İSTANBUL TECHNICAL UNIVERSITY ★ GRADUATE SCHOOL OF SCIENCE ENGINEERING AND TECHNOLOGY

EVALUATION OF WASTEWATER TREATMENT TECHNOLOGIES USING RENEWABLE ENERGY FOR DISPERSED SETTLEMENTS: STORM VALLEY ARDEŞEN – ÇAMLIHEMŞİN PILOT REGION APPLICATION

M.Sc. THESIS

Orçun LEBLEBİCİ

Department of Environmental Engineering

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Thesis Advisor: Prof. Dr. Orhan İNCE

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ FEN BİLİMLERİ ENSTİTÜSÜ

DAĞINIK YERLEŞİMLER İÇİN YENİLENEBİLİR ENERJİ KULLANAN ATIKSU ARITMA TEKNOLOJİLERİNİN DEĞERLENDİRİLMESİ: FIRTINA VADİSİ ARDEŞEN – ÇAMLIHEMŞİN PİLOT BÖLGE UYGULAMASI

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HAZİRAN 2017

Orçun Leblebici, a M.Sc. student of İTU Graduate School of Science Engineering and Technology student ID 501071815, successfully defended the thesis entitled "EVALUATION OF WASTEWATER TREATMENT TECHNOLOGIES USING RENEWABLE ENERGY FOR DISPERSED SETTLEMENTS: STORM VALLEY ARDEŞEN-ÇAMLIHEMŞİN PILOT REGION APPLICATION", which he prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

Thesis Advisor : **Prof. Dr. Orhan İNCE** ....
İstanbul Technical University

Jury Members : **Prof. Dr. Erdem GÖRGÜN** ....
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Assoc. Prof. Dr. Gülsüm YILMAZ ....
İstanbul University

Date of Submission : 03 May 2017
Date of Defense : 22 June 2017

To my spouse and family,

FOREWORD

I would first like to thank my thesis advisor Prof. Dr. Orhan İNCE. After we met in Energy Institute of Istanbul Technical University, in 2008, I was going round in circles about my postgraduate future. Thanks to Prof. İNCE I had a chance to create an alternative pathway to combine my achievements from undergraduate education and my professional carrier in the renewable energy field.
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TABLE OF CONTENTS

Page

ABBREVIATIONS

TÜİK : Türkiye İstatistik Kurumu
TÜRKAK : Türk Akreditasyon Kurumu
BOD : Biological Oxygen Demand
sBOD : Soluble Biological Oxygen Demand
BOD_5 : Biological Oxygen Demand within 5 days
COD : Chemical Oxygen Demand
TOC : Total Organic Carbon
DEHP : Bis (2-ethylhexyl) phthalate
DOP : Di-octyl phthalate
NPE : Nonylphenol
PAH : Polyaromatic Hydrocarbons
VOC : Volatile Organic Compounds
SS : Suspended Solids
TPC : Technical Procedure Announcement for WWTP
SBR : Sequencing Batch Reactor
MBR : Membrane Bioreactors
RBC : Rotating Biological Contactors
HRT : Hydraulic Retention Time
AS : Activated Sludge
PVC : Polyvinyl chloride
HDPE : High-density polyethylene
BNR : Biological Nitrogen Removal
TDS : Total Dissolved Solids
PV : Photovoltaic
MTA : Maden Teknik Arama Enstitüsü
EIE : Elektrik İşleri Etüd İdaresi
ISES : International Solar Energy Society
TEP : Tons of Oil Equivalent
DC : Direct Current
AC : Alternative Current
a-Si : Amorphous Silicon
µc-Si : Micromorph Silicon
Cd-Te : Cadmium Telluride
CIS : Copper Indium Selenide
CIGS : Copper Indium Gallium Selenide
GWp : Gigawatt Peak
kWp : Kilowatt Peak
TEMSAN : Türkiye Elektromekanik Sanayii A.Ş.
WWF : World Wildlife Fund
WWTP : Wastewater treatment plant
GDP : Gross Domestic Product
OECD : Organization of Economic Cooperation and Development

SYMBOLS

S_n	: Effluent BOD_5 Concentration
A_s	: Total Surface Area of Biodiscs
Q	: Flow Rate
qBOD	: BOD_5 load
q_N	: Unit Nitrogen Load
L_{BOD}	: BOD_5 Load
L_N	: Nitrogen Load
PF	: Peak Factor
P_e	: Power derived from turbine
ρ	: Water density
g	: Gravitational Acceleration
H_o	: Net head height
η_g	: Total efficiency
ns	: Specific speed of turbine
HP	: Horse Power
E	: Kinetic Energy
m	: Mass
V	: Velocity
V_h	: Volume of air
S	: Swept area
t	: Unit time

LIST OF TABLES

Page

LIST OF FIGURES

Page

EVALUATION OF WASTEWATER TREATMENT TECHNOLOGIES USING RENEWABLE ENERGY FOR DISPERSED SETTLEMENTS: STORM VALLEY ARDEŞEN – ÇAMLIHEMŞİN PILOT REGION APPLICATION

SUMMARY

Under the scope of this thesis wastewater treatment alternatives for dispersed settlements are examined considering the environmental, climatic, economical and location specific aspects of selected locations of Storm Valley which is located at the Eastern Black Sea Region.

Black Sea Region is one of the seven geographic region of Turkey, which has taken its name of the Black Sea, covers the 18% of Turkey. Black Sea Region is one of the richest geographical area of the Turkey with its large amount of rivers and streams, which are flow in to the black sea. In the coastal line, rainy and mild climate conditions are dominant, thanks to moist air coming from the black sea. Black Sea Region gets the highest precipitation rate of Turkey and rainy days are spread throughout the year, not only limited within a season. Besides that, this rainy climate prevents forest fires and protects the regional flora and fauna.

Especially in the Black Sea Region of Turkey, significant numbers of dispersed settlements are located and remarkable numbers of them are located in the environmentally sensitive areas. Most of these areas are protected by governmental and local authorities in order to maintain sustainable life cycle to the endemic species living in these areas. In order to protect the endemic species and natural habitat of Storm Valley from domestic wastewater originated from dispersed settlements of Ardeşen and Çamlıhemşin districts, different wastewater treatment technologies are examined. Beside that in order to minimize electricity consumption from grid, to a certain extent designing of energy independent treatment systems, renewable energy potential of region is inspected and according to the results of the evaluations utilization of renewable energy sources such as hydroelectricity, solar and wind energy generation systems are studied.

For the treatment of domestic wastewater, it can be stated that there are large number of common wastewater treatment technologies, which are nationally and internationally proved, based on characteristics of domestic wastewater, which varies dramatically according to daily habits of residents. In general, 99% of domestic wastewater comprises of just water and only rest of 1% creates pollution. Pollutants can be both in the soluble form and suspended solid form. Treatment methods are also show an alteration in order to remove these pollutants according to their characteristics. While the selection of the most suitable treatment technology these parameters must be evaluated such as receiving environment and discharge limits, amount of wastewater and its characteristics and available land for wastewater treatment plant, considering Notice of Selection Methods of Wastewater Treatment Plants which entering in force by official gazette 27527. Based on that regulation,

treatment plants must be designed according to wastewater amount and population. Regulation states that in the regions, where the sewer collection system is established and population is less than 84 habitants, on-site treatment units must be maintain. Similarly, independently from the population, regulation states that if a central sewer system is not established, than on-site treatment units must be maintain. Under this study, target community population is selected between 100 to 1000 people, and alternative treatment technologies, which will be served to those communities, were evaluated.

Planning, design and operation of wastewater treatment plants are very comprehensive procedure and requires specialty. In parallel with that, it needs political, social and technical considerations also. Sustainability of wastewater treatment systems can be evaluate through different assessment tools such exergy analysis, economic analysis, and life cycle assessment. For that reason, besides meeting the requirements of discharge standards, a well-designed treatment plant will prevent many environmental problems such as odor and noise pollution, water pollution via physical, chemical and biological contaminants, aquatic ecosystem damage, quality degradation of receiving water sources, spread of diseases through utilization of untreated wastewaters for agricultural purposes, decrease in value of land costs.

Wastewater treatment is usually classified as preliminary, primary, secondary and tertiary. Main purpose of preliminary treatment is to eliminate coarse solids from influent wastewater via screening, mixing, flocculation, sedimentation, flotation, and filtration. Primary treatment targets suspended solids and organic matter removal, which are separated as sludge. The major purpose of secondary treatment is elimination of dissolved organic matter via oxidation by microorganisms, nitrogen and phosphorus. Aim of the tertiary treatment is elimination of remaining compounds such as COD, BOD, SS, bacteria, and toxic matters, which are not biologically degradable. Generally, chemical oxygen demand value of a wastewater typically characterizes the biodegradable and non-biodegradable organic constituents.

While the selection of the most appropriate wastewater treatment technology, energy independency and sustainability aspects are also considered. For that reason, renewable energy generation systems and regional hydraulic, solar and wind potentials are also studied in this thesis.

Precipitation index of Turkey is quite irregular and unbalanced in terms of time and location, and it depends on meteorological conditions, which varies significantly through years. Resulting from that it is inevitable to have significant variations in the hydroelectric generation potential. According to the observed meteorological data of many years reflects that annual precipitation average is around 643 mm in Turkey and that equals to 501 m^3 water in total. Turkey utilizes only 48.5 billion kWh of its technical and economic hydroelectricity potential, which means 39% of its technical and economical hydraulic potential.

Wind energy potential of Turkey is indicated that total installed wind power capacity of Turkey reached up to 5.146 MW by the end of 2016, and 1.868 MW new capacity will be added from continued wind power plants.

Turkey has a geographical advantage for the solar energy compared with the other countries. Turkey’s average sunshine duration is calculated as 2640 h (7.2 h per day) and average global solar irradiation level is 1311 kWh/m^2-a according to the studies made by EIE. Besides that according to the studies and measurements were performed locally proved that Turkey’s real solar potential higher than the calculated data above.

