection. Formaldehyde is also used in chrurgical operations. It shows acute toxicity for humans, is hazardous to the environment; is flammable, carcinogenic and corrosive (sigmaaldrich.com, 2018c). In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for formaldehyde

waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

6. Giemsa Stain: Giemsa stain is a staining agent used in both pathology and microbiology sections. Giemsa stain consists of azur A eosinate, azur B eosinate, methylene blue eosinate and methylene blue chlorid. Solution contains methanol as solvent and is dissolved in methyl alcohol with glycerol as a stabilizer. Methylene blue in this stain is a mutagenant and is highly toxic (ihcworld.com, 2018). In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (Waste Management Regulation, 2015). The suggested disposal for Giemsa Stain waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

7. Gomori's Reticulum Stain: This stain is used in the identification of bacteria. It is used in pathology section this chemical is corrosive and is hazardous to environment (sigmaaldrich.com, 2018d). In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (Waste Management Regulation, 2015). The suggested disposal for Gomori's Reticulum Stain waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

8. Jones methenamine silver (PAMS): Jones methenamine silver is used in pathology section. In contains hexamethylenetetramine and silver nitrate. It is highly flammable, corrosive, allergen and toxic to environment. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (Waste Management Regulation, 2015). The suggested disposal for Jones methenamine silver (PAMS) waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

9. Karmin: It is used in staining as a coloring agent. It is used in pathology. Karmin has allergen properties. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (Waste Management Regulation, 2015). The suggested disposal for Karmin waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

10. Congo Red: It is a stain used in pathology laboratory. It is applied as droplets on the glass slide during staining. These glass slides are then washed. Congo Red contains 3% methanol and 70% ethanol. These materials are toxic and corrosive. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for Congo Red waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

11. Xylene: Xylene was produced from the automatic staining device in pathology section. It is also a solvent used in laboratories, as well as pathology. It is flammable, corrosive and hazardous for environment. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (Waste Management Regulation, 2015). The suggested disposal for xylene waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

12. Crystal Violet: This stain is used at 75% purity in microbiology and pathology laboratories. It is a mutagen, carcinogen and is ecotoxic. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (Waste Management Regulation, 2015). The suggested disposal for Crystal Violet waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

13. Alcohols: The alcohols that have been used are diluted with ethanol to 70%. Alcohol is used in a wide variety of units and devices. In pathology, 70%

ethanol is used in Tissue Tracking Device and Automatic Staining Device. 96% ethanol is used for chemical purposed. In microbiology and biochemistry laboratory, it is used for general uses. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (Waste Management Regulation, 2015). The suggested disposal for alcohol waste is R2- reclamation or reproduction of solvent according to the data given by Tübitak, 2017 (Tübitak, 2017).

14. Acetone: Acetone is generally used in every laboratory such as pathology laboratory, Tissue Tracking Device in pathology laboratory. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (Waste Management Regulation, 2015). The suggested disposal for acetone waste is R2- reclamation or reproduction of solvent according to the data given by Tübitak, 2017 (Tübitak, 2017).

15. Masson Trichrome: Masson Trichrome is a stain l used in the pathology laboratory. It is applied as droplets on the glass slide during staining which is afterwards washed. It contains 90% ethanol and 2.5% picric acid. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (Waste Management Regulation, 2015). The suggested disposal for Masson Trichrome waste is R2- reclamation or reproduction of solvent according to the data given by Tübitak, 2017 (Tübitak, 2017).

16. Mayer’s Hematoxylin: Mayer’s Hematoxylin consists of 5% aluminum potassium sulfate, 3% chroral hydrate, 0.1% hematoxylin, 0.01% sodium iodide and 0.1% citric acid. It is used in pathology for staining. It is flammable and toxic. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation, 2015). The suggested disposal for Mayer’s Hematoxylin waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

17. Methanamine Silver Stain: Methanamine staining agent is used in pathology laboratories and it consists of 9% Hexamethylene tetraamine and 4% Sodium tetraborate decahydrate. It is highly flammable, is allergen and is toxic to reproduction. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for Methanamine Silver Stain waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

18. Methyl Green Stain: This stain is 99% pure and is consist by methyl green. Methyl green is ecotoxic and corrosive. This stain is used in pathology laboratories. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for Methyl Green Stain waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

19. Methylene Blue Solution: Methylene blue solution is used in microbiology laboratories in the staining procedures. Solution also includes 40% alcohol. It is toxic, flammable, is ecotoxic, carcinogen and corrosive. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for Methylene Blue Solution waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

20. Modified Giemsa: This stain consists of 61% methanol, 20% propylene glycol and 3% bis-tris. It is used in the pathology laboratory. Modified giemsa is flammable, allergen and highly toxic. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for Modified Giemsa waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

21. Oil Red O Stain: It is 99% 1-(2-methyl-4-(2-methyphenylazo) phenylazo)-2-n naphthol this type of strain is corrosive and carcinogen. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for Oil Red O Stain waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

22. Organic Acids (Except for all Mentioned – If Hazardous): These are all the other organic acids that have not been mentioned above. If such materials are not carcinogen, mutagen or toxic, they can be discharged after being neutralized. If those are hazardous, they are included here. These acids can be found in every type of laboratory. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for organic acids waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

23. Osteodec: This is a decalcification agent (bone breaker). Osteodec is used in bone marrow softening process in pathology laboratory. It consists 99% EDTA dipotassium salt. It is corrosive and ecotoxic. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for osteodec waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

24. Waste Solvents Containing Halogens: Examples of this group are dichloromethane, ethylbenzene, trichloroethylene and chloroform. These are used in every type of laboratory. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for waste solvents containing halogens waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

25. Sudan Black B Stain: Sudan black B is a perimidine. It contains 2,2-dimethyl-2,3-dihydro-1H-perimidine and [4-(phenyldiazenyl) naphthalen-1-yl] diazinyl. This stain is used in hemotology tests carried out in the pathology laboratories. It is carcinogen. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for Sudan Black B Stain waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

26. Automatic Staining Device Waste (Ethylbenzene): Automatic staining device is in pathology laboratory. Waste from this device contains ethylbenzene. Ethylbenzene is a known carcinogen. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for automatic staining device waste (Ethylbenzene) waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

27. Trifluoracetic Acid: 99% trifluoracetic acid is used in the microbiology laboratory. It is corrosive, toxic and ecotoxic. In the studied hospital this waste is collected by the licenced firms such as YA-SE according to the Waste Management Regulation (2015) (Waste Management Regulation). The suggested disposal for trifluoracetic acid waste is D10-incineration according to the data given by Tübitak, 2017 (Tübitak, 2017).

The sources and the treatment methods of all the materials mentioned above are summarized in Table 6.1.

Table 6.1 Hazardous chemicals (Tübitak, 2017)

Waste Material	**Source Unit**	**Treatment**
Bouin's	Pathology	D10- Incineration
Tissue Tracking Device Waste	Pathology	D10- Incineration
Eosin Alcoholic	Pathology	R2- Reclamation or reproduction of solvent
Phenol	Laboratories	D10- Incineration
Formaldehyde	Pathology	D10- Incineration
Giemsa Stain	Pathology/Laboratories	D10- Incineration
Gomori's Reticulum Stain	Pathology	D10- Incineration
Jones methenamine silver (PAMS):	Pathology	D10- Incineration
Karmin	Pathology	D10- Incineration
Congo Red	Pathology	D10- Incineration
Xylene	Pathology/Laboratories	D10- Incineration
Crystal Violet	Pathology/Laboratories	D10- Incineration
Used Alcohols	Pathology/Laboratories	R2 - Reclamation or reproduction of solvent
Used Acetone	Pathology/Laboratories	R2 - Reclamation or reproduction of solvent
Masson Trichrome	Pathology	R2 - Reclamation or reproduction of solvent
Mayer's Hematoxylin	Pathology	D10- Incineration

Table 6.1 continues

Methanamine Silver Stain	Pathology	D10- Incineration
Methyl Green Stain	Pathology	D10- Incineration
Methylene Blue Solution	Laboratories	D10- Incineration
Modified Giemsa	Pathology	D10- Incineration
Oil Red O Stain	Pathology	D10- Incineration
Organic Acids (Except for all Mentioned – If Hazardous)	Pathology/Laboratories	D10- Incineration
Osteodec	Pathology	D10- Incineration
Waste Solvents Containing Halogens	Pathology	D10- Incineration
Sudan Black B Stain	Pathology	D10- Incineration
Automatic Staining Device Waste (Ethylbenzene)	Pathology	D10- Incineration
Trifluoracetic Acid	Laboratory	D10- Incineration

6.2.4 Cytotoxic/Cytostatic Drugs (18 01 08)*

The wastes of the Cytotoxic/Cytostatic drugs are the second largest group of the studied hospital. Its ratio is 31.60% of the total hospital waste. “18 01 08*” indicates the drug wastes and the liquids remaining from the injectors. These are hazardous (A) according to Waste Management Regulation (2015) and suggested treatment method for those is D10 incineration on land (Waste Management Regulation, 2015).

6.2.5 Waste Oils (20 01 26)*

These are the cooking oils coming from the cafeteria of the hospital. Their total occurrence in the hospital is unknown. Huge amount of waste oils is produced. Preventing their discharge is essential. Waste oils can be recycled and can be used as valuable chemicals such as biofuels.

CHAPTER SEVEN
SUGGESTED WASTE MANAGEMENT PROCEDURE FOR THE WASTES OF SELECTED HOSPITAL

7.1 Suggested Solid Waste Management Procedure for Selected Hospital

Solid wastes coming from the hospital studied are hazardous waste, medical waste, domestic waste, paper-cardboard waste, plastic waste, metal waste, glass waste, waste battery, organic waste, composite waste, electronic waste, wood waste. All these wastes should be collected and transported according to procedure prescribed by Waste Management Regulation, (2015) (Waste Management Regulation, 2015) throughout the hospital and should be taken to the temporary storage area. Finally they should be transported by a licensed company for sterilization, recycle and disposal. The management of the hospital wastes should be as follows;

1. To make some arrangements for waste management throughout the hospital such as to provide trainings for the all hospital staffs, to ensure the correct separation of the wastes and to check all the storage areas and the waste boxes with specific colours, regularly,
2. To reduce and to treat separately the amount of hazardous and medical wastes in their sources. These waste should not be mixed with non-hazardous domestic wastes since the ratio of the hazardous wastes will be increased. On the other hand, the hospital administration pay for disposal of hazardous and medical wastes while the domestic wastes are not treated by paying money. These waste are collected by the municipality according to the Waste Management Regulation, (2015), so the separation of wastes at source is the most important waste management step (Waste Management Regulation, 2015).
3. To provide training on the employees relevant to waste management and waste collection in the hospital, to send the relevant employees to the all environmental trainings of Environment and Urbanisation Ministry and Health Ministry. Finally to work with the expert emplooyes and stuffs who

have received all necessary trainings by completing the relevant certificate programs,

4. To follow the appropriate waste management methods according to physical structure of the hospital such as number of employees and beds, financial and operational capabilities of the hospital. Otherwise wrong management techniques and excess treatment facilities affect negatively the economic situation of the hospital.
5. To plan the waste collection and storage processing and to prepare the application schedule according to Waste Management Regulation, (2015) (Waste Management Regulation, 2015).
6. To have adequate tools and equipment for the implementation of all these waste management activities and sufficient financial resources for payments to licensed disposal companies, to ensure proper use of the economic resources of hospital administrative and financial affairs.
7. To use again the reusable products by sterilizing instead of disposable accoding to Zero Waste Regulation, (2019) (Zero Waste Regulation, 2019).