Based on the collected measurement data since 1992 it was assumed that on site solar potential of Turkey will be almost 25% higher than the calculated one.

In order to find the most feasible treatment technology and electricity generation technology, Çamlıhemşin and Ardeşen districts of Rize province were visited and total amount and characteristics of wastewaters generated and discharged to Storm Valley unrestrainedly was observed pursuant to examinations and analysis. In order to determine the total amount and characteristics of domestic wastewaters of regarding dispersed settlements, wastewater samples were taken during the site studies. The samples were analyzed by TÜRKAK. Population data was obtained from the district governorship and during the site studies, these population data were crosschecked with the habitants for the purpose of determination of domestic wastewater amount from these dispersed settlements.

During the selection of the most appropriate treatment technology for the dispersed settlements of regarding region, ten important parameters are taken into consideration for the evaluation of multi criteria analysis of treatment plant technology alternatives for wastewater management of dispersed settlements of Çamlıhemşin and Ardeşen region, which are meeting discharge standards, flexibility for flow rate and load deviations, sensitivity to climate, land requirement, upgradable/modularity, investment costs, staff requirement, maintenance costs, energy requirement and noise level. As a result, after the evaluation of alternatives, rotating biological contactors are come to the forefront as the most convenient treatment technology for regarding project region in terms of modularity, staff requirement, maintenance costs, energy demand and noise.

In order to maintain sustainable wastewater management, where dispersed settlements of Çamlıhemşin and Ardeşen districts of Eastern Black Sea Region, seven major criteria, which are renewable energy potential of region, continuous electricity generation, land requirement, extendibility or modularity, investment cost, maintenance cost and noise level, were considered very carefully for the establishment of planned RBC wastewater treatment unit and electricity generation system to feed the required energy of regarding treatment units. As a result, according to the comparison table, solar energy is the most applicable technology in order to meet the electricity requirement of wastewater treatment system, considering the regarding parameters.

Within the scope of this thesis, it is planned to establish a solar energy power unit in order to meet the continuous electricity requirement of pilot scaled rotating biological contactor. Detailed cost and equipment analysis have been done in order to determine the most feasible renewable energy sources in consideration of energy potential of the region.

Thanks to that planned project, a series of innovations will be gained to region such as biological contactor type wastewater treatment plant will be erected in Eastern Black Sea Region, Turkey’s first solar powered wastewater treatment plant will be established, planned treatment plant will be the first one which is operated with sustainable wastewater management concept, it will be the first environmental project that contributes sustainable tea agriculture and it will be the first project that contributes protection of biodiversity of Storm Valley.

DAĞINIK YERLEŞİMLER İÇİN YENİLENEBİLİR ENERJİ KULLANAN ATIKSU ARITMA TEKNOLOJİLERİNİN DEĞERLENDIRILMESİ: FIRTINA VADİSİ ARDEŞEN-ÇAMLIHEMŞİN PİLOT BÖLGE UYGULAMASI

ÖZET

Bu yüksek lisans tezi çalışması ile Doğu Karadeniz Bölgesi'nin Rize ili Fırtına deresi çevresindeki dağınık yerleşim yerlerinde üretilen evsel atıksuların arıtılarak alıcı ortama deşarjı için çeşitli arıtma tesisi alternatifleri değerlendirilmiş olup seçilen aplikasyon bölgesinin çevresel, iklimsel, ekonomik ve yerel özellikleri de göz önünde bulundurularak en uygun arıtma sistemi belirlenmeye çalışılmıştır. Bununla birlikte arıtma tesisinin çalışması için gerekli enerjinin karşılanması için seçilen bölgeye ve spesifik konuma uygun olarak çevreyle uyum içinde faaliyet gösterebilecek yenilenebilir enerji üretim sistemi de tasarlanmıştır.

Uygulama alanı olarak belirlenen Karadeniz Bölgesi, Türkiye'nin yedi coğrafik alanından birisi olup yüzey alanı itibariyle Türkiye'nin üçüncü büyük coğrafik bölgesidir ve toplam yüzey alanının %18'ini kapsamaktadır. Bölgenin toplam nüfusu 2010 sayımına göre 8.439.213 dir. Bölgenin çevresel ve coğrafik özelliklerinden ötürü kırsal kesimde yaşayan nüfus merkezde yaşayanlardan önemli ölçüde fazladır. Bu durum Karadeniz Bölgesi'ni nüfus dağılımı açısından Türkiye'de eşsiz bir konuma yerleştirmektedir. Bölgenin iklimsel özellikleri incelendiğinde yağışlı havanın yıl boyunca baskın iklim koşulu olduğu gözlenmektedir. Söz konusu iklim koşulları Türkiye'nin ormanlarının %25'ini oluşturan Karadeniz doğal ormanlarını beslediği gibi kurak havadan kaynaklanan yangınların oluşmasını engellemekte ve bu şekilde bölgenin eşsiz flora faunasını korumaktadır. Özellikle Fırtına deresi etrafındaki Ardeşen ve Çamlıhemşin bölgesinde 145 adet ender görülen ve 24 adet endemik tür yaşamaktadır. Bölgede 1430 farklı flora gözlemlenmiş olup endemiklik oranı %17'dir. Bununla birlikte tüm dünyada koruma altında olan doğal yaşlı ormanlar Çamlıhemşin'in yüksek yerlerinde, Ayder yaylasında, Fırtına ve Elevit derelerinin her iki yamacında oldukça yaygındır. Rize'nin Ardeşen ve Çamlıhemşin bölgelerinin eşsiz forası ve jeomorfolojik özellikleri sebebiyle yapılan detaylı araştırma ve çalışmalar göstermiştir ki bölge kaydadeğer sayıda vahşi yaşamı barındırmaktadır.

Karadeniz Bölgesi'nde yerleşim tipi genel olarak ikiye ayrılmaktadır. Her ne kadar sosyoekonomik gelişmişlik önemli bir kriter olsa da nüfus açısından değerlendirildiğinde, nüfusu bin kişinden az olan kırsal yerleşim ve bin kişiden fazla olan kentsel yerleşim şekilleridir. Kentsel yerleşimler arazi büyüklüğü, ekonomik yapı, kültürel özellikler ve yönetim birimleri açısından farklanmakta olup kentsel yerleşim tipinin en büyük birimi şehir yapılanmasıdır. Kırsal yerleşkeler ise köy ve mezralardan oluşmaktadır. Gündelik hayat çiftçilik ve hayvancılık faaliyetleri üzerine kuruludur. Kırsal yerleşkelerin en karakteristik özelliği ise düşük nüfus miktarı ve yoğunluğu, çiftçilik ve hayvancılığa dayalı ekonomidir. Köylerde yapılaşma blok tipi ve dağınık yerleşim yeri şeklinde gözlenmektedir. Blok tipi yerleşim şekli dar

sokakları ve bitişik binaları ile nüfus yoğunluğu yüksek bir yapılaşma şeklidir. Bu kırsal yerleşke tipinde tarlalar genel yaşam alanına uzakta konumlanmıştır. Bu tip yerleşim şekli genellikle Orta ve Güneydoğu Anadolu'da yaygındır. Diğer taraftan dağınık yerleşim yerlerinde evler birbirlerinden genellikle 50 ile 100 metre mesafeler ile konumlanmış olup yerleşim yeri geniş bir alana yayılmıştır. Bu tip yerleşim şekli genellikle Karadeniz Bölgesi'nde sıklıkla görülmekte olup en büyük dezavantajları ulaşım güçlükleri, güvenlik sorunları ve kamusal harcamalardaki yüksek maliyetlerin yanı sıra elektrik, içme suyu ve atıksu altyapı hizmetlerine erişimde güçlüklerdir. Bu sebeple dağınık yerleşim yerlerinde hala elektrik jeneratörler vasıtasıyla üretilmekte olup kullanımları yüksek yakıt maliyetinden ötürü oldukça sınırlıdır. Yüksek noktalara içme suyu tedariğinde de pompa arızası ve elektrik hatlarında oluşan sorunlar sebebiyle güçlükler yaşanmaktadır. Altyapı sorunlarında yaşan diğer başlıca sorun da coğrafik sebeplerden ötürü merkezi bir kanalizasyon sisteminin tesis edilemeyişi sebebiyle konutlarda oluşan atıksuyun kontrolsüz şekilde nehir, göl gibi alıcı ortamlara deşarj edilmesi sonucu zamanla su ve toprak kirliliklerinden kaynaklı doğal ekosistemin zarar görmesi ve hastalıkların yayılmasıdır.

Günümüzde atıksu arıtma teknolojileri oldukça ilerlemiş olup farklı kirlilik problemleri için ulusal ve uluslararası kabul görmüş çok sayıda arıtma sistemi çözümü bulunmaktadır. Türkiye'de 20.03.2010 tarihli 27527 sayılı Resmi Gazete ile yürürlüğe giren Atıksu Artıma Tesisileri Teknik Usuller Tebliği ile arıtma tesisi teknolojisi seçiminde alıcı ortam tipi, deşarj limitleri, atıksu miktarı ve özellikleri, arıtma tesisi için uygun arazinin mevcudiyeti gibi parametreler tanımlanmıştır. Atıksu arıtma tesisi planlama, tasarım ve işletmesi oldukça kapsamlı ve karmaşık bir süreç olup uzmanlık gerekmektedir. Bir arıtma tesisi tasarımının sürdürülebilirliği onun ekserji analizi, ekonomik analizi ve sistemin teknik ömrünün değerlendirmesinin etkinliği ile ölçülüdür. Bu sebeple deşarj standartlarının karşılanmasının yanısıra iyi tasarlanmış bir atıksu arıtma tesisi koku ve gürültü kirliliği, fiziksel, kimyasal ve biyolojik kontaminantlar sonucu su kaynaklarında oluşan kirlilik, akuatik ekosistemin bozulması, alıcı ortamdaki su kaynaklarının kalitesinin düşmesi ve atıksuların arıtılmadan tarlalarda sulama suyu maksatlı kullanımı sonucu hastalıkların yayılması gibi risklerin de önemli ölçüde önüne geçebilecektir. Özellike proje alanı olarak belirlenen Ardeşen ve Çamlıhemşin bölgelerinde yukarıda bahsedilen çevresel sorunların tamamı dağınık yerleşim yerlerinde üretilen evsel atıksuların uzun yıllardır kontrolsüz şekilde Fırtına deresine ve onu besleyen yan kollarına bırakılması sonucu akuatik çevre üzerinde gözardı edilemez bir sorun olarak su üzerine çıkmıştır. Tanımlanan bu çevresel sorunların bertarafı ya da yönetilebilir şekilde kontrol altına alınabilmesi için gerekli kanalizasyon altyapıları ve atıksu arıtma sistemleri devreye alınmalıdır.