Incineration and burial methods of the solid wastes are not applied in the studied hospital. Disposal on-site is not recommended due to high operating costs, environmental factors, difficult operational activities, and due to the absence of trained and equipped employees. Furthermore, for this application special permits and licenses is required. On the other hand, the Medical Waste Control Regulation stipulates that "Health institutions cannot establish and operate individual medical waste treatment plants". Therefore, the wastes should be stored by categorising the solid wastes by appropiate waste management techniques according to the Waste Management Regulation (2015) (Waste Management Regulation, 2015).

Solid waste quantities for the year 2018 collected from the examined hospital are recorded and it is presented in the Table 7.1.

Table 7.1 Waste production in the studied hospital for year 2018

Waste Types of Investigated Hospital	2018 Production (kg)
Domestic Waste	unknown
Packaging Waste	12000
Waste Battery	10
Hazardous Waste	20346.44
Medical Waste	582706
Total	615062.44

The current solid waste management in the investigated hospital is described as follows.

In the management of the **domestic wastes;** the solid wastes should be collected in black plastic bags and they should be labeled in the relevant units. However in the studied hospital these wastes are transported to the domestic waste depot without weigthing. By using some specialized trucks for domestic waste, they should be sent to domestic waste depot everyday. According to the Waste Management Regulation, domestic waste is handled by the municipality facilities (Waste Management Regulation, 2015) and there is no fee for this job. This is the best way to dispose the domestic wastes produced from the hospital. However, the domestic waste should be weigthed and labeled. In this way, the waste amount and the waste mixture will be recorded. This will provide to identify the waste and the origin of the responsible unit. Finally, the quantities of each waste type will be determined. Then, the waste type and the waste amounts should be log in to the online system entries of the Ministry of Environment and Urbanization. The management of the domestic wastes in the investigated hospital was summarized in Figure 7.1.

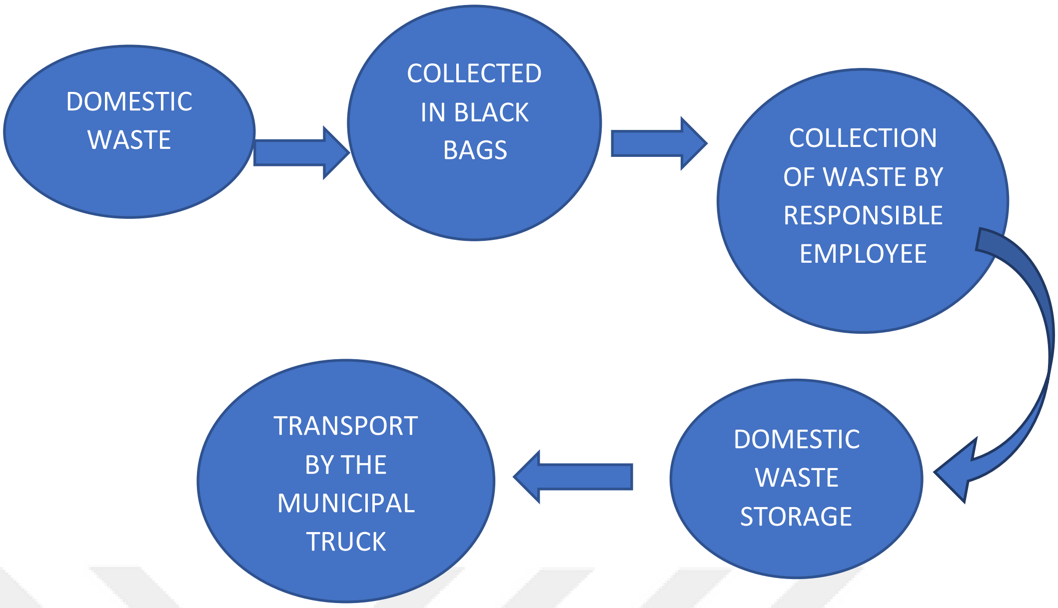


Figure 7.1 Management of the domestic wastes

In the management of **packaging wastes;** the packaging wastes should be collected in blue plastic bags. Then, they will store in a packaging depot. Packaging wastes in the hospital are nonhazardous and they are recyclable. Main types of nonhazardous hospital wastes are paper, cardboard, plastic, mixed packaging and glass packagings. Nonhazardous hospital waste materials should be gathered in blue plastic bags and should be stored. According to the Packaging Wastes Control Regulation, the packaging wastes should be collected by licensed firms such as MENSAN which has an agreement with municipality administration (Packaging Wastes Control Regulation, 2017). There is no fee for this job, too. The bags should be weighted and labeled. The labels should contain the source of the waste, the date and the weights of the packacing wastes. Labeling of the bags provides to identify the waste types for a possible mix-up of packacing wastes with the hazardous waste. The packacing wastes should be managed according the steps mentioned in Figure 7.2.

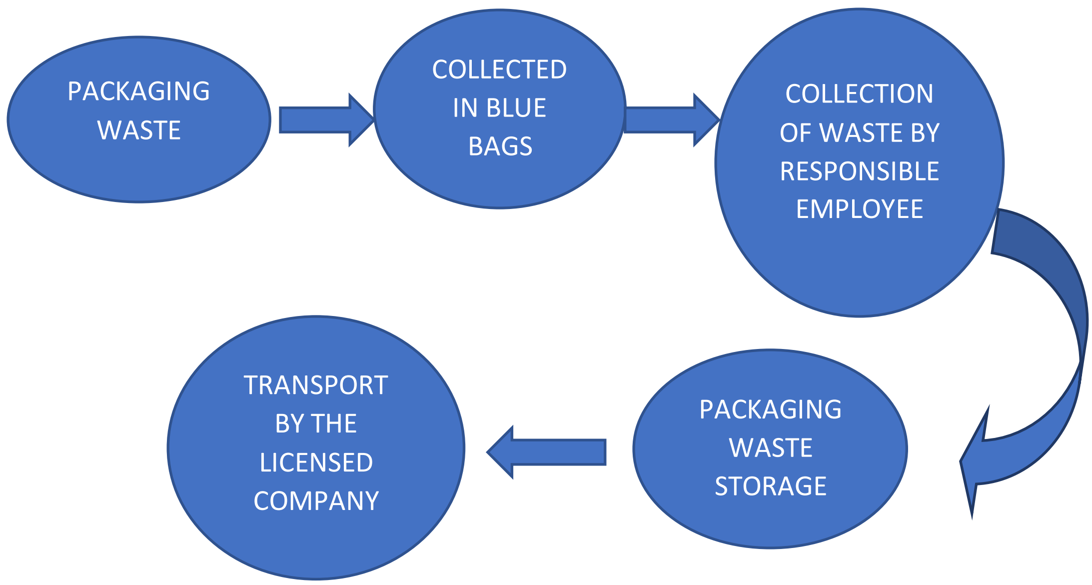


Figure 7.2 Management of the packaging wastes

Waste batteries in the studied hospital are collected in special boxes, which supplied from MBMIA (Mobile Battery Manufacturers and Importers Association). Then MIBMIA takes back the waste batteries. According to Waste Batteries and Accumulators Control Regulation, (2012) (Waste Batteries and Accumulators Control Regulation, 2012) Ministry of Environment and Urbanisation has given the responsibility for the collection of waste batteries to MBMIA. No money is paid for the delivery of the waste batteries to MBMIA. In the studied hospital, the waste battery management was performed according to regulation given above. The collection of the wasted batteries were performed according to the procedure given in Figure 7.3.

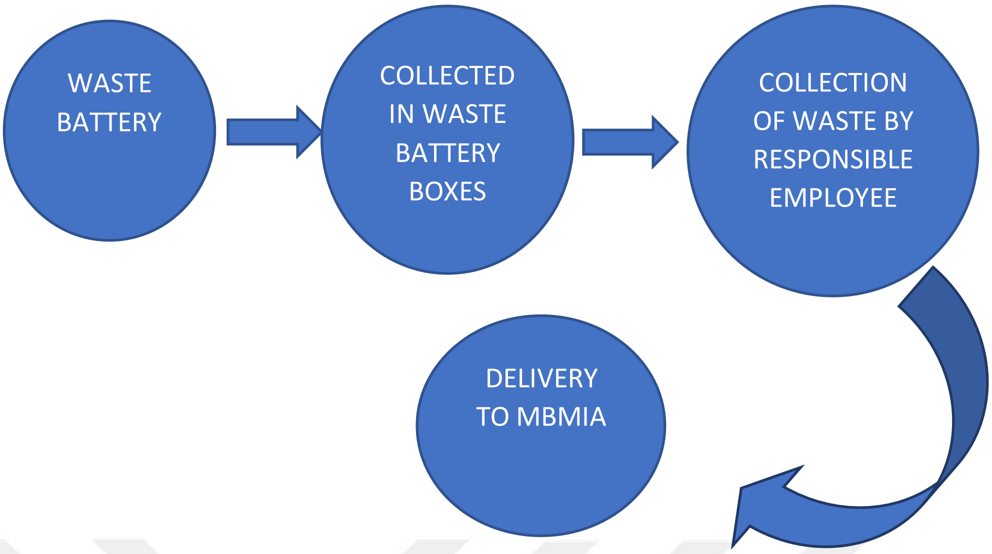


Figure 7.3 Management of the waste battery

The **hazardous wastes** in the studied hospital are collected in yellow bags and blue containers then they are stored in a hazardous waste storage depots according to the steps given in Figure 7.4. These hazardous wastes are collected and disposed by licensed firm. Hospital pays the fee for disposal process.

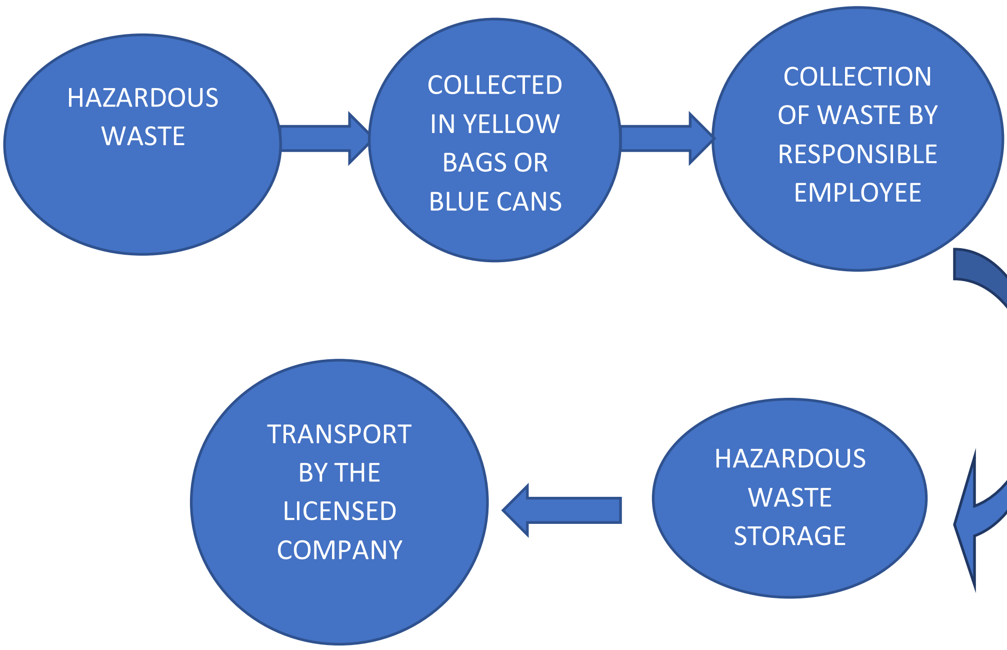


Figure 7.4. Management of the hazardous wastes

Medical wastes in the studied hospital are to be handled separately from the other wastes and should be placed to the red plastic bags as shown in Figure 7.5. Plastic yellow cutter-piercing box is used to collect the sharps and the needles. The medical wastes are delivered by a licensed company named MİROĞLU for disposal by D9 disposal method. D9 is the physico-chemical treatment resulting in a final compound or mixtures which are discarded by any of the operations numbered D1 to D12, e.g. evaporation, drying, calcination. The studied hospital pays fee for this disposal process. The management of the medical wastes were performed according to the procedure given in Figure 7.5.

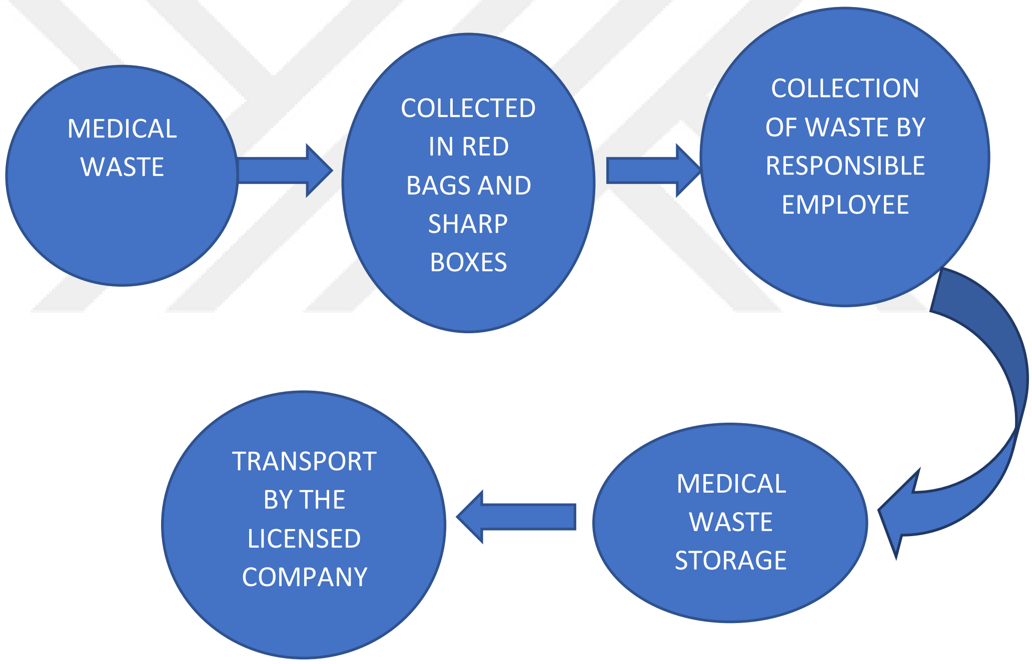


Figure 7.5 Management of medical wastes

7.2 Suggested Liquid Wastes and Wastewaters Management Procedure for Selected Hospital

Currently, the liquid wastes of studied hospital are collected separately and they stored until it is sent to a licensed disposal company (YA-SE) since the liquid wastes of hospital are hazardous. However, the studied hospital needs to a specific storage area for the storage of the liquid wastes coming from many surgical procedures such as drug treatment, radiological studies, laundry, cafeteria services, operating room and laboratory activities. All these units are the major source of the pollutants emitted to the hospital wastewater furthermore; the hospital wastewaters may contain a variety of potentially hazardous components, including microbiological pathogens, hazardous chemical compounds, disinfectants, pharmaceuticals, and radioactive substances. According to the Water Pollution Control Regulation, (2004), hospital wastewaters are similar to domestic wastewater. Most of the pollutants coming from these units are discharged to municipal sewage system without any treatment process (Water Pollution Control Regulation, 2004). The municipal treatment process treat only some conventional parameters such as COD, BOD, TN, TP, TSS and SS. The present treatment facility in the municipal wastewater treatment plant can not remove the toxic substances, drugs, pathogens and pharmaceuticals. As a result, these chemicals are discharged to the receiving body (river, lake and marine) since they could not be removed in the conventional treatment plants concstructed for the treatment of municipal wastes. Therefore the hospital wastewaters should be treated on-site with novel treatment process before discharged to the sewage system or to the receiving body.

Nonhazardous liquid wastes of the studied hospital were discharged to the municipal sewerage system. The hazardous chemical liquid wastes were collected separately and are disposed by the licenced firms namely YA-SE according to the Waste Management Regulation, (2015) (Waste Management Regulation, 2015). The nonhazardous solid wastes can be disposed as is in domestic wastes furthermore; there are two main important groups to be handled with care namely infectious and hazardous wastes. Infectious wastes in the studied hospital should be disinfected, after a proper segregation was performed. For the wastewaters of the hospital it was suggested a contact Anoxic Aerobic sequential Membrane Bio Reactor (AAMBR) on site.

An exemplary approach to manage the solid, liquid wastes and wastewaters in the studied hospital is illustrated in Figure 7.6.

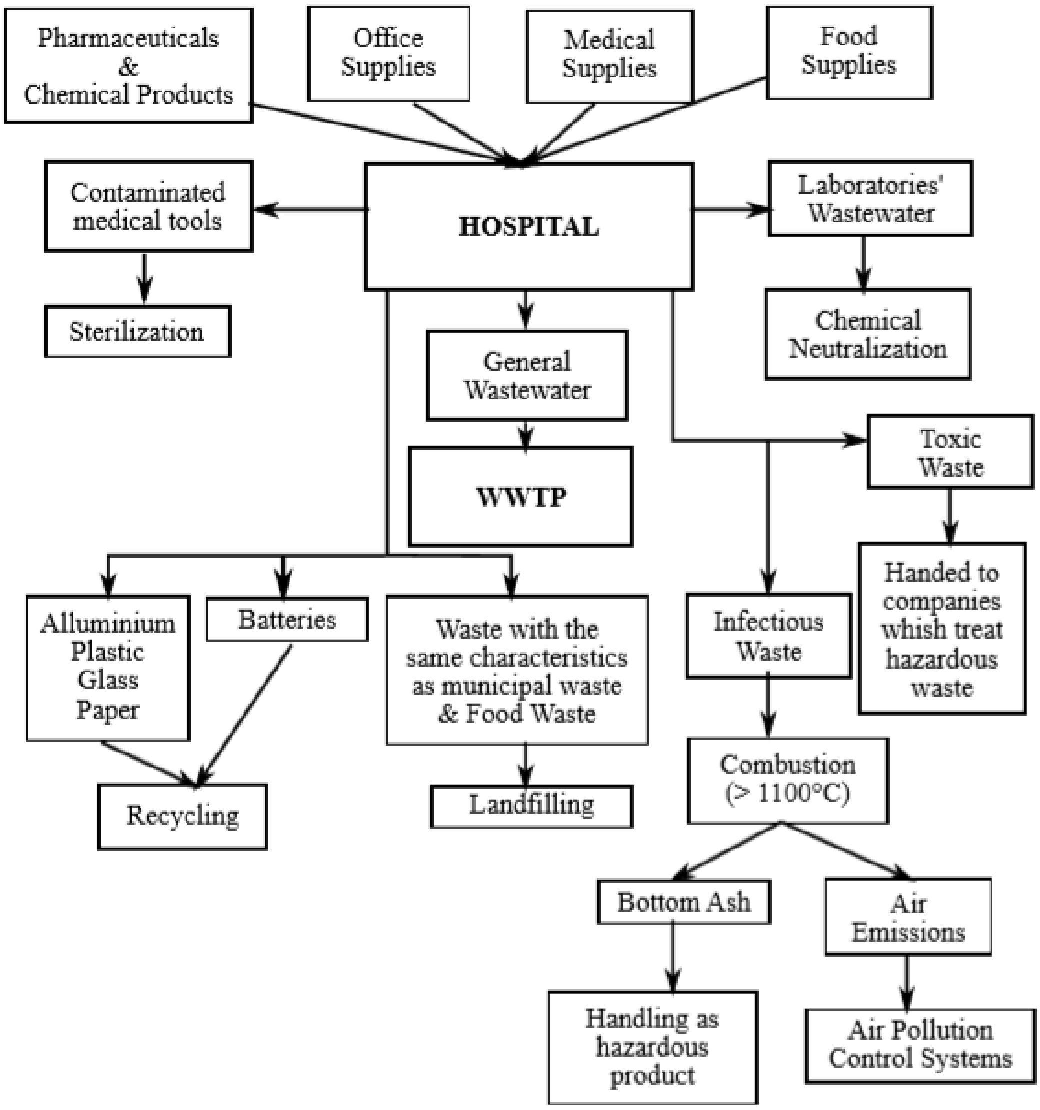


Figure 7.6 Schematic representation of the waste categories and the proposed treatment and disposal methods at the studied hospital

In conclusion, on-site biological advanced wastewater treatment is suggested to treat the wastewaters of the selected hospital. According to the literature review, it is clearly seen that contact Anoxic/Aerobic sequential Membrane Bio Reactor (AAMBR) processes is very promising for the treatment of hospital wastewaters. If the effluent of this advanced treatment can meet with the limits given for the regulation namely the utilisation of treated wastewater as irrigation purpose (Regulation for treated wastewater to be used as irrigation water (2010), and Guidelines for interpretations of irrigation water quality (2010)) according to characterization of the contact AAMBR effluent water may be used for cooling, for irrigation or for cleaning purposes.