Atıksu arıtma işlemi genel olarak ön arıtma, primer arıtma, sekonder arıtma ve tersiyer arıtma olarak sınıflandırılabilir. Ön arıtmanın amacı büyük katı materyallerin atıksudan alınarak arıtma sisteminde tıkanıklıklara ve fiziksel hasara sebep olmasının engellenmesidir. Primer arıtmada ise temel hedef askıdaki katıların ve organik maddenin arıtma çamuru olarak atıksudan ayrılmasıdır. Sekonder arıtmadaki amaç ise çözünmüş organik maddenin mikroorganizmalar ile oksidasyonu sonucu bertarafı ve azot, fosfor giderimidir. Tersiyer arıtmadaki amaç ise bakterilerin ve biyokimyasal olarak bertarafı mümkün olmayan toksik maddelerin giderimidir. Atıksu arıtma tesisleri genel olarak spesifik birimler ve onların birbirleri ile entegrasyonu sonucu oluşan bütün sistemlerdir. Genel olarak dört temel atıksu arıtma metodu vardır, bunlar fiziksel arıtma, kimyasal arıtma, biyolojik arıtma ve ileri arıtma metodlarıdır. Fiziksel arıtma genel olarak atıksudaki kirlilik bileşenlerinin eleme, karıştırma, çöktürme, sedimentasyon, yüzdürme ve filtrasyon gibi fiziksel yöntemler ile tutulması ve atıksudan ayrıştırılmasıdır. Kimyasal arıtma ise kirlilik bileşenlerinin nötralizasyon, koagulasyon, flokulasyon, yağmurlama, adsorpsiyon ve dezenfeksiyon gibi kimyasal reaksiyonlar ile bertarafıdır. Biyolojik arıtma ise atıksudaki kirlilik bileşenlerinin mikroorganizmalar ve nitrifikasyon, denitrifikasyon, organik madde giderimi gibi biyokimyasal aktivite ile bertarafı işlemidir.

Çamlıhemşin ve Ardeşen bölgesindeki dağınık yerleşim yerlerinden üretilen evsel nitelikli atıksuların arıtması için aerobik ve anaerobik biyolojik arıtma sistemleri detaylı şekilde incelenmiştir. Sürdürülebilir ve kendi kendine yetebilir bir paket arıtma tesisi için gerekli olan en önemli parametrelerden biri olan elektriğin yine bölgenin kendi potansiyeli ile karşılanması ve bu sırada enerji üretim sisteminin de doğal ortam ile uyumlu çalışması amaçlanmıştır. Bu doğrultuda global ve yerel yenilenebilir enerji potansiyeli incelenip hidrolik, rüzgar ve güneş enerjisi üretim teknolojileri ile bu sistemlerden teorik olarak üretilebilecek elektriğin hesaplamaları değerlendirilmiştir. Yenilenebilir enerji üretim sisteminin seçimi ve bu sistemden üretilebilecek enerjinin miktarının hesaplanmasının yanısıra, sistemin ilk kurulum birim maliyetleri ve işletme birim maliyetleri de detaylı olarak incelenmiştir.

Atıksu arıtma tesisinin kapasitesinin belirlenmesi için tesisin kurulması planlanan Ardeşen ve Çamlıhemşin bölgesindeki dağınık yerleşim yerlerinde yapılan saha tespitleri neticesinde bölgenin nüfusu ve yıl içerisindeki nüfus hareketleri için yerel yönetimden ve halktan bilgi alınmıştır. Ardeşen ilçesi Aşağıdurak köyünden ve Çamlıhemşin ilçesi Çayırdüzü köyünden atıksu numuneleri alınmıştır. Ölçüm ve analiz laboratuarında yaptırılan analizler neticesinde Çayırdüzü ve Aşağıdurak köylerinin atıksularındaki organik kirlilik yükleri ortaya çıkarılmıştır. Buradan yola çıkarak Çamlıhemşin'in merkezinden ve dağınık yerleşimlerinden kaynaklanan kirlilik miktarları hesaplanmıştır. Buna göre bölgeden yılda yaklaşık 453.000 m^3 atıksu herhangi bir arıtma işlemi uygulanmadan doğrudan Fırtına deresi ve onu besleyen yan kollarına deşarj edilmekte olduğu hesaplanmıştır. Aynı şekilde Ardeşen ilçesi ve dağınık yerleşim yerlerinden üretilen yıllık yaklaşık 2.940.000 m^3 atıksu herhangi bir arıtma işlemine tabi tutulmadan direk olarak alıcı ortama deşarj edildiği hesaplanmıştır. Yapılan analizlerde atıksu içindeki mikrobiyal kirlilik de ölçülmüş olup Çamlıhemşin ve Ardeşen ilçelerinin dağınık yerleşimlerinden kaynaklanan toplam E.coli de hesaplanmıştır.

Arıtma işlemine tabi tutulmayan atıksular tarafından kontamine edilmiş su kaynakları bölgede yaşayan yerel halk tarafından tarımsal sulama ve günlük tüketim amaçlı kullanıldığı tespit edilmiştir. Kontamine olmuş su kaynaklarının bu şekilde kullanılması yerel halk arasında tifo, kolera ve hepatit gibi salgın hastalıkların artması riskini de beraberinde getireceğinden bölgede acil olarak evsel nitelikli atıksuların toplanması için kanalizasyon altyapısı ve yeterli kapasitelerde paket arıtma tesislerine ihtiyaç olduğu tespit edilmiştir. En uygun arıtma teknolojisinin belirlenmesi için aktif çamur, ardışık kesikli reaktör, membran biyoreaktörü, havalandırma havuzu, döner biyodisk ve yapay sulak alanlar alıcı ortamın deşarj standartlarını karşılaması, debi ve kirlilik yüklerindeki değişimlere karşı esneklik, iklim koşullarına duyarlılık, arazi gereksinimi, geliştirilebilirlik ve modülerlik, yatırım maliyeti, işletme personeli gereksinimi, bakım maliyeti, enerji tüketimi ve gürültü gibi parametreler ile karşılaştırılarak skor tablosu hazırlanmıştır. Yapılan değerlendirme sonucu döner biyodiskler Ardeşen ve Çamlıhemşin dağınık yerleşimlerinin atıksularının arıtılması için en uygun arıtma tekniği olarak öne çıkmış ve 200, 400 ve 800 kişi kapasiteli döner biyodisk üniteleri için tasarım, ilk yatırım ve işletme maliyeti çalışmaları yapılmıştır.

Döner biyodisk arıtma sisteminin tüketeceği elektriğin bölgenin kendi potansiyeli ile yenilenebilir enerji kaynaklarından karşılanması için yapılan saha ziyaretlerinde Dikkaya, Aşağıdurak ve Murat köylerindeki akarsulardan TEMSAN saha mühendisleri tarafından debi ölçümleri gerçekleştirilmiştir. Yine bölgenin güneş enerjisi potansiyelini belirlemek amacıyla mobil cihazlar ile direkt solar radyasyonu ölçümleri yapılmıştır. Bölgenin rüzgar potansiyelini belirleyebilmek adına T.C. Enerji ve Tabii Kaynaklar Bakanlığı'na bağlı Elektrik İşleri Etüd İdaresi tarafından hazırlanan Türkiye Rüzgar Enerjisi Potansiyeli haritasından faydalanarak anlık ve yıllık elektrik üretim potansiyeli hesaplanmıştır. Güneş, rüzgar ve hidroelektrik üretim sistemlerinden hangisinin, kurulacak olan döner biyodisk sisteminin ihtiyaç duyduğu elektrik enerjisini en etkin şekilde karşılayabileceğinin belirlenmesi amacıyla söz konusu üç yenilenebilir enerji üretim teknolojisi için skor tablosu hazırlanmıştır. Buna göre her üç üretim tekniği bölgenin enerji potansiyeli, stabil ve istenen kalitede enerji üretebilirliği, arazi gereksinimi, ihtiyaç halinde kapasite arttırım imkanı ve modülerlik, yatırım maliyeti, bakım maliyeti ve gürültü seviyeleri açısından karşılaştırılmış ve neticede güneş enerjisi üretim sistemi en yüksek skorla arıtma tesisinin iç elektrik ihtiyacını karşılayacak yenilenebilir enerji üretim tekniği olarak belirlenmiştir. 200, 400 ve 800 kişilik kapasitelere sahip döner biyodisk ünitelerinin iç enerji ihtiyacını karşılamak için kurulması gereken güneş, rüzgar ve hidroelektrik sistemlerinin ilk yatırım ve işletme maliyetleri hesaplanmıştır. Değerlendirme sonucu her ne kadar hidroelektrik tesisi en düşük yatırım maliyetine sahip olsa da bölgenin kırılgan ekolojisi göz önünde bulundurularak ikinci sıradaki güneş enerjisi üretim sisteminin kullanımı ön plana çıkmıştır.