7.3 Design of a Contact Anoxic/Aerobic Sequential Membrane Bio Reactor (AAMBR) for the Treatment of Hospital Wastewaters

Hospital wastewater will be treated by contact Anoxic/Aerobic sequential Membran Bio Reactor (AAMBR) to remove the carbonaceous compounds, the ammonia and the nitrates and phosphate produced during treatment. It provides very good quality and absolute purified water quality. In this way, the treated wastewater can be recovered and reused for irrigation in hospital. Sustainability of natural resources is achieved through recovery of wastewater. Hospital wastewaters generally contain macro and micro pollutants. Physicochemical pollutants are defined as pH, redox potential, conductivity; macro pollutants are COD, BOD_5, TOC, TSS. Furthermore, ammonium, chloride and free chlorine and microbiological pollutants such as coliforms bacteria (Enterococcus, Staphylococcus, Shigella, Salmonella), viruses are present in the hospital wastewater (Yaşar et al., 2013). Micropollutants are pharmaceuticals and personal care products (PPCPs) is defined as antibiotics, anesthetics, analgesics and anti-inflammatories, cytostatic drugs, and inhibitors. Furthermore, β blockers, anticancer drugs and other pollutants (antiepileptic drugs, blood oil regulators, endocrine system drugs), radioactive substances and AOX (chlorine-giving reagents, AOX and iodine X-Ray, contrast agents) are found in the hospital wastewater. The disinfectants (such as sodium hypochlorite, aldehydes, alcohols, chlorophenols, quaternary ammonium), metals and heavy metals (metals such as Rb, Li, Sr, rare elements in nature such as gadolinium, indium and osmium, Zn, Co, Pb, Fe, Cr, Ni), Endocrine Disruptors (Phthalates, Bisphenol A, PVC, Triclosan, Tris (2-Chlorethyl) Phosphate, 4-

Nonylphenol, PCBs, Dioxin, Furan, Alkylphenol were identified in the hospital wastewaters (Yaşar et al., 2013). Numerous types of micro pollutants in hospital wastewaters can cause major environmental problems in their discharge to the environments. Conventional treatment methods are not sufficient for the permanent and definitive solution of these problems and it becomes necessary to use some advanced treatment technologies with higher cost and relatively high difficulties in their operation. Therefore, ensuring sustainable water and wastewater management is one of the most important problems of hospitals (Altın, A. & Altın, S, 2017).

7.4 Design Calculations

During design of the contact AAMBR, the data and the kinetic constants were taken from the Table 7.2 and Table 7.3 (Zaerpour, 2014).

Table 7.2 Zenon manufacturer's design specifications (Judd, S. & Judd, C., 2015)

Name / Model	ZeeWeed (ZW500D)
Membrane material	PVDF, braided
Pore size, µm	0.04
Filament outside diameter, mm	1.9
Module dimensions,	(a) 1837 x 844 x 49
length x width x depth, mm	(b) 2198 x 844 x 49
Module effective membrane area, m^2	(a) 25.5 & 27.9
	(b) 31.6 & 34.4
Cassette dimensions,	(a) 1744 x 738 x 2208
length x width x depth, mm	(b) 1744 x 738 x 2568
	2122 x 1745 x 2590
Number of modules per cassette	(a) 16
	(b) 16, 48
Total membrane area per module, m^2	(a) 408, 446.4
	(b) 505.6 , 550.4
	1516.8, 1651.2
Packing density, m^2 membrane area/m^3	
Internal module volume	
Clean water permeability, LMH/bar	(a) 0.42, 0.39
Recommended membrane aeration rate,	(b) 0.34, 0.31
Nm^3/h per m^2 membrane area	0.3l, 0.29

Table 7.3 Aeration system operating parameters and design calculations (Zaerpour, 2014)

Parameter	Unit	Biology	Membrane
Diffuser type		fine bubble	coarse bubble
SOTEx	%/m	0.05	0.02
Air density, ρA	kg/m^3	1.2	1.2
correction factor exponent, ωx		0.084	0.084
mass % oxygen in air, OA,m	%	23.2	23.2
mass transfer correction, solid, α	-	0.51	0.43
mass transfer correction, salinity, β	-	0.95	0.95
F fouling factor		0.9	0.9
mass transfer correction, temperature, Φ	-	0.83	0.83
Aerator depth, yx	m	5	2.3

The design flux of contact AAMBR was chosen as 10 $L/m^2.h$ (Zaerpour, 2014) while the wastewater flow rate of the investigated hospital is 500 m^3/d.

7.4.1 Determination of Required SAD_m in Aerobic Reactor

In this thesis, specific air demand based on membrane area (SAD_m) is defined as scouring the air flow rate per membrane area as illustrated in Eq. 7.1 It is necessary to aerate the membrane unit to scout solids (Zaerpour, 2014).

$$SAD_m = Q_A/A_m, \tag{7.1}$$

Here,

SAD_m: $Specific\ Air\ Demand\ of\ Membran\ Area\ (Nm^3/\ (m^2.h))$

Q_A: $Membrane\ Aeration\ Rate\ (Nm^3/h)$

A_m: $Total\ Membrane\ Surface\ Area\ (m^2)$

In the Equation (28); Q_A is 20.83 m^3/h while A_m is 2083 m^2 (Zaerpour, 2014).

$$SAD_m = 0.29\ Nm^3/\ (m^2.h)$$

7.4.2 Calculation of SAD_p in Aerobic Reactor

The Specific air demand of permeate volume was calculated using the Eq. 7.2 (Judd, S. & Judd, C., 2015).

$$SAD_p = 1000 * SAD_m/\ J\ , \tag{7.2}$$

Here,

SAD_p: $Specific\ Air\ Demand\ of\ Permeate\ Volume\ (m^3\ air/\ m^3)$

J: $Design\ Flux\ (L/m^2.h)$(LMH)

In the Equation 29; SAD_p is 29 m^3 air/ m^3 permeate while SAD_m is 0.29 $Nm^3/m^2.h$ and J is 10 $L/m^2.h$

$$SADp = 1000 * 0.29\ Nm^3/\ (m^2.h)/\ 10\ L/\ (m^2.h)\ =\ 29\ m^3Air/\ m^3\ permeate$$

7.4.3 Determination of Membrane Area Required in Aerobic Reactor

The membrane area required was calculated according to Eq. 7.3 (Zaerpour, 2014).

$$A_m = \frac{Q}{J}, \tag{7.3}$$

Here,

A_m: Required Membrane Area (m^2)

In the Eq. 7.3 A_m is 2083 m^2, while Q_A is 20.83 and J is 10 $L/m^2.h$ (Zaerpour, 2014).

$$A_m = \frac{(500/24)\ m^3/h}{10\ L/m^2.h} = 2083\ m^2$$

7.4.4. Determination of Effluent Concentration of COD in the Aerobic Reactor

To determine the effluent Concentrations of COD, Eq. 7.4 is used. (Judd, S. & Judd, C., 2015).

$$S_e = \frac{K_s(1+k_e\Theta_{x,aer})}{\Theta_{x,aer}(\mu_m-k_e)-1} \ , \qquad (7.4)$$

Here,

S_0: $Influent\ COD\ Concentration\ (mg/L)$

S_e: $Effluent\ COD\ Concentration\ (mg/L)$

K_s: $Saturation\ Coefficient, (g/m^3)$

k_e: $Death\ Coefficient, (d^{-1})$

$\Theta_{x,aer}$: $Aerobic\ Sludge\ Retention\ Time\ (SRT), (d)$

μ_m: $Maximum\ Specific\ Growth\ Rate, (d^{-1})$

$S_0 = 250\ mg/L$

$K_s = 226\ g/m^3$

$k_e = 0.067\ d^{-1}$

$\Theta_{x,aer} = 15.63\ d$

$\mu_m = 3.24\ d^{-1}$

$$S_e = \frac{226 * (1 + 0.067 * 15.63)}{15.63 * (3.24 - 0.067) - 1}$$

$$S_e = 9.52\ mg/L$$

7.4.5 Determination of Effluent Concentration of NH_4-N in the Aerobic Reactor

To determine the Effluent Concentration of NH_4-N in aerobic reactor Eq. 7.5 is used (Orhon & Artan, 1997).

$$(S_{NH})_e = \frac{K_{NH}(1+k_{e,n}*\Theta_{x.aer})}{\Theta_{x.aer}(\mu_{nm}-k_{e,n})-1}, \tag{7.5}$$

Here,

$(S_{NH})_e$: $Effluent\ Ammonia\ Concentration, (mg/L)$

K_{NH}: $Half\ Saturation\ Concentration\ of\ NH_4 - N, (mg/L)$

$k_{e,n}$: *Coefficient of Death for Nitrifying Bacteria,* (d^{-1})

$\Theta_{x.aer}$: $Sludge\ Retention\ Time, (d)$

μ_{nm}: $Maximum\ Growth\ Rate\ of\ Nitrifying\ Bacteria, (d^{-1})$

$(S_{NH})_i = 25\ mg/L$

$K_{NH} = 0.03\ g/m^3$

$k_{e,n} = 0.15\ d^{-1}$

$\mu_{nm} = 0.22\ d^{-1}$

$\Theta_{x.aer} = 15.63\ d$

$$(S_{NH})_e = \frac{0.03 * (1 + 0.15 * 15.63)}{15.63 * (0.22 - 0.15) - 1}$$

$$(S_{NH})_e = 1.03\ mg/L$$

7.4.6 Determination of Total N Concentration Converted to Biomass in Aerobic Reactor

Total N concentration converted to biomass is calculated by the Eq. 7.6 (Orhon & Artan, 1997).

$$N_x = I_\beta * P_{xVSS}/Q, \tag{7.6}$$

Here,

I_β: $Constant\ Number$

$P_{x,VSS}$: $VSS\ Concentration, (g/d)$

$I_\beta = 0.06$ unitless

$P_{x,VSS} = 51.90\ kg/d$

$Q = 500\ m^3/d$

$$N_x = 0.06 * 51.90 * 10^3 g/kg/500 = 6.04\ g/m^3$$

7.4.7 Determination of Effluent NO_3-N Concentration in the Aerobic Reactor (This NO_3-N is the Influent of Anoxic Reactor)

Total nitrogen concentration converted from NH_4-N to NO_3-N per unit wastewater volume is calculated by using Eq. 7.7 (Orhon & Artan, 1997).

$$NO_3 - N = (S_{NH})_i - ((S_{NH})_e + N_x) \quad (7.7)$$

$$NO_3 - N = 25 - (1.03 + 6.04) = 17.93\ mg/L$$

$$(S_{NO})_i = 17.93\ mg/L$$

7.4.8 Determination of Required Membrane Air Scouring Capacity in Aerobic Reactor

To determine the net air required for biological treatment, M_0 (Oxygen requirement for biological treatment) Eq. 7.8 is used (Judd, S. & Judd, C., 2015).

$$M_0(\text{kg/h}) = Q(S - S_e) - 1.42M_{x.Bio} + 4.33QNO_x - 2.86Q(NO_x - NO_e), \quad (7.8)$$

Here,

M_0: $Oxygen\ requirement\ for\ biological\ treatment\ (kg/d)$

Q: $Design\ Flow\ Rate\ (m^3/d)$

S_0: $Influent\ COD\ Concentration\ (mg/L)$

S_e: $Effluent\ COD\ Concentration\ (mg/L)$

$M_{x.Bio}$: $Biomass\ Yield\ (g\ VSS/d)$

NO_x: *TKN Concentration Oxidized to Nitrate (mg/L)*

NO_e: *Effluent Nitrate Concentration (mg/L)*

$Q = 500\ m^3/d$

$S_0 = 250\ mg/L$

$S_e = 9.52\ mg/L$

$M^{X,Bio} = 2.44\ kg/d$

$NO_x = 17.93\ mg/L$

$NO_e = 0.57\ mg/L$

$$M_0 = 500\ m^3/d * (250 - 1.34) g/m^3 - 1.42 * 2440\ g/d + 4.33 * 500\ m^3/d * 17.93\ g/m^3 - 2.86 * 500\ m^3/d * (17.93 - 0.57) g/m^3$$

$$M_0 = 134.87\ kg/d$$

7.4.9 Determination of Effluent Concentration of PO_4-P in the Aerobic Reactor

To determine the effluent concentrations of PO_4-P in aerobic reactor Eq. 7.9 is used (Orhon & Artan, 1997).

$$(S_{PO})_i = \frac{K_{PO} * (1 + k_e * \Theta_{x,aer})}{\Theta_{x,aer} * (\mu_m - k_e) - 1}, \tag{7.9}$$

$(S_{PO})_i$: *Influent Phosphate Concentration*, (mg/L)

K_{PO}: *Half Saturation Concentration of* $PO_4 - P$, (mg/L)

k_e: *Death Coefficient*, (d^{-1})

$\Theta_{x.aer}$: *Sludge Retention Time*, (d)

μ_m: $Maximum\ Specific\ Growth\ Rate,\ (d^{-1})$

$K_{PO} = 1.65\ mg/L$

$k_e = 0.12\ d^{-1}$

$\mu_m = 0.2\ d^{-1}$

$\Theta_{x.aer} = 15.63\ d$

$(S_{PO})_i = 12\ mg/L$

7.4.10 Determination of Effluent PO_4-P in the Anoxic Reactor

Effluent PO_4-P from anoxic reactor is calculated by using Eq. 7.9 (Orhon & Artan, 1997).

$$(S_{PO})_e = \frac{1.65 * (1 + 0.12 * 15.63)}{15.63 * (0.2 - 0.12) - 1}$$

$$(S_{PO})_e = 19\ mg/L$$

7.4.11 Determination of Effluent PO_4-P in the Aerobic Reactor

Effluent PO_4-P in the Aerobic reactor is calculated by using Eq. 7.9 (Orhon & Artan, 1997).

$$(S_{PO})_e = \frac{0.58 * (1 + 0.04 * 15.63)}{15.63 * (0.18 - 0.04) - 1}$$

$$(S_{PO})_e = 0.8\ \text{mg/L}$$

$(S_{PO})_i = 19\ mg/L$

$K_{PO} = 0.58\ mg/L$

$k_{e,n} = 0.04\, d^{-1}$

$\mu_{nm} = 0.18\, d^{-1}$

$\Theta_{x.aer} = 15.63\ d$

$(S_{PO})_e = 0.8\ mg/L$

7.4.12 Determination of Oxygen Transferred by Membrane Aeration

The Oxygen Transferred by Membrane during aeration is calculated by using Eq. 7.10 (Judd, S. & Judd, C., 2015).

$$M_m = Q_{A,m}\ \rho_A (SOTE_{coarse} y_{coarse}) O_{A,m} \alpha\beta\phi\ , \qquad (7.10)$$

$$= 500 \frac{m^3}{d} * 1.2 \frac{kg}{m^3} * 0.02 \frac{1}{m} * 2.3m * 0.232 * 0.43 * 0.95 * 0.83$$

$$M_m = \ 2.17\ kg\ O_2/d$$

Here,

M_m: $Oxygen\ transferred\ by\ membrane\ aeration, (kg/d)$

ρ_A: $Air\ Density, (kg/m^3)$

$SOTE_{coarse}$: $Coarse\ Bubble\ Aeration, (1/m)$

$SOTE_{fine}$: $Fine\ Bubble\ Aeration, (1/m)$

y_{coarse}: *Coarse Bubble Aerator Depth, (m)*

y_{fine}: *Fine Bubble Aerator Depth, (m)*

$O_{A,m}$: *Mass Ratio of Oxygen in the Air, (%)*

α: *Ratio of Oxygen Mass Transfer in Suspension to Mass Transfer in Pure Water*

β: *Ratio of Oxygen Mass Transfer in Salt Water to Mass Transfer in Pure Water*

ϕ: *Temparature Correction Factor*

According to Zenon Manufacturer's Design Specifications the values of the parameters given below are as follows (Zaerpour, 2014).

$\rho_A = 1.2 \ \frac{kg}{m^3}$

$SOTE_{coarse} = 0.02 \ \frac{1}{m}$

$y_{coarse} = 2.3 \ m$

$O_{A,m} = \ 0.232$ (%)

α = 0.43 unitless

β = 0.95 unitless

ϕ = 0.83 unitless

7.4.13 Determination of Net Air Flow Required for Biological Aeration

To determine the net air flow required for biological aeration Eq. 7.11 is used (Judd, S. & Judd, C., 2015).

$$Q_{A,b} = \frac{M_0 - M_m}{\varrho A(SOTE_{fine} * y_{fine}) O_{A,m} \alpha \beta \phi}, \quad (7.11)$$

$$Q_{A,b} = \frac{(134.87 - 2.17)\text{kg / d}}{1.2 * 0.05 * 5 * 0.232 * 0.51 * 0.95 * 0.83} = 4739.28\ Nm^3\ \text{/ h}$$

Here,

$Q_{A,b}$: $Net\ Air\ Flow\ Rate\ for\ Biological\ Requirements$ (Nm^3 / h)

$O_{A,m}$: $Mass\ Ratio\ of\ Oxygen\ in\ the\ Air,$ (%)

According to Zenon Manufacturer's Design Specifications there valus of parameters are assumed below.

$\varrho A = 1.2\ \frac{kg}{m^3}$

$SOTE_{fine} = 0.05\ \frac{1}{m}$

$y_{fine} = 5\ m$

$O_{A,m} = 0.232$ %

α = 0.51 unitless

$\beta = 0.95$ unitless

ϕ = 0.83 unitless

7.4.14 Determination of Minimum Aerobic Membrane Tank Volume

The minimum membrane tank volume ($V_{m,min}$) was calculated by Eq. 7.12 (Judd, S. & Judd, C., 2015).

$$V_{m,min}(m^3) = \frac{A_m}{\varphi_{tank}}, \qquad (7.12)$$

$$= \frac{2083\ m^2}{253\ (1/m)} = 8.2\ m^3$$

Here,

$V_{m,min} = Minimum\ Membran\ Tank\ Volume\ (m^3)$

φ_{tank}: *Density of Membrane Packing: Area per Membrane Tank,* (m^2/m^3)

$\varphi_{tank} = 253\ (1/m)$

7.4.15 Determination of Aerobic SRT

For fully complete-mix activated sludge nitrification system, at temperature below 25°C with sufficient DO present, nitrification rates are affected by the liquid DO concentration in activated sludge. To account for the effects of DO, the expression for the specific growth rate is given in Eq. 7.13 (Zaerpour, 2014).

$$\mu_n = \left(\frac{\mu_{nm} * N_e}{K_n + N_e}\right)\left(\frac{DO}{K_0 + DO}\right) - k_{e,n}, \quad (7.13)$$

Here,

μ_n: $Specific\ Growth\ Rate\ of\ Nitrifying\ Bacteria, (g\ new\ cells/\ g\ cells.d)$

μ_{nm}: $Maximum\ Specific\ Growth\ Rate\ of\ Nitrifying\ Bacteria, (g\ new\ cells$
$/g\ cells.d)$

N_e: $Effluent\ Ammonia\ concentration, (g/m^3)$

K_n: *Half Saturation Coefficient for Nitrification,* (g/m^3)

$k_{e,n}$: $Endogenous\ Decay\ Coefficient\ for\ Nitrifying\ Organisms, (g\ VSS\ /\ g\ VSS.d)$

DO: $Dissolved\ Oxygen\ Concentration, (g/m^3)$

$K_0 =\ Half\ Saturation\ Coefficient\ for\ DO, (g/m^3)$

According to Zenon Manufacturer's Design Specifications (Zaerpour, 2014). The kinetic values were as follows:

$\mu_{n,m} = 0.26\ g/g.d$

$K_n = 0.26\ g/m^3$

$k_{e,n}$= 0.06 $g/g.d$

$N_e = 1.03\ mg/L$

$DO = 1.5\ mg/L$

$K_0 = 0.5\ mg/L$

$$\mu_n = \{\frac{0{,}26\ g/g.d * 1.03\ g/m^3}{(0{,}26+1.03)\ g/m^3}\} * \{\frac{1{,}5\ g/m^3}{(0{,}5+1{,}5) g/m^3}\} - 0.06\ g/g.d = 0.096\ g/g.d$$

Theoretical SRT is calculated by using Eq. 7.14. (Judd, S. & Judd, C., 2015).

$$SRT = \frac{1}{\mu_n}, \tag{7.14}$$

$$SRT = \frac{1}{0.096\ g/g.d} = 10.42\ d$$

Design SRT must be greater than therotical SRT so it is calculated by using the Eq. 7.15 (Orhon & Artan, 1997).

$$Design\,SRT = \delta_{SA} * theoritical\,SRT\ , \tag{7.15}$$

$\delta_{SA}: Safety\ Factor$

$\delta_{SA} = 1.5$

$Design\,SRT = 1.5 * 10.42 = 15.63\ d$

Here,

$SRT\ is\ solids\ retention\ time\ (day)$

7.4.16 Calculation of Sludge/Biomass Production in Aerobic Reactor

The formula for calculation of sludge production is given in Eq. 7.16 (Judd, S. & Judd, C., 2015).

$$P_{x,vss} = \frac{QY(S_0 - S_e)}{1+(k_e)SRT} + \frac{(f_d)QY(S_0 - S_e)SRT}{1+(k_e)SRT} + \frac{QY_n(NO_X)}{1+(k_{e,n})SRT} + (nbVSS), \tag{7.16}$$

$$QY(S_0 - S_e) = 500 * 0.4 * (250 - 1.34) = 49.73\ kg/d$$

$$(f_d)QY(S_0 - S_e)SRT = 0.15 * 500 * 0.4 * (250 - 1.34) * 15.63\ = 116.59\ kg/d$$

$$1 + (k_e)SRT = 1 + 0.088 * 15.63 = 3.38$$

$$1 + (k_{e,n})SRT = 1 + 0.06 * 15.63 = 1.94$$

$$QY_n(NO_X) = 500 * 0.26 * 17.93 = 2.33\ kg/d$$

$$Q(nbVSS) = 500 * {}^{3}/_{1000} = 1.5\ kg/d$$

$P_{x,bio}$ in aerobic reactor is calculated by using Eq. 7.17 (Judd, S. & Judd, C., 2015).

$$P_{x,bio} = \frac{QY(S_0 - S_e)}{1+(k_e)SRT} + \frac{(f_d)QY(S_0 - S_e)SRT}{1+(k_e)SRT} + \frac{QY_n(NO_X)}{1+(k_{e,n})SRT}, \quad (7.17)$$

$$P_{x,bio} = \frac{49.73\ kg/d}{3.38} + \frac{116.59\ kg/d}{3.38} + \frac{2.33\ kg/d}{1.94} = 50.40\ kg/d$$

$P_{x,VSS}$ is calculated by using Eq. 7.18 (Judd, S. & Judd, C., 2015).