Sonuç olarak Rize ili Çamlıhemşin ve Ardeşen ilçelerinin dağınık yerleşim yerlerinden kaynaklanan evsel atıksuların kontrolsüz şekilde Fırtına deresi ve su kaynaklarına deşarj edilmesi sonucu alıcı ortamdaki kirlilik miktarının tehlikeli seviyelere ulaştığı gözlenmiştir. Ve yine söz konusu su kaynaklarının tarımsal sulama ile kullanım suyu amaçlı tüketimi sonucu doğal ortamın zarar görmesini ve insan sağlığının riske girmesini önlemek amacıyla bölgeye atıksu arıtma tesislerinin kazandırılması zorunludur. Bu sebeple çeşitli atıksu arıtma sistemleri pek çok parametre göz önünde bulundurularak karşılaştırılmış ve döner biyodisklerin kullanımı öne çıkmıştır. Yapılan çıkış suyu kirlilik değerlerinin analizine göre biyolojik (BOİ) ve kimyasal oksijen ihtiyacı (KOİ), askıda katı madde (SS) ve pH seviyeleri regülasyonda tanımlanan yasal seviyenin altında kaldığı görülmüş ve sistemin planlandığı şekilde çalıştığı tespit edilmiştir. Ayrıca arıtma sisteminin ihtiyaç duyduğu iç enerjinin bölgenin kendi potansiyeli ve doğal ortamla dengeli şekilde karşılanması için 10 kW'a kadar kurulu güce sahip güneş enerjisi üretim sistemi tesis edilmesinin enerji probleminin çözümünde en etkili yöntem olacağı sonucuna varılmıştır.

1. INTRODUCTION

Based on the definitions of United States Environmental Protection Agency, a small community or a dispersed settlement refers to a countryside community, which has less than 3500 people (USEPA, 1992). Wastewater treatment alternatives for dispersed settlements, in generally, are natural treatment systems, conventional treatment systems and wastewater collecting systems, such as septic tanks. The main drawback of conventional treatment systems, for instance activated sludge or anaerobic treatment systems or trickling filter systems, are excessive electricity consumption, sludge disposal problem and complex maintenance requirements (Liehr et al., 2004).

Especially for the dispersed settlements, these disadvantages became more crucial because of the geographical and technical difficulties during collection of wastewater and pumping it from one location to another, maintenance service team supply or meeting the continuous electricity requirement with required quality. Considering these major difficulties a pilot scale treatment plant must be feasible, technically applicable, site-specific, and practical in terms of maintenance requirements.

Wastewater treatment solutions in dispersed settlements of targeted area of Black Sea Region of Turkey have been studied in order to minimize the negative effects of wastewaters on ecological balance, especially on the endemic species living in the region. Along with that, in order to meet required electricity of selected treatment system from renewable sources of the region hydroelectricity, solar and wind electricity generation systems are compared and evaluated in detail.

1.1 Black Sea Region

Black Sea Region is one of the seven geographic region of Turkey, which has taken its name of the Black Sea, covers the 18% of Turkey. Borders of the region reach out from Sakarya lowland to Georgia border. Based on the land area, Black Sea Region is in the rank number three among the other geographical regions of Turkey, besides that this region has the biggest time difference because of its wide east-west distance.

Samsun is the largest and the most populated city of the region with its 1.295.927 residents in total, based on TUİK statistics, in 2016 (Url-1). Besides that, Ordu and Trabzon are the other largest provinces of the region with one and a half million people. The total population of the region is 8.439.213 based on the 2010 population census (Black Sea Region, n.d.). Because of the environmental and geographical conditions of the settlements of Black Sea Region, population of rural areas is significantly more than urban areas, and that population distribution makes the Black Sea Region as a unique one among the other geographical regions of Turkey.

According to geographical, climatic and socio-cultural structure, Black Sea Region is divided in to three major region, which are western black sea, central black sea and Eastern Black Sea Region.

1.1.1 Geography

Black Sea Region is one of the richest geographical area of the Turkey with its large amount of rivers and streams, which are flow in to the black sea. Kızılırmak river, which is the longest one of Turkey, flow in to the black sea from the central Black Sea Region. Besides that, Çoruh River has one of the world's fastest flow rate and largest river of Artvin province that is located in the Eastern Black Sea Region. There are also large amount of rivers that are passing through North Anatolian Mountains or Pontic Mountains, and disembogue into the black sea (Pontic Mountains, n.d.).

Because of the mountain lines, which are standing in parallel with the coastal, logistics and access in to the inner parts of the Black Sea Region is quite difficult. Because of these natural boundaries, traditions and social live is isolated from the rest of the Anatolia, throughout the years.

1.1.2 Climate

In the coastal line, rainy and mild climate conditions are dominant, thanks to moist air coming from the black sea. Black Sea Region gets the highest precipitation rate of Turkey and rainy days are spread throughout the year, not only limited within a season. Besides that, this rainy climate prevents forest fires and protects the regional flora and fauna. Because of the high moist and large amount of cloudy days, Black Sea Region has the lowest temperature difference within a day and year. On the other hand, North Anatolia Mountains are run in parallel along the coastline and that mountainous geographical structure prevents penetration of soft climate to the inner parts of region, which results with a continental climate through the inner part of black sea. At the same time, due to the low elevation rates at the central part of Black Sea Region and existence of Kızılırmak and Yeşilırmak Valleys, it makes the coastal climate to penetrate the inner parts, which causes relatively soft climate conditions throughout the year.

Natural flora of the black sea region is dense forests with broad-leaved trees, thanks to rainy and humid climate conditions. This region holds almost 25% of Turkey's forests (Karadeniz Bölgesi, n.d.).

1.1.3 Endemic species of Black Sea Region

Especially in the Black Sea Region of Turkey, significant number of dispersed settlements are located and remarkable number of them are located in the environmentally sensitive areas, for instance in Storm Valley, which is one of the most important ecological area in terms of its flora and fauna. With these unique environmental characteristics of Storm Valley, it is considered as one of the most important protected areas. Besides that, Karçal Mountains, Kure Mountains, Storm Valley, İstanbul Forests, Datça Peninsula, İbradi-Akseki Forests, Babadağ, Yenice Forests, Amanos Mountains are considered as nine Forest Hot Spots by Ministry of Environment (UNDP Turkey, 2011). Moreover, WWF determined 100 Hot Spots for biodiversity conservation in Europe, and Storm Valley and Kaçkar Mountains are considered among them. Kaş-Kekova, Eğridir Lake, Konya Catchment, Küre Mountains and Caucasia Corridor areas are protected by governmental and local authorities in order to maintain sustainable life cycle to the endemic species living in these areas.

1.1.3.1 Flora

According to the studies in regarding dispersed settlements located around the Fırtına river, especially in Çamlıhemşin and Ardeşen settlements, there are 145 rare, 24 endemic species (Byfield, A. 1995), 1430 different floras and endemism rate is around 17% (Güner, A. 1987). Old growth forests are rapidly decreasing for all over the world and accepted as one of the most valuable ecosystems, and due to that must be protected strictly. Based on the studies, old growth forests are very common in upper parts of

Çamlıhemşin and also Ayder highlands, both sides of Fırtına and Elevit valleys (Kurdoğlu, O. 1996).

1.1.3.2 Fauna

As a result of the unique flora and geomorphological structures of Rize province, especially Çamlıhemşin and Ardeşen region, studies are proved that there are remarkable wild life population have found a living space in this region. Even a detailed inventory study did not performed for the mammals living in these places, some of the possible major species, which can be concluded from the previous studies, are Capreolos capreolus (blackish), Capra aegagrus (chevrotain), Rupicapra rupicapra (chamois), Sus scrofa (boar), Ursus arctos (brown bear), Canis aureus (jackal), Canis lupus (wolf), Vulpes vulpes (fox), Felix silvertris (wildcat), Lynx lynx (bobcat), Martes martes (beech marten), Mustela nivalis (weasel), Lutra lutra (sea otter), Vormela peregusna (marbled polecat), Putorius putorius (skunk), Sciurus vulgaris (squirrel). Besides that Steelhead or Salmo trutta and Salmo trutta labrax, which a distant relative of Salmo trutta are the endemic fish species living in the streams of Storm Valley (Url-2). Beside Scotland and Sweden, natural living environment of Salmo turulla labrax, sea trout or black sea salmon, is eastern black sea, Turkey (E. P. Slastenenko, 1959).

1.1.4 Socio economic features

During the 1950s and 1980s, Black Sea Region played a buffer area role between socialism and capitalism. However, during these times, locals appropriated socialism instead of the capitalism or liberalism, on the contrary of the government's current policies.

Major sources of income of the local population are tea, tobacco and hazelnut farming and working for the state owned factories, but thanks to changes in the national political trends from socialism to liberalization, regarding state owned factories are privatized beginning from the end of 1980s. At the end of this privatization trend, unemployment problems arisen through the region, and most of the young population migrated to the other cities in order to find better job opportunities.

From the end of 1990s and beginning of 2000s, tableland tourism became popular in the Black Sea Region, and that creates an alternative employment, especially for the younger locals, to this historically agriculture based economy (Alaeddinoğlu, F. Et al, 2016). Since the elections in 2002, new government conducted a strong campaign for the new infrastructure lines, which is called green road, in order to connect the settlements, tablelands and highlands to each other and aimed the acceleration of regional tourism for the black sea. As a result, tourism played a crucial role for the sustainable socio-economic development of the region and significantly decreased unemployment rates via creating job alternatives with different sectors (Yuceol, H. M. 2011).

1.1.5 Settlement types

Settlements can be divide in to two main group as rural settlements and urban settlements according to their population such as less than a thousand and more than a thousand. But of course beside the population, socio-economic development of a settlement is a significant factor while grouping it (Url-3).

Major differences between urban settlements and rural settlements are population differences, land area, dominant employment sector, accessing opportunity to art centers, theaters and any other social facilities, social and cultural effects on surrounding places, possibility of different ethical and religious societies living together.

Urban settlements can be derive according to their land area, economical functions, cultural structures, administrative functions. City is the biggest urban settlement unit, which have more than 10.000 inhabitants and economically developed thanks to trade and industry other than farming and husbandry.

Rural settlements consist of villages and hamlets, where the farming and husbandry are becoming prominent for main daily activities and living. Population of these settlements is stays generally less than a thousand. In some of these rural settlements permanent settlement type is observed and in some of them nomadic settlement habits are observed. The major characteristics of a rural settlement are their limited population and low population density, economically dependency on farming and husbandry, narrowcasting structuring, strong social solidarity with common structures such as sanctuaries, schools and grasslands. Occupation and ethical variety are also very limited in these rural areas. In the villages, permanent settlement type is observed. Habitants life is generally depended on soil, farming. Besides that, husbandry, forestry, hunting and fishing are another common jobs for living in villages, where the population is less than 2000 in general. Legally, in order to use village term for a land, an approval must be granted from the central government. That means only population amount is not enough for changing a place' status into village. Because of that besides population some of the factors such as security, transportation, natural environment, utilization of water sources must be considered (Url-4).

Villages are also grouped according to their structural concepts, such as block type villages and dispersed type villages. In the block type villages, all of the structures and accommodation units are established in a very dense area (Url-5). Streets are very narrow and in general houses are constructed in contiguous. Farms are generally far away from the residential area. The main advantages of block type villages are security and common usage chance of structures. Besides the advantages, there are also some disadvantages for the block type villages such as spreading diseases, transportation problems to the farms etc. This kind of villages are very common in Central Anatolia, southeastern and southern part of Turkey. For the dispersed type village settlements houses are erected interleaved with 50 to 100 m or more. This settlement type covers larger amount of lands compared with the other settlement types, and especially in the Black Sea Region of Turkey, regarding settlement type can be observed very commonly. The biggest disadvantages of these dispersed village settlements are transportation and security problems, insufficient infrastructure lines such as electricity distribution sewage and drinking water, difficulties to reach over the public investments and significant increases in the public expenses.

Besides geographical formations and environmental conditions, also historical and economic factors are the major variants during the determination of a settlement is a block settlement or dispersed settlement. Besides that, especially water sources, mountainous terrain and dispersed agricultural lands have also a significant impact on this determination. Block type settlements are very common in the places, where the water sources are collected in a certain area, dominant geographical structures are flat areas or planes, which is suitable for agriculture and grazing, such as Central Anatolia. Nevertheless dispersed settlements are become prominent where the mountainous terrain or highlands, which have very limited area for farming and husbandry activities, is dominant such as Black Sea Region.

1.2 Wastewater Treatment

There are large numbers of common wastewater treatment technologies, which are nationally and internationally proved, based on characteristics of domestic wastewater, which varies dramatically according to daily habits of residents. In general, 99% of domestic wastewater comprises of just water and only rest of 1% creates pollution. Pollutants can be both in the soluble form and suspended solid form. Treatment methods are also show an alteration in order to remove these pollutants according to their characteristics. While the selection of the most suitable treatment technology these parameters must be evaluated such as receiving environment and discharge limits, amount of wastewater and its characteristics and available land for wastewater treatment plant, considering Notice of Selection Methods of Wastewater Treatment Plants which entering in force by official gazette 27527.

In the region, necessity of new wastewater treatment plants is evaluated under the legal regulations. As a consequence of continuous domestic wastewater discharge from Ardeşen and Çamlıhemşin dispersed settlements to Storm Valley, absorbing limits of receiving environment is exceeded in the end and soil pollution problem will be arisen. This situation violate the constitution of republic of Turkey bylaw 56 principle which states that “citizens have the right of living in a healthy and in balanced environment” and with the same bylaw it’s a requirement that necessary precautions must be taken by both government and citizens in order to maintain environmental development and prevent pollution.

1.2.1 Wastewater treatment technologies

Planning, design and operation of wastewater treatment plants are very comprehensive procedure and requires specialty. In parallel with that, it needs political, social and technical considerations also. Sustainability of wastewater treatment systems can be evaluate through different assessment tools such exergy analysis, economic analysis, and life cycle assessment (Helen E. M. et al., 2007). For that reason, besides meeting the requirements of discharge standards, a well-designed treatment plant will prevent many environmental problems such as odor and noise pollution, water pollution via physical, chemical and biological contaminants, aquatic ecosystem damage, quality degradation of receiving water sources, spread of diseases through utilization of untreated wastewaters for agricultural purposes, decrease in value of land costs.

Improvement in global health and sanitation and consequent reduction in the spread of disease depends largely on good hygiene practices, availability of health facilities, and reliable collection and treatment of wastewater. According to The World Health Organization (WHO) more than two billion people has no access to any type of hygiene and health care services equipment (WHO and UN Children's Fund, 2000).

Wastewater treatment systems and sewer networks are designed in order to protect human health and securitize sustainable environment (Helen E. M. et al., 2007). During selection of a domestic wastewater treatment technologies, these aspects must be considered and convenient treatment technologies must be selected, in accordance with population, population density, settlement structure, geographical and climatic conditions, energy and water sources, culture and daily habits of residents, receiving environment etc. Especially, in sparsely populated residential areas, for instance dispersed settlements, some treatment technologies are come to forefront.

The removal of pollutants during treatment in order to reach a desired quality or required discharge standard is associated with the concepts of treatment level and treatment efficiency (M. Sperling, 2007). Wastewater treatment is usually classified as preliminary, primary, secondary and tertiary. Main purpose of preliminary treatment is to eliminate coarse solids from influent wastewater. Primary treatment targets suspended solids (SS) and organic matter removal, which are separated as sludge.

The major purpose of secondary treatment is elimination of dissolved organic matter, via oxidation by microorganisms, nitrogen and phosphorus. Aim of the tertiary treatment is elimination of remaining compounds such as BOD, SS, bacteria, and toxic matters, which are not biologically degradable (T J Casey, 2006). The chemical characterization of wastewaters is commonly undertaken to determine their biological treatability, load on an existing treatment system, or compliance with the final discharge standards. In each case, one of the most important parameters to be measured is the chemical oxygen demand. Generally, chemical oxygen demand value of a wastewater typically characterizes the biodegradable and non-biodegradable organic constituents (B.Kasapgil Ince, et al. 2000).

Wastewater treatment technologies are consist of specific units and their integration creates a whole treatment system. In generally, there are four major wastewater treatment methods, which are physical treatment, chemical treatment, biological treatment and advance treatment methods. Physical treatment term is generally used for treatment methods in which physical forces are determinant, for instance screening, mixing, flocculation, sedimentation, flotation, and filtration. Chemical treatment term is used for the treatment methods in which the degradation of the contaminants by the chemical reactions, for instance neutralization, coagulation, flocculation, precipitation, adsorption and disinfection. For biological treatment term is used for the treatment methods in which the removal of the contaminants achieved by the microbial or biochemical activity, such as nitrification, denitrification, carbonaceous organic matter removal (Metcalf & Eddy, 2003).

1.2.1.1 Biological treatment systems

Biological treatment technologies are classified based on the primary biochemical reactions of predominant microorganisms in the treatment system. According to the availability of oxygen, the biochemical treatment processes are classified as aerobic, anoxic, and anaerobic (Shizas and Bagley, 2004).

Aerobic systems

Wastewater treatment processes, which occur in the presence of oxygen, are named aerobic process and in these systems microorganisms utilize molecular oxygen as electron donor for the metabolic respiration or oxidation cycle. Aerobic wastewater treatment systems generate more residual solids in the form of cell mass, which is called biological sludge that is generated as a final product of a certain wastewater treatment process (Metcalf and Eddy, 2003).

Anoxic systems

Anoxic reactions occur in the absence of free molecular oxygen. In generally, microorganisms and the biochemical pathways for the anoxic reactions are different from anaerobic reactions. In the anoxic systems, microorganisms can use oxygen when it is available, but in the absence of oxygen, they can use combined oxygen as an electron donor for the oxidation reactions from inorganic material in the waste (e.g., nitrate) as their terminal electron acceptor. Anoxic processes are common in biological nitrogen removal systems (S.Z. Ahammad, T.R. Sreekrishnan, 2016).

Anaerobic systems

In the anaerobic processes organic compounds in the wastewater is degraded under absence of oxygen and with an electron donor other than oxygen, for instance sulphate, resulting with the methane or acetic acid as the lowest oxidation level of carbon. In anaerobic systems produced biogas, which is a final product of anaerobic respiration reactions and a mixture of methane and carbon dioxide, is utilized for electricity generation and that biochemical conversion results with a lower amounts of bio solids or sludge as final product (W. Reineke, 2001).

Anaerobic digestion of organic materials is considered one of the most applicable and maintainable treatment alternative due to biogas production opportunities and nutrient regaining. Biogas generated from anaerobic digestion process is also a sustainable renewable energy source and also an efficient alternative for clean electricity generation for the developing countries like Turkey. Animal and plant residues with high organic compounds, such as cattle or poultry manure, have a great biodegradation potential, which enables renewable and sustainable electricity generation through anaerobic fermentation and biogas generation (A. Jaxybayeva, et al., 2014). Organic rich residues like animal manure consist of significant biodegradable organic carbon that is essential for renewable energy generation via anaerobic fermentation. Manure is an unavoidable byproduct of livestock farming and can be a valuable source of nutrients for crop production if properly managed.

Apart from a classification based on microbial metabolism and/or oxygen utilization, biological wastewater treatment processes can also be classified based on the growth conditions in the reactor, as shown in Figure 1.1.