$$P_{x,VSS} = P_{x,bio} + Q(nbVSS), \quad (7.18)$$

$$P_{x,VSS} = 50.40 + 1.5 = 51.90\ kg/d$$

$P_{x,TSS}$ is calculated by using Eq. 7.19 (Judd, S. & Judd, C., 2015).

$$P_{x,TSS} = \frac{P_{x,bio}}{0.85} + Q(nbVSS + iTSS, \quad (7.19)$$

$$P_{x,TSS} = \frac{50.40\ kg/d}{0.85} + 1.5\ kg/d + \left(\frac{500\ m^3}{d}\right)\left(18.3\frac{g}{m^3}\right)\left(1\frac{kg}{10^3 g}\right) = 69.94\ kg/d$$

Here,

$P_{x,TSS}$: $Total\ Sludge\ Yield, (g/d)$

$P_{x,VSS}$: $VSS\ Concentration, (g/d)$

$P_{x,bio}$: $Biomass\ Concentration, (g/d)$

Y: $Cell\ Mass\ Produced\ per\ Mass\ of\ Nutrients\ Consumed, (g\ VSS/g\ BOD)$

S_0: $Influent\ COD\ Concentration, (mg/L)$

S_e: $Effluent\ COD\ Concentration, (mg/L)$

f_d: $Residual\ Biomass\ Fraction\ as\ Cell\ Debris,(g\ VSS/g\ substrate)$

Y_n: $Nitrification\ Sludge\ Yield,(g\ VSS/gNH_4-\mathrm{N})$

SRT: $Sludge\ Retention\ Time,(d)$

k_e: $Death\ Coefficient,(d^{-1})$

$k_{e,n}$: $Death\ Coefficient\ for\ Nitrification\ Bacterium,(d^{-1})$

k_e= 0.088 $g/g\ .d$

$k_{e,n}$= 0.06 $g/g\ .d$

SRT= 15.63 d

$f_d = 0.15\ g\ VSS/g\ substrate$

$Y = 0.4\ g\ VSS/g\ BOD$

$Y_n = 0.26\ g\ VSS/gNH_4 - \mathrm{N}$

7.4.17 Determination of Aerobic Tank Volume

In order to calculate the aerobic tank volume the following three equations (Eqs 7.20, 7.21 and 7.22) are used (Judd, S. & Judd, C., 2015).

$$\text{Mass} = P_x(SRT), \tag{7.20}$$

$$X_{VSS}*V = P_{x,VSS} * SRT, \tag{7.21}$$

$$Mass\ of\ MLVSS = 51.90\ \frac{kg}{d} * 15.63\ d = 811.197\ kg$$

$$Mass\ of\ MLSS = X_{TSS} * V = P_{x,TSS} * SRT = 69.94 * 15.63 = 1093.16\ \text{kg}$$

$$MLSS = 1400\ g/\ m^3$$

$$V_{aer} = \frac{P_{x,TSS} * SRT}{X_{aer}}\ , \tag{7.22}$$

$$V_{aer} = \frac{(1093.16\ kg)(\ 10^3 g/1\ kg)}{1400\ g/\ m^3} = 781\ m^3$$

Here,

$MLSS$: $Mixed\ Liquor\ Suspendend\ Solid, (g/\ m^3)$

$MLVSS$: $Mixed\ Liquor\ Volatile\ Suspendend\ Solid, (g/\ m^3)$

V_{aer}: $Aerobic\ Tank\ Volume,\ (m^3)$

7.4.18 Determination of Effluent COD Concentration from Anoxic Reactor

To determine the effluent COD concentration from Anoxic Reactor, Eq. 7.23 is used (Judd, S. & Judd, C., 2015).

$$S_e = \frac{K_s(1 + k_e \Theta_{x,aer})}{\Theta_{x,aer}(\mu_m - k_e) - 1}, \tag{7.23}$$

$S_0 = 9.52\ mg/L$

$K_s = 50\ g/m^3$

$k_e = 0.02\ d^{-1}$

$\Theta_{x,aer} = 15.63\ d$

$\mu_m = 3.24\ d^{-1}$

$$S_e = \frac{50 * (1 + 0.02 * 15.63)}{15.63 * (3.24 - 0.02) - 1}$$

$$S_e = 1.34\ mg/L$$

Here,

S_0: $Influent\ COD\ Concentration, (mg/L)$

S_e: $Effluent\ COD\ Concentration, (mg/L)$

7.4.19 Determination of the Recirculation Ratio in Anoxic Reactor

Recirculation ratio is calculated by using Eq. 7.24 (Judd, S. & Judd, C., 2015).

$$r_{int} = \frac{NO_x}{NO_e} - 1, \tag{7.24}$$

$$r_{int} = \frac{17.93}{0.57} - 1 = 30.46$$

Here,

r_{int}: $Recirculation\ Rate$

7.4.20 Fraction of Active Biomass in Anoxic Reactor

Fraction of active biomass in anoxic zone is calculated as given in Eq. 7.25 (Judd, S. & Judd, C., 2015).

$$X_b = \left[\frac{Q(SRT)}{V}\right]\left[\frac{Y(S_0 - S_e)}{1 + (k_e)SRT}\right]\left[\frac{r_{int}}{r_{int} + 1}\right], \tag{7.25}$$

$$X_b = \frac{500 * 15.63}{781} * \frac{0.4 * (250 - 1.34)}{3.38} * \frac{30.46}{1 + 30.46} = 284.95\ g/m^3$$

Here,

X_b: $Active\ Biomass\ in\ Anoxic\ Zone, (mg/L)$

7.4.21 Determination of Nitrate Loading Entering to Anoxic Reactor

Nitrate load to anoxic reactor is calculated as given in Eq. 7.26 (Judd, S. & Judd, C., 2015).

$$NO - loading\ in\ g/d = Qr_{int}(TKN - N_e - 0{,}12\ \ M_{x,bio}/Q), \qquad (7.26)$$

$$= 500 * 30.46 * \left(33 - 1.03 - 0.12 * \frac{50.40 * \frac{10^3\ g}{kg}}{500}\right) = 288.91 kg/d$$

$$NO - loading\ in\ g/d = 288.91\ kg/d$$

7.4.22 Choosing Anoxic HRT and Determining F/Mb Ratio in Anoxic Reactor

Eqs. 7.27, 7.28, 7.29, 7.30 and 7.31 are used for choosing anoxic HRT and determining F/M_b ratio and bCOD fraction, respectively (Judd, S. & Judd, C., 2015).

$$\tau = \frac{3\ h}{24\,\frac{h}{d}}, \qquad (7.27)$$

$$\tau = HRT_{anox=} 0.13\ d$$

$$V_{anox} = \tau * \mathrm{Q}, \qquad (7.28)$$

$$= 0.13\ \mathrm{d} * 500\, m^{\ 3}/d$$
$$= 65\ m^{\ 3}$$

$$^{F}/_{M_b}\ in\ (g\ BOD/g\ TSS\ d) = \frac{Q * S_0}{V_{anox} X_b}, \qquad (7.29)$$

$$=\frac{500\ m^3/d * 250\ g/m^3}{65\ m^3 * 284.95\ g/m^3} = 6.75\ g/g.d$$

Here,

${}^{F}/_{M_b}$: *Ratio of Organic Matter to Biomass in Anoxic Zone,* $(g\ BOD/g\ TSS\ d)$

Based on Judd book $SDNR_b = 0.21\ g/g.d$ @ 20 °C

$$SDNR_{12} = 0.21\ (1.026)^{12-20} = 0.17\ g/g.d, \quad (7.30)$$

$$NO_r = V_{anox} * X_{b,anox} * SDNR, \quad (7.31)$$

$$=65\ m^3 * 284.95 \frac{g}{m^3} * \frac{0.17g}{g}.d = 3.15\ kg/d$$

Here,

V_{anox}: $Anoxic\ Tank\ Volume, (m^3)$

$SDNR$: $Specific\ Denitrification\ Rate, (g\ NO_3 - N/g\ VSS)$

NO_r: $Denitrification\ Capacity, (g/d)$

7.4.23 Determination of Total SRT and Total Process Volume in Aerobic Reactor

The total SRT and the total process volume were determined by using Eqs. 7.32, 7.33 and 7.34, respectively (Judd, S. & Judd, C., 2015).

$$Q_w = \frac{V_{aer}}{\Theta_{x,aer}}, \tag{7.32}$$

$$Q_w = \frac{781}{15.63} = 49.97\ m^3\ /d$$

$$\Theta_{x,process} = \frac{V_{aer}X_{aer}+V_{anox}X_{anox}}{Q_w X_{aer}} = \Theta_{x,aer} + \Theta_{x,anox}, \tag{7.33}$$

$$= \frac{781\ m^3 * 1400\ g/m^3 + 65\ m^3 * 284.95\ g/m^3}{49.97\ m^3/d * 1400\ g/m^3} = 15.90\ \text{d}$$

$$V_{process}\ (m^3) = V_{anox} + V_{aer}, \tag{7.34}$$

$$V_{process} = 65\ m^3 + 781\ m^3 = 846\ m^3$$

Here,

$\Theta_{x,process}$: $SRT\ of\ Total\ Process, (d)$

$V_{process}$: $Total\ Process\ Volume, (m^3)$

V_{aer}: $Aeration\ Tank\ Volume, (m^3)$

X_{aer}: $MLSS\ Concentration\ in\ Aerobic\ Zone, (mg/L)$

V_{anox}: $Anoxic\ Tank\ Volume, (m^3)$

X_{anox}: $MLSS\ Concentration\ in\ Anoxic\ Zone, (mg/L)$

Q_w: $Sludge\ Waste\ Rate, (m^3/d)$

$\Theta_{x,aer}$: $Aerobic\ SRT, (day)$

$\Theta_{x,anox}$: $Anoxic\ SRT, (day)$

7.4.24 Determination of Effluent NO_3-N Concentration in Anoxic Reactor

To determine of effluent NO_3-N concentration Eq. 7.35 is used (Orhon & Artan, 1997).

$$(S_{NO})_e = \frac{K_{NO}*(1+k_{e,n}*\Theta_{x,aer})}{\Theta_{x,aer}*(\mu_{n,m}-k_{e,n})-1}, \tag{7.35}$$

$(S_{NO})_i$: $Influent\ Nitrate\ Concentration, (mg/L)$

$(S_{NO})_e$: $Effluent\ Nitrate\ Concentration, (mg/L)$

K_{NO}: $Half\ Saturation\ Concentration\ of\ NO_3 - N, (mg/L)$

$k_{e,n}$: *Coefficient of Death for Denitrifying Bacteria,* (d^{-1})

$\Theta_{x.aer}$: $Sludge\ Retention\ Time, (d)$

μ_{nm}: $Maximum\ Growth\ Rate\ of\ Denitrifying\ Bacteria, (d^{-1})$

$(S_{NO})_i = 17.93\ mg/L$

$K_{NO} = 0.44\ mg/L$

$k_{e,n} = 0.055\ d^{-1}$

$\mu_{nm} = 0.21\ d^{-1}$

$\Theta_{x.aer} = 15.63\ d$

$$(S_{NO})_e = \frac{0.44 * (1 + 0.055 * 15.63)}{15.63 * (0.21 - 0.055) - 1} = 0.57\ mg/L$$

$$(S_{NO})_e = 0.57\ mg/L$$

Design calculations, raw hospital wastewater characterization, aerobic reactor effluent concentrations and anoxic reactor effluent concentrations are presented in Table 7.4.