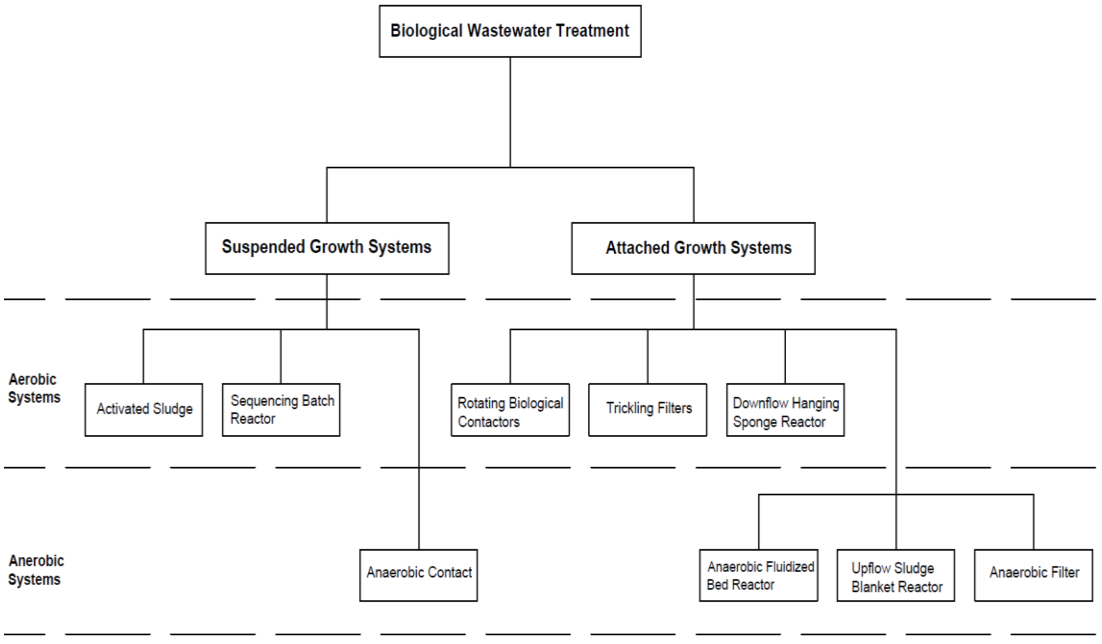

Figure 1.1 : Biological treatment systems according to growth conditions.

In this case, the two main categories are suspended growth and attached growth processes. In suspended growth processes, the microorganisms that are responsible for the conversion of organic matter, present in the waste, to simpler compounds and biomass are maintained in suspension within the liquid phase. However, there are different types of aerobic and anaerobic suspended growth processes. Aerobic processes include activated sludge (AS), aerated lagoons, and sequencing batch reactors (SBR), whereas anaerobic processes Anaerobic Contact Process (ACP) include bag digesters, plug-flow digesters, stirred-tank reactors, and baffled reactors with organisms primarily in the liquid phase. In attached growth processes, the microorganisms responsible for degrading the waste are attached to surfaces (e.g., stones, inert packing materials), or are self-immobilized (microorganisms being attached to one another) as flocs or granules in the system (Ahammad et al., 2013a). Attached growth processes can be aerobic or anaerobic. Aerobic attached growth processes include Rotating Biological Contactors (RBC), Trickling Filters (TF), and Downflow Hanging Sponge Reactor (DHS). Anaerobic systems include Upflow Anaerobic Sludge Blanket reactors (UASB), anaerobic filter (AF), Anaerobic Fluidized Bed Reactors (AFBR), reactors, and Hybrid UASB, which combines advantages of conventional UASB and AF process. (S.Z. Ahammad, T.R. Sreekrishnan, 2016). Up-to-date anaerobic processes such as UASB or AF process have a wide implementation area especially for the treatment of industrial wastewaters with high soluble COD levels (Oktem Y.A. et al., 2007). Especially hybrid UASB reactors have a wide implementation area specifically for the partial treatment of distillery spent wash water and slaughterhouse effluent (Torkian A. et al., 2003).

Aerobic biological treatment systems

Conventional activated sludge and extended aeration systems

Activated Sludge (AS) process is one of the earliest wastewater treatment technology, which was developed by Edward Arden and William T. Lockett in England 1914. It can be defined as a treatment method, which utilizes suspended microorganisms for the purpose of enhancement the quality of wastewaters up to certain level. There are many upgraded version of this original method. Anyhow, original AS is the most common application for the small scale plants, especially in municipal treatment plants. Basically depends on the addition of pretreated wastewater and microorganisms in order to maintain degradation of carbonaceous biological matter and nitrogenous matter which is mainly ammonium and nitrogen. The process begins by mixing the wastewater with an aerobic bacterial culture in an aerated reactor (M. Scholz, 2016-b). Reaction time of aeration tank must be regulated carefully to achieve sufficient organic matter degradation or treatment. After biochemical reactions are completed, treated water is pumped into the separation tank for phase separation. Settled AS then mainly recycled back to the aeration tank in order to maintain a fixed concentration of depolluting microorganisms (M. Scholz, 2016-b). AS systems are designed principally to eliminate the organic substances. Furthermore carbon, nitrogen and phosphorus can be eliminate from wastewater with some modifications in the conventional system. For instance, in the aerated tank nitrification process, which is basically conversion reaction of ammonia to nitrates, occurs owing to nitrifying microorganisms. These microorganisms oxidize pollutants through the presence of an enzyme, which is called ammonia monooxygenase (J. Margot et al., 2013). As it can be seen in the Figure 1.2. basic components for the AS system are an aeration tank, oxygen source, secondary tank, and pumping system. In the basic AS system, influent wastewater enters in the aeration tank where the biological reactions occur and thanks to air pumped into the system collected wastewater can be mixed and microorganisms are able to obtain required oxygen for the metabolic activities while degradation of organic compounds in the wastewater for next 4 to 8 hours. After this stage, wastewater and the sludge, pumped into the secondary clarifier in order to separate effluent water from the sludge. From secondary clarifier effluent water can be discharged or pump into the further treatment units in order to eliminate nitrogen and phosphorus also. During the bacterial activities, some part of the generated sludge is feed back to the aeration tank in order to keep the bacterial flora stable, and the rest of the sludge is taken out from the system.

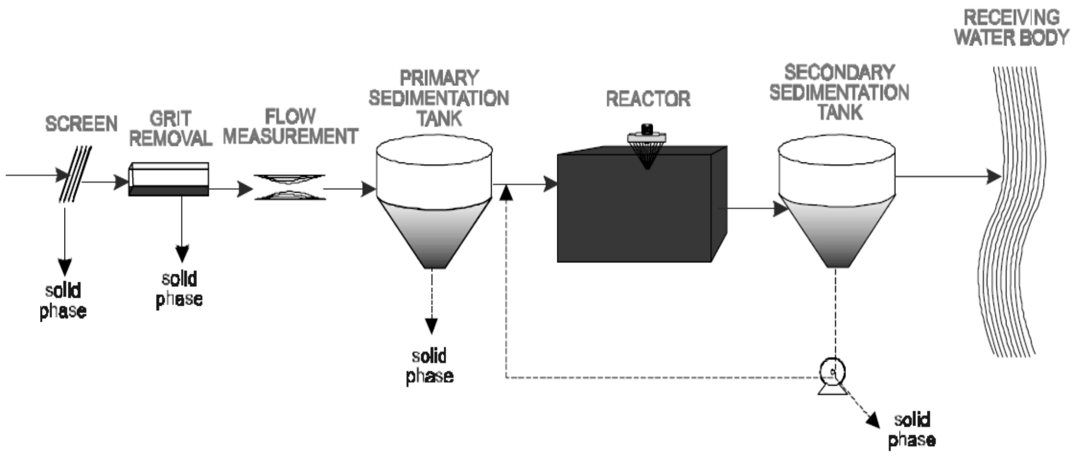

Figure 1.2 : Conventional activated sludge process (M. Sperling, 2007).

Excess sludge must be mechanically stabilized or dried with the proper methods based on the characteristics and water content.

Extended aeration systems or activated sludge systems are very similar to conventional activated sludge system, but the main difference is in the extended aeration systems biomass stays longer in the process (M. Sperling, 2007). In order to extend the reaction time up to 18 hours or more, aeration tank must be enlarged. Required oxygen have to be supplied by a blowers or diffused aeration. Mixing is achieved by blowers during the aeration or via a mechanical stirrer, as seen in the Figure 1.3. Because of the high retention times in the extended aeration systems, the process works under low food and microorganism ratio, and that both makes possible the nitrification process and also create a competition for the food among the microorganisms. As a result of that competition there will be less biomass, sludge, in the system.

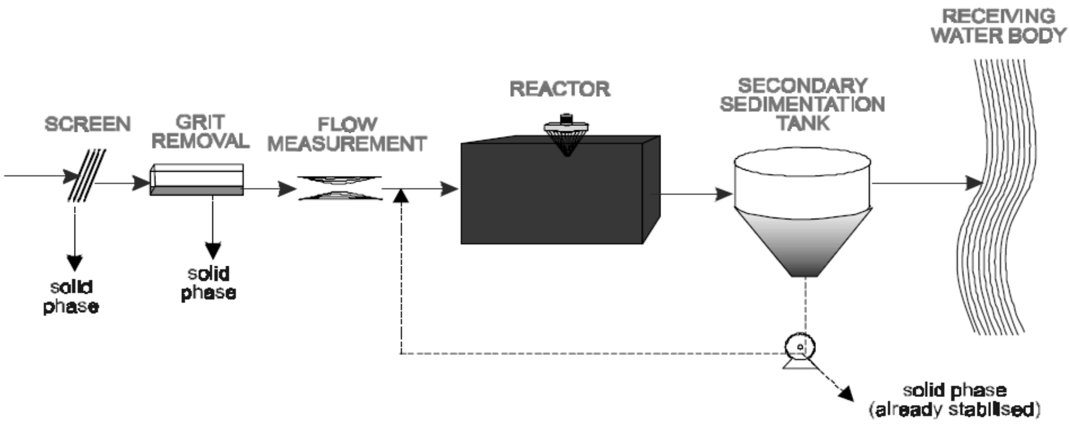

Figure 1.3 : Extended aeration process (M. Sperling, 2007).

One of the biggest advantage of extended aeration systems is their relatively low food to microorganism ratio working conditions, which make them remarkably stable process, and thanks to that stability this process are very popular for small communities and schools. This process can work discontinuously without upsetting it and generated sludge at the end of the process significantly lower than the conventional activated sludge systems, however, excess sludge must still be pump out from the system in order to maintain sustainable process (Pipeline, 2003).

Sequencing batch reactors

Sequencing batch reactors (SBR) are fill and draw type activated sludge reactors, which have a common usage for residential areas that have small and medium scale population. On the contrary of conventional activated sludge systems, of which different steps are located in different tanks, equalization, aeration and settlement are completed in the same reactor. (Pipeline, 2003). Sludge wasting usually occurs during the settling phase.

The SBR acts as an equalization basin when filling with wastewater, enabling the system to tolerate peak flows or loads. Before influent wastewater enters into the SBR system physical pre-treatment, such as screening, must be done in order to remove grits and etc. SBR consisted of five different stages which are fill, react, settle, decant and idle as shown in Figure 1.4.

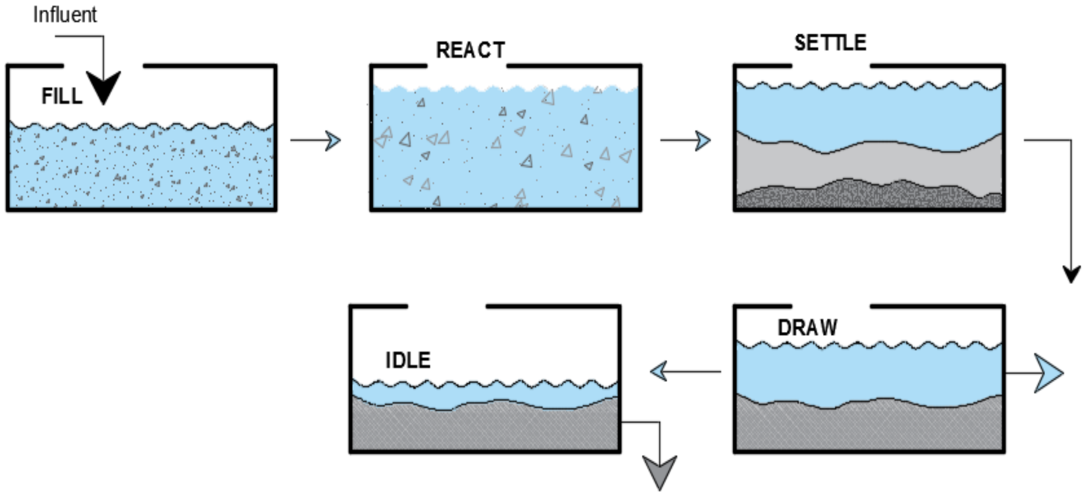

Figure 1.4 : Phases of a typical SBR.

As a first stage SBR must be stay partially loaded, but not whole empty, after every cycle. Untreated wastewater influent will be mixed with the old remaining and reactor will be filled up and after that stage SBR is closed and from that point it operates like conventional activated sludge system, but the main difference is in SBR there will be no more continuous feed in or effluent flow from the reactor. In the aerobic stage, thanks to air pumped in to system, mixing and aeration is performed in order to maintain metabolic activities of microorganisms. In a certain time period, mineralization of organic pollutants are occur biologically under aerobic conditions. After that stage, completed air pumping must be stopped in order to make suspended solids to settle down on the bottom of the reactor, and make the anoxic phase to initiate. In anoxic phase (absence of oxygen but presence of nitrates), when aeration interrupted, some nutrients presents in reactor such as nitrite and nitrite. Nitrite and nitrate must be eliminate before settling step. For that purpose, reactor is kept under anoxic conditions and wait for the completion of transformation reaction of nitrite and nitrate, which are formed during the aerobic process, are used in the respiration of facultative microorganisms in the anoxic zones, being reduced into the molecular nitrogen gas (M. Sperling, 2007). After that settling of activated sludge occurs. After the settle process completed, treated water at the top of the reactor is discharged from reactor via overflow. And finally reactor is converted into the recovery mode before the next process is initiated, as shown in Figure 1.5.

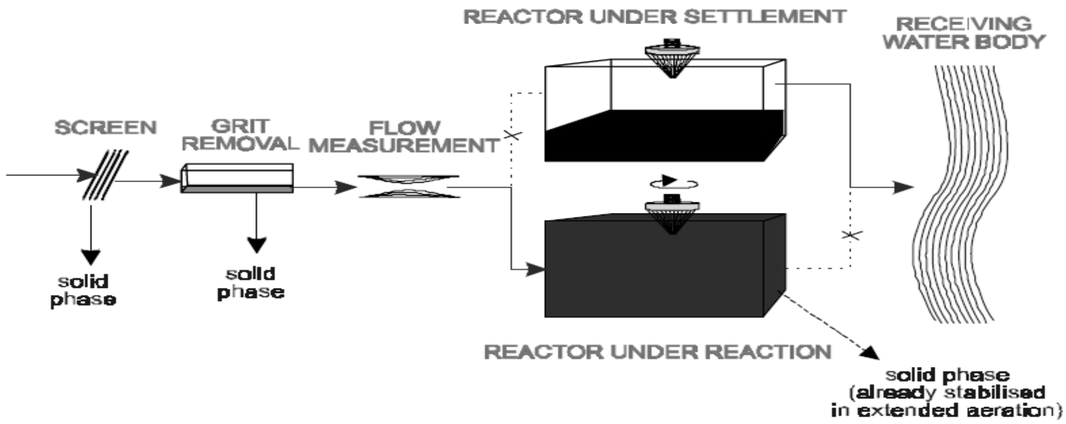

Figure 1.5 : Sequencing batch reactor process (M. Sperling, 2007).

The sum of required time for the completion of these phases gives total cycle time. Organic carbon, biological nitrogen and phosphorus can also be eliminated from wastewater, while adjusting the phase time. Organic carbon and biological substrate elimination can be achieved effectively, thanks to different filling, mixing and aeration.

Membrane bioreactors

Membrane bioreactors (MBR) are suspended growth activated sludge systems and in a way, they are combination of bioreactors and membrane technology (Huang et al., 2010). Membrane bioreactors (MBRs) have been widely used for the separation of solid/liquid phases of wastewater through low-pressure membrane equipment and engineering over the past decade. Main precedence of the membrane bioreactor technology on activated sludge method is the lower sludge production and higher effluent water quality.

But besides that the major disadvantage of the MBR technology is its operational costs. Especially electricity consumption of this treatment technology is significantly higher than the conventional activated sludge system (Judd and Judd, 2011). The biggest portion of the consumed electricity, which is almost 70% of consumed energy during the treatment process, arises from the aeration process which is required for both biodegradation reactions and membrane blockages (Brepols et al., 2010; Yan et al., 2015).

There are two different types of membrane bioreactors as shown in Figure 4.6. In the first one decomposition and separation occur in the same reactor, but in the second one, these reactions all occur in different tanks. In these systems supernatant flow is available through hydrostatic forces and/or vacuum. In separate systems tubular, spiral or hollow fiber membranes are used. Wastewater occurred from biological systems is pumped through the membrane. In the membrane wastewater flow is separated; supernatant is removed and concentrated liquid pump back to reactor again. For the treatment of domestic wastewater, nowadays, MBR systems have a common usage especially in the rural areas.

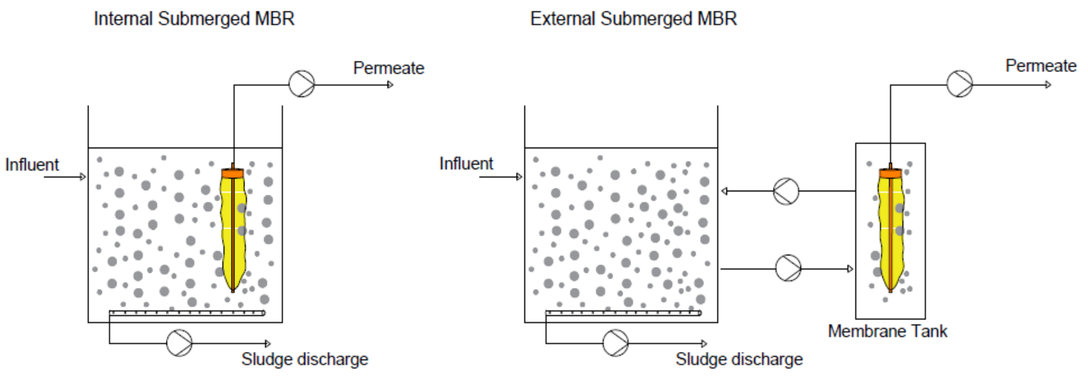

Figure 1.6 : Internal and external submerged MBR (Krause S. et al., 2011).

MBR systems are one of the most convenient systems when considering water recycling especially such as hotels, holiday camps or the places where the water sources are limited. Besides domestic wastewater treatment, it also have an extensive usage for the treatment of industrial wastewater treatment applications. Recently, large capacity plants are also have an application areas.

1.2.1.2 Aerated lagoons

Waste stabilization ponds or aerated lagoons have a comprehensive application area in all over the world in order to biologically treatment of the domestic wastewaters, because of their low capital and operational costs (R. Leduc et al., 1990). In generally wastewater treatment systems are very sensitive to short term quality and flow variations of influent wastewater, which is determined by the daily human activities.