Table 7.4 Design calculations, raw hospital wastewater characteristics, aerobic rector and anoxic reactor effluent concentrations

Design Calculations	**Raw Hospital Wastewater Characterisation**	**Aerobic Reactor Effluent Concentration**	**Anoxic Reactor Effluent Concentration**
SAD_p		29 m^3air/ m^3permeate	
A_m		2083 m^2	
COD_e	250 mg/L	9.52 mg/L	1.34 mg/L
$(NH_4\text{-}N)_e$	25 mg/L	1.03 mg/L	-
$(NO_3\text{-}N)_e$	17.93 mg/L	-	0.57 mg/L
M_0		134.87 kg/d	
$(PO_4\text{-}P)$	12 mg/L	0.8 mg/L	19 mg/L
M_m		2.17 kg/d	
$Q_{A,b}$		201.03 Nm^3/h	
$V_{m,min}$		8.2 m^3	
Design SRT		15.63 d	
$P_{x,bio}$		50.40 kg/d	

Table 7.4 continues

$P_{x,VSS}$		51.90 kg/d	
$P_{x,TSS}$		69.94 kg/d	
V_{aer}		781 m^3	
r_{int}= 30.46			
X_b			284.95 g/ m^3
NO_3-loading			288.91 kg/d
V_{anox}			65 m^3
F/M_b			6.75 d^{-1}
NO_r			3.15 kg/d
Q_w		49.97 m^3/d	
$\Theta_{x,proccess}$ = 15.90 d			
$V_{proccess}$ = 846 m^3			

CHAPTER EIGHT
THE PROPERTIES OF THE HOSPITAL WASTEWATER EFFLUENT TREATED BY CONTACT AAMBR

This plant has a treatment capacity of 500 cubic meters per day and is designed to produce a high quality treatment plant effluent. According to the data is obtained from the investigated hospital, wastewater influent parameters such as COD, TSS, TKN, NH_3, Organic N, NO_3-N and NO_2-N concentrations are 250 mg/L, 398 mg/L, 33 mg/L, 25 mg/L, 4.9 mg/L, 17.93 mg/L and 1 mg/L. After contact AAMBR treatment, effluent parameters were measured such as COD, TSS, TKN, NH_3, Organic N, NO_3-N and NO_2-N concentations are 1.34 mg/L, 2.79 mg/L, 1.62 mg/L, 1.03 mg/L, 0.01 mg/L, 0.57 mg/L and 0.01 mg/L. These parameters are shown in Table 8.1.

Table 8.1 Aerobic and anoxic reactor design parameters and effluent characteristics

Aerobic Reactor		**Anoxic Reactor**	
MLSS	1400 mg/L	MLSS	2000 mg/L
$P_{x,vss}$	69.94 kg/d	$X_{b,anox}$	284.95 g/m^3
SRT	15.63 d	NO-loading	288.91 kg/d
V_{aer}	781 m^3	V_{anox}	65 m^3
$(COD)_e$	9.52 mg/L	$(COD)_e$	1.34 mg/L
$(NH_4\text{-}N)_e$	1.03 mg/L	$(NH_4\text{-}N)_e$	-
$(NO_3\text{-}N)_e$	-	$(NO_3\text{-}N)_e$	0.57 mg/L
$(PO_4\text{-}P)_e$	0.8 mg/L	$(PO_4\text{-}P)_e$	19 mg/L

The effluent quality of hospital wastewater treated by contact AAMBR was investigated for reusing the treated wastewater as garden irrigation water. Treated water was measured according to chemical quality for irrigation water and it was given in Table 8.2. Then, it was compared with the Table 1.4 was given in Chapter 1 based on Regulation for treated wastewater to be used as irrigation water (2010), and Guidelines for interpretations of irrigation water quality (2010). Treated water effluent concentrations were found suitable for use as irrigation water when compared with regulatory limits (Table 1.4). It is useful for irrigation water by considering electro conductivity (EC), total dissolved solids (TDS), Sodium, Chloride, SAR, Boron, NH_3, PO_4, total nitrogen (TN), coliform, HCO_3, RSC, SSP, ESP and pH parameters. In addition to parameters, heavy metal concentrations were measured in treated water and they were given in Table 8.3. It was compared with the permissible concentrations for irrigation in Table 1.5 in Chapter 1. The concentrations of heavy metals in treated water were lower than the limits given by the Regulation for treated wastewater to be used as irrigation water (2010), and Guidelines for interpretations of irrigation water quality (2010) (Table 1.5). Consequently, the chemical components in treated wastewater, met with the limits given by Irrigation Water Regulation (Regulation for treated wastewater to be used as irrigation water (2010), and Guidelines for interpretations of irrigation water quality (2010)) above. In the contact AAMBR, the pollution parameters given in all tables were treated with yields varying between 61.90 % and 100 %. This treated hospital wastewater quality is safe and suitable for its reuse as garden irrigation water according to the all parameters present in the regulations relevant to the irrigation.

Table 8.2 The results of hospital wastewater after AAMBR treatment to be used as irrigation water (Regulation for Treated Wastewater to be used as Irrigation Water, 2010 and Guidelines for Interpretations of Irrigation Water Quality, 2010)

Parameters	Qualification of Raw Hospital Wastewater	Qualification of Treated Water after AAMBR Treatment	Removal Efficiency (%)	Limit Values for Irrigation		
				None	Slight to moderate	Severe
COD (mg/L)	250	1.34	99.46%			
NH_3 (mg/L)	25	1.03	95.88%			
NO_3-N (mg/L)	17.93	0.57	96.82%	< 5	5–30	> 30
PO_4-P (mg/L)	12	0.8	93.33%			
Total Nitrogen (TN) (mg/L)	33	1.62	96%			
Total Suspended Solid (SS) (mg/L)	398	2.79	93.33%			
Conductivity (µS/cm)	5	0.85	83%			
SAR_d (mg/L)	3	0.55	81.67%	0-3		
Boron (B) (mg/L)	2.3	0.22	90.43%	< 0.7	0.7–3	> 3
Sodium (Na) (mg/L)	25	3	88%	<10	10-26	>26
Chlorine (Cl) (mg/L)	1000	100	90%	<140	140-350	>350

Table 8.2 continues

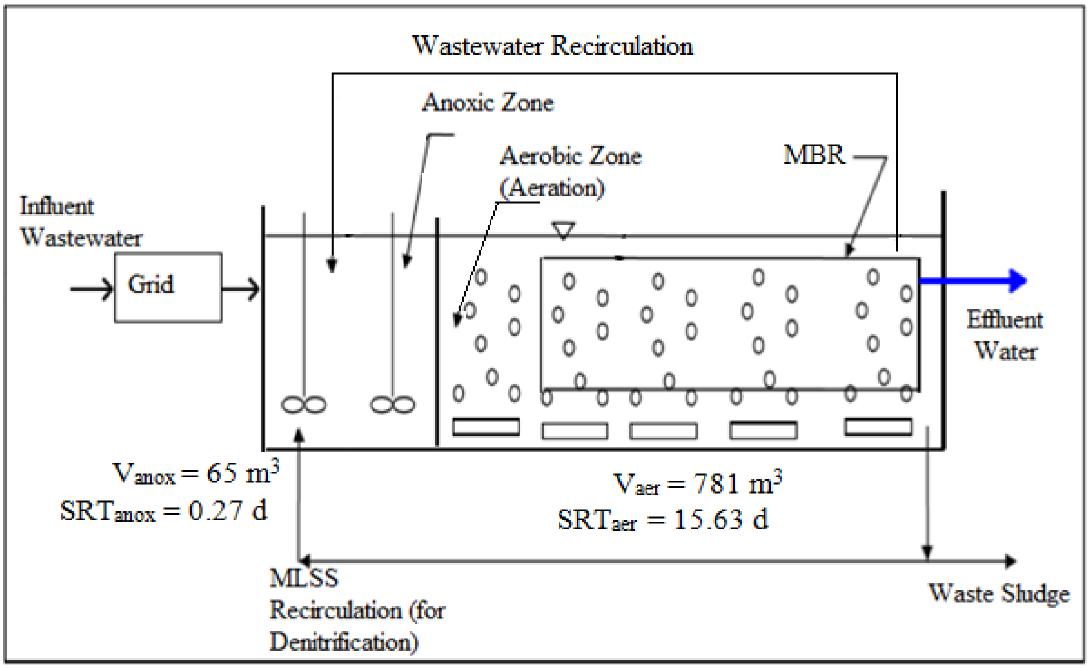
Coliform (cfu/mL)	20000	0	100%			
EC (dS/m)	2.1	0.80	61.90%	< 0.7	0.7-3	>3
Total Dissolved Solids (TDS) (mg/L)	500	15	97%	< 450	450–2,000	> 2,000
HCO_3 (mg/L)	12	0.77	93.58%	< 1.5	1.5–8.5	>8.5
RSC	3.5	0.07	98%	< 0	0–1	> 1
SSP	200	50	75%	< 60	60–80	> 80
ESP	120	5	95.83%	2–10	10–40	> 40
pH	8	7.8		6.5-8.4		
Penicillin (ng/L)	120	20	83.33%			

Table 8.3 The results of heavy metal concentration of hospital wastewater after AAMBR treatment (Regulation for Treated Wastewater to be used as Irrigation Water, 2010 and Guidelines for Interpretations of Irrigation Water Quality, 2010)

Elements	AAMBR Influent	AAMBR Effluent	Removal Efficiency (%)	Maximum Allowed Concentrations According to Regulation for Treated Wastewater to be used as Irrigation Water, 2010 and Guidelines for Interpretations of Irrigation Water Quality, 2010
				Limit Values for Irrigation (mg/L)
Al (mg/L)	2	0.3	85%	5.0
As (mg/L)	1	0.01	99%	0.1
Be (mg/L)	1.2	0.05	95.83%	0.1
B (mg/L)	2.3	0.22	90.43%	3
Cd (mg/L)	1.6	0.1	93.75%	0.01
Cr (mg/L)	2.2	0.07	96.82%	0.1
Co (mg/L)	2.4	0.04	98.33%	0.05
Cu (mg/L)	3	0.09	97%	0.2
F (mg/L)	3.6	0.8	77.78%	1.0
Fe (mg/L)	2.5	0.2	92%	5.0
Pb (mg/L)	2	0.05	97.5%	5.0
Li (mg/L)	1.8	0.1	94.44%	2.5
Mn (mg/L)	4	0.1	97.5%	0.2
Mo (mg/L)	1.3	0.005	99.61%	0.01
Ni (mg/L)	2.4	0.08	96.67%	0.2
Se (mg/L)	1.6	0.02	98.75%	0.02
V (mg/L)	0.9	0.03	96.67%	0.1
Zn (mg/L)	3.4	0.1	97.06%	2.0

In addition to these parameters, a schematic representation of the contact AAMBR design is presented in Figure 8.1.

Figure 8.1 Schematic overview of contact AAMBR design



In Table 8.4, some parameters effluent concentrations and SRT values are given.

Table 8.4 Effluent concentrations of COD, ammonia, nitrate, phosphate in anoxic and aerobic reactors

Effluent Parameters	Aerobic Reactor	Effluent Parameters	Anoxic Reactor
$(COD)_e$	9.52 mg/L	$(COD)_e$	1.34 mg/L
$(NH_4\text{-}N)_e$	1.03 mg/L	$(NH_4\text{-}N)_e$	-
$(NO_3\text{-}N)_e$	-	$(NO_3\text{-}N)_e$	0.57 mg/L
$(PO_4\text{-}P)_e$	0.8 mg/L	$(PO_4\text{-}P)_e$	19 mg/L

CHAPTER NINE
CONCLUSIONS

Waste management in hospitals is an issue that needs to be addressed carefully. A hospital in İzmir was selected to examine the current situation of waste management. Solid and liquid wastes and wastewaters from hospitals constitute the main waste sources. The administrative activities to be applied to these wastes have been examined within the scope of the "Zero Waste" Project, which is a current practice in these days. Each types of wastes originating from the hospital and the sources of these wastes were identified, and management steps of these wastes were examined and necessary suggestions were made. As a result of the examinations, regular training programs should be carried out, the wastes should be separated at their source, appropriate storage space for each waste type should be made. Furthermore, the wastes should be collected in special colored bags and the nonhazardous wastes such as domestic and packaging wastes should not to be mixed with hazardous wastes. Economic losses are prevented by decreasing the amount of hazardous and medical wastes. In the studied hospital since on-site disposal or recovery applications are not possible according to current Medical Waste Control Regulation. It was suggested that the hospital should be update the solid waste management process. In the hazardous liquid waste management, the hazardous liquid wastes were collected in special bins and these bins were labelled. Then they were sent to the licensed company for disposal via incineration procedure. İZSU recommended the treatment of wastewater before discharge to the municipal sewage system. In this study, a contact AAMBR system to treat the hospital wastewater was suggested. Therefore, a contact Anoxic/Aerobic Sequential Membran Bio Reactor (AAMBR) was designed to treat the studied hospital wastewaters. The volume of anoxic and aerobic reactors were calculated as 65 m^3 and 781 m^3, respectively while the SAD_m is designed as 0.29 $Nm^3/m^2.h$. SAD_p is calculated as 29 m^3 air/m^3 permeate while A_m is 2083 m^2. M_0 is 134.87 kg/d and M_m is 2.17 kg/d while $Q_{A,b}$ is 4739.28 Nm^3/h. MLSS in anoxic zone is 2000 mg/L while SRT is 0.27 d. The calculated effluent concentrations of COD, NH_3, NO_3 and PO_4 are 1.34 mg/L, 1.03 mg/L, 0.57 mg/L and 0.8 mg/L, respectively. Effluent water characteristics were examined according to Regulation for treated wastewater to be used as irrigation water (2010), and Guidelines for interpretations of irrigation water quality (2010) and the quality of the treated hospital water was considered suitable for use as irrigation water. It has been proposed to be used as garden irrigation water depending on the quality of the effluent water.

CHAPTER TEN
RECOMMENDATIONS

In this study, the wastes and the wastewaters of a hospital in İzmir was examined. The waste management and "zero waste" approach were examined through the examined hospital. This study is considered to be a resource for waste management activities to be implemented in hospitals. It is tried to give hints on how to manage solid, liquid wastes and wastewaters originating from hospitals with zero waste approach. It is thought to be beneficial for contact AAMBR design for domestic and industrial resources that want to treat and reuse wastewater. Because contact AAMBR treatment is provides high quaility purified water. Its use for industrial wastewater can also be a resource for industries as the AAMBR's low space requirement. It is thought that it can be a source where all the equations and design parameters to be used to design AAMBR can be found.

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APPENDICES

APPENDIX-1: Nomenclature

AAMBR	: Contact Anoxic/Aerobic sequential Membrane Bioreactor
Ag	: Silver
Al	: Aluminum
AOX	: Halogenated Organic Compounds Adsorbable on Activated Carbon
As	: Arsenic
B	: Boron
Be	: Beryllium
BOD	: Biological Oxygen Demand
BPA	: Bisphenol A
CAS	: Conventional Activated Sludge
Cd	: Cadmium
CH_4	: Methane
Cl	: Chlorine
ClO_2	: Chlorine Dioxide
Cl_2O	: Dichloro Monoxide
Co	: Cobalt
CO_2	: Carbon Dioxide
COD	: Chemical Oxygen Demand
Cr	: Chromium
Cr	: Total Chrome
Cu	: Copper
DDT	: Dichloro Diphenyl Trichloroethane
DEHP	: Di(2-ethylhexyl) phthalate
DES	: Diethylstilbestrol
DNA	: Deoxyribo Nucleic Acid
DO	: Dissolved Oxygen Concentration in Aerobic Tank
DOC	: Dissolved Organic Compounds
EC	: Electro Conductivity
EDCs	: Endocrine Disruptor Compounds

EDTA : Ethylenediaminetetraacetic Acid

F : Flourine

F.Cl : Free chlorine

Fe : Iron

$FeCl_3$: Iron (III) Chloride

H_2S : Hydrogen Sulphur

HCO_3 : Bicarbonate

Hg : Mercury

HRT : Hydraulic Retention Times

HWW : Hospital Wastewater

ICM : Iodinated Contrast Media

iTSS : Inert Total Suspended Solid

İZSU : İzmir Water and Sewage Administration

J : Design Flux

K_s : Saturation Coefficient

Li : Lithium

MBMIA : Mobile Battery Manufacturers and Importers Association

MBR : Membrane Bio Reactor

MF : Microfiltration

MLSS : Mixed Liquor Suspended Solids

MLVSS : Mixed Liquor Volatile Suspendend Solid

Mn : Manganese

Mo : Molybdenum

Na : Sodium

NaClO : Sodium Hypochlorite

$NaClO_3$: Sodium Chlorate

nbVSS : Non Biodegredable Volatile Suspended Solid

NH_3 : Ammonia

NH_4-N : Ammonium Nitrogen

Ni : Nickel

NO : Nanofiltration

NO_2-N : Nitrite Nitrogen

NO_3 : Nitrate

NO_3-N : Nitrate Nitrogen

O_3 : Ozone

ϕ : Temparature Correction Factor

PAC : Powdered Activated Carbon

Pb : Lead

pCBA : P-chlorobenzoic acid

PCBs : Polychlorinated Biphenyls

PhACs : Pharmaceutical Active Compounds

PO_4-P : Phosphate Phosphore

PPCPs : Pharmaceuticals Personal Care Products

Q : Design Flow Rate

RAS : Return Activated Sludge

RO : Reverse Osmosis

S : Sulfur

SDNR : Specific Denitrification Rate

Se : Selenium

Sn : Stannous

SO_4 : Sulfate

SQ : Q volumetric feed flow rate

SRT : Solids Retention Time

SS : Suspended Solids

TDS : Total Dissolved Solids

TKN : Total Kjeldahl Nitrogen

TN : Total Nitrogen

TOC : Total Organic Compounds

Tot. Cn : Total Cyanide

TP : Total Phosphate

TSS : Total Suspended Solids

TÜBİTAK : The Scientific and Technological Research Council of Turkey

UF : Ultrafiltration

UV : Ultra Violet

UWW : Urban Wastewater

V : Vanadium

VOC : Volatile Organic Compounds

WAS : Waste Activated Sludge

Y : Heterotrophic Conversion Coefficient

Zn : Zinc

α : Ratio of Oxygen Mass Transfer in Suspension to Mass Transfer in Pure Water

β : Ratio of Oxygen Mass Transfer in Salt Water to Mass Transfer in Pure Water

$(S_{NH})_e$: Effluent Ammonia Concentration

$(S_{NH})_i$: Influent Ammonia Concentration

$(S_{NO})_e$: Effluent Nitrate Concentration

$(S_{NO})_i$: Influent Nitrate Concentration

$(S_{PO})_e$: Effluent Phosphate Concentration

$(S_{PO})_i$: Influent Phosphate Concentration

μ_m : Maximum Specific Growth Rate

μ_n : Specific Growth Rate of Nitrifying Bacteria

μ_{nm} : Maximum Growth Rate of Nitrifying Bacteria

A_m : Total Membrane Surface Area

F/M_b : The Ratio of Food to Active Biomass in Anoxic Region,

f_d : Fraction of Biomass left over from Dead Cells

I_β : Constant Nıumber

K_0 : Half Saturation Constant for Oxygen

$k_{e,n}$: Coefficient of Death for Nitrifying Bacteria,

k_e : Mortality Coefficient

K_n : Half Saturation Coefficient for Nitrification

K_{NH} : Half Saturation Concentration of NH_4

K_{PO} : Half Saturation Concentration of $PO_4 - P$

M_0 : Oxygen Requirement for Biological Treatment

M_m : Oxygen Transferred by Membrane Aeration,

$M_{X,aut}$: Sludge Production for Nitrification

$M_{X,bio}$: Sludge Production for Carbonaceous Organic Degrading Organisms

$M_{X,TSS}$: Total Sludge Yield

$M_{x.Bio}$: Biomass Yield

N_e : Total Ammonia, Effluent Nitrogen or TKN Concentration

NO_e : Effluent Nitrate Concetration

NO_r : Denitrification Capacity

NO_x : TKN Concentration Oxidized to Nitrate Form

$O_{A,m}$: Mass Ratio of Oxygen in the Air

$\Theta_{x,aer}$: Aerobic SRT

$\Theta_{x,anox}$: Anoxic SRT

$\Theta_{x,process}$: SRT of Total Process

$\Theta_{x.aer}$: Aerobic Sludge Retention Time

$P_{x,bio}$: Biomass Concentration

$P_{x,TSS}$: Total Sludge Yield

$P_{x,VSS}$: VSS Concentration

$Q_{A,b}$: Net Air Flow Rate for Biological Requirements

Q_A : Membrane Aeration Rate

Q_W : Waste Sludge Rate

R_0 : Total Oxygen Required

r_{int} : Recirculation Rate

R_{SS} : VSS / MLSS Ratio in Biomass

S_0 : Influent COD Concentration

SAD_m : Specific Air Demand of Membran Area

SAD_p : Specific Air Demand of Permeate Volume

S_e : Effluent COD Concentration

$SOTE_{coarse}$: Coarse Bubble Aeration,

$SOTE_{fine}$: Fine Bubble Aeration

V_{aer} : Aeration Tank Volume

V_{anox} : Anoxic Tank Volume

$V_{m,min}$: Minimum Membran Tank Volume

$V_{process}$: Total Process Volume

X_{aer} : MLSS Concentration in Aerobic Zone

X_{anox} : MLSS Concentration in Anoxic Zone

$X_{b,anox}$: Active Biomass in Anoxic Zone

X_b : Active Biomass in Anoxic Zone

y_{coarse} : Coarse Bubble Aerator Depth

y_{fine} : Fine Bubble Aerator Depth

Y_n : Nitrification Sludge Yield

δ_{SA} : Safety Factor

ρ_A : Air Density

φ_{tank} : Density of Membrane Packing: Area per Membrane Tank

μ : Daily Growth Rate