When the aerated lagoons or stabilization ponds is concerned sensitivity to variations become more trivial because of their stable operation. Regarding variations of wastewater flow, quality, organic matter amount, BOD and suspended solid contents and the effects on the treatment performance are successfully characterized (Thomann 1970, Wallace and Zollman 1971, Randtke and McCarty 1977). An aerated lagoon is soil structure with 2.5-5 m depth and made by mechanical aerators that are located at top of aeration barges or fixed columns as shown in Figure 1.7. Compared with stabilization ponds they have 10-20% less volume. Primary function of this treatment system is waste conversion. As in other suspended solid systems turbulence occurred by aeration and that both keeps the components suspended and system aerated. Based on hydraulic retention time, almost half of the organic matter in the wastewater coming to lagoon transforms into microorganisms. Most of these solids are eliminated by settling.

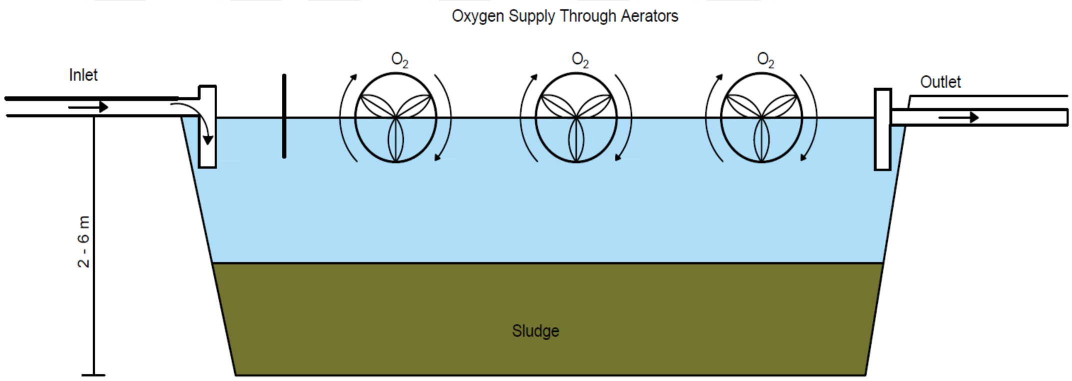

Figure 1.7 : Aerated lagoons.

There are large numbers of alternatives during design of these ponds. These kinds of lagoons, in one way, can be projected as simple facultative or, in another way, can be more efficient and intense units where the sludge feed-back occur.

1.2.1.3 Constructed wetlands

Wetlands are the important ecosystems and play the interface role between water and soil (Millennium Ecosystem Assessment, 2003). In all over the world, since 1950, wetlands in different types and in different sizes are constructed for the domestic, industrial or agricultural wastewater streams treatment purposes. In order to treat wastewater, constructed wetlands are complex integrated systems, which provide an ecologic environment that covers microorganisms, animals, plants and aquatic environment.

Natural wetlands have a wide range of classification according to the treatment components such as plantation, soil structure and permeability and that typical variations makes them unique solution for the site specific which means that almost every natural wetland has its own characteristics on the site it evolved (Brix H., 1993a). Since past few decades, utilization of wetlands in the wastewater treatment systems are examining and some serious implementations are performed. Wastewater treatment applications and studies on water quality increasement potential of wetland systems are investigating seriously (Bastian, 1993).

Constructed wetlands are an alternative and natural way of wastewater treatment and they can design with advance control parameters through well-defined influent characteristics, region specific plantation types and calculated daily flow rate (J. Vymazal, 2016). One of the most well-known application of constructed wetlands is for primary and secondary treatment of domestic wastewaters. Basic mechanisms of the treatment depends on physicochemical and microbiological foundations, as seen in Figure 1.8.

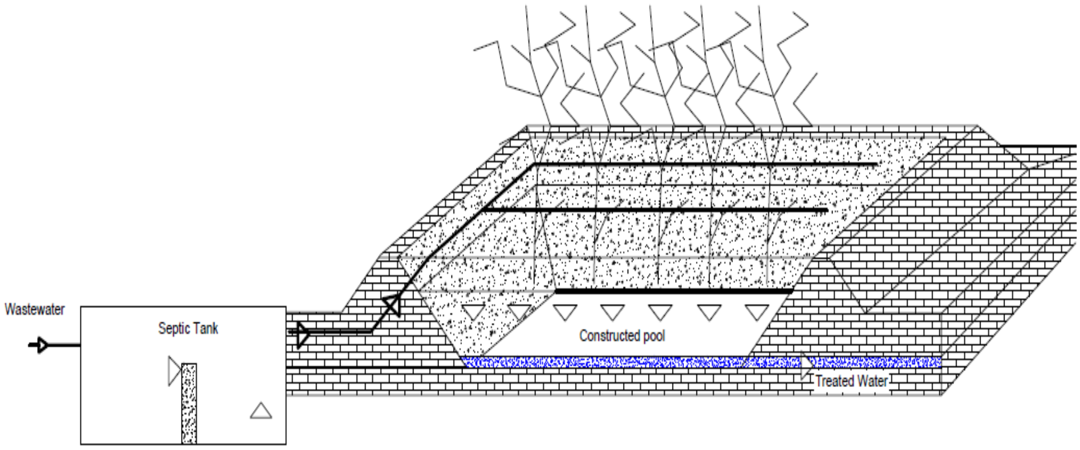

Figure 1.8 : Constructed wetlands.

1.2.1.4 Aerobic biofilm reactors

Trickling filter is a very common technique for the aerobic treatment of wastewaters, which is also nomenclature as biofilter that is used to remove organic matter and ammonium nitrogen from wastewater (Zhu et al., 2016). Biofilters or trickling filters are basically packed bed type of reactor, which is filled with an inert and porous material, plastic material for instance, that makes the microorganisms to be able to attach. The development of plastic packings as high-rate trickling filter media has been one of the most significant advances in the field of biological wastewater treatment.

Microorganism growth is occur on the surface of this bed material and that creates a biofilm layer. Wastewater influent steps in to the system through a moving nozzle system and degradation of the organic pollutants and nitrogen is achieved thanks to the microorganisms attached on the surface of the bed material, as shown in Figure 1.9.

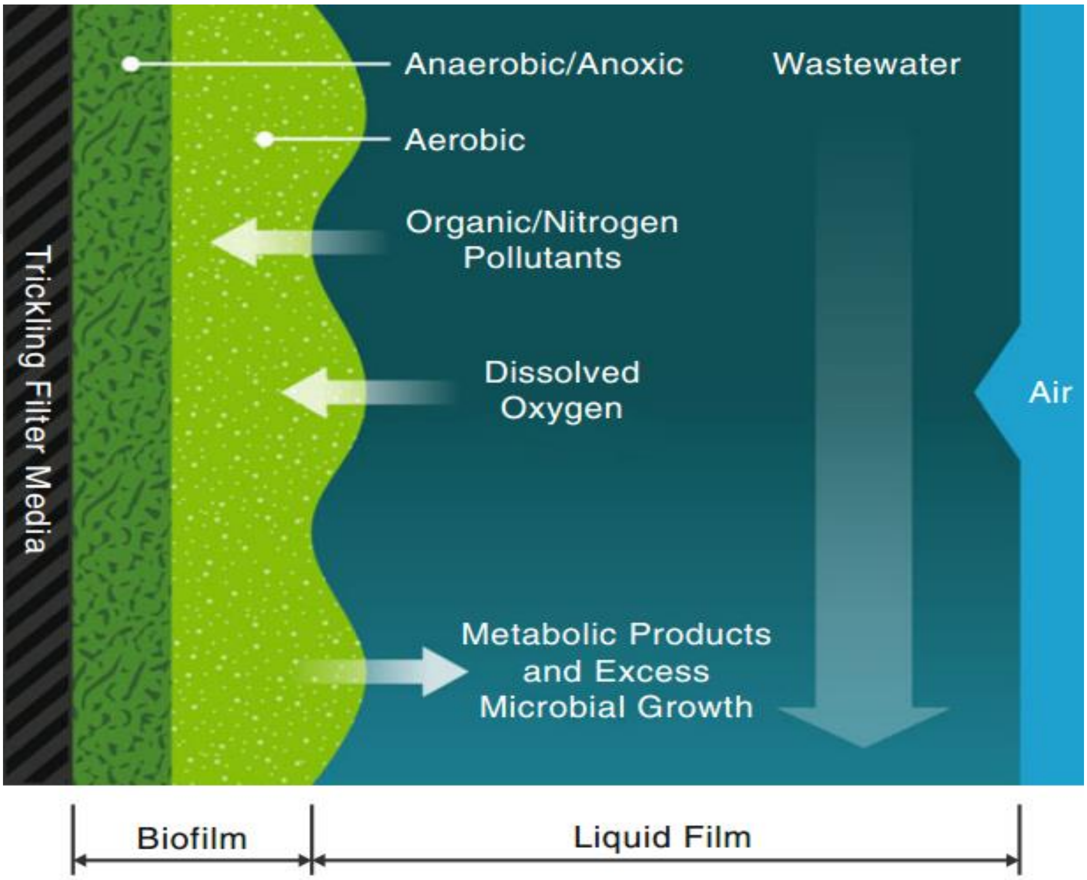

Figure 1.9 : Mass transfer directions of a trickling biofilter (Zhu et al., 2016).

Aerobic condition is achieved by active or passive aeration by using either a blower or fan (forced aeration) or natural convection of air due to the temperature and pressure difference of dissolved oxygen between the wastewater and ambient air. Low strength wastewaters (COD < 1000 mg l^{-1}) such as domestic wastewater can easily be treated using this system as shown in Figure 1.10 and desired effluent wastewater discharge limits, which are already described in the national regulations, can be achieved (S.Z. Ahammad, T.R. Sreekrishnan, 2016).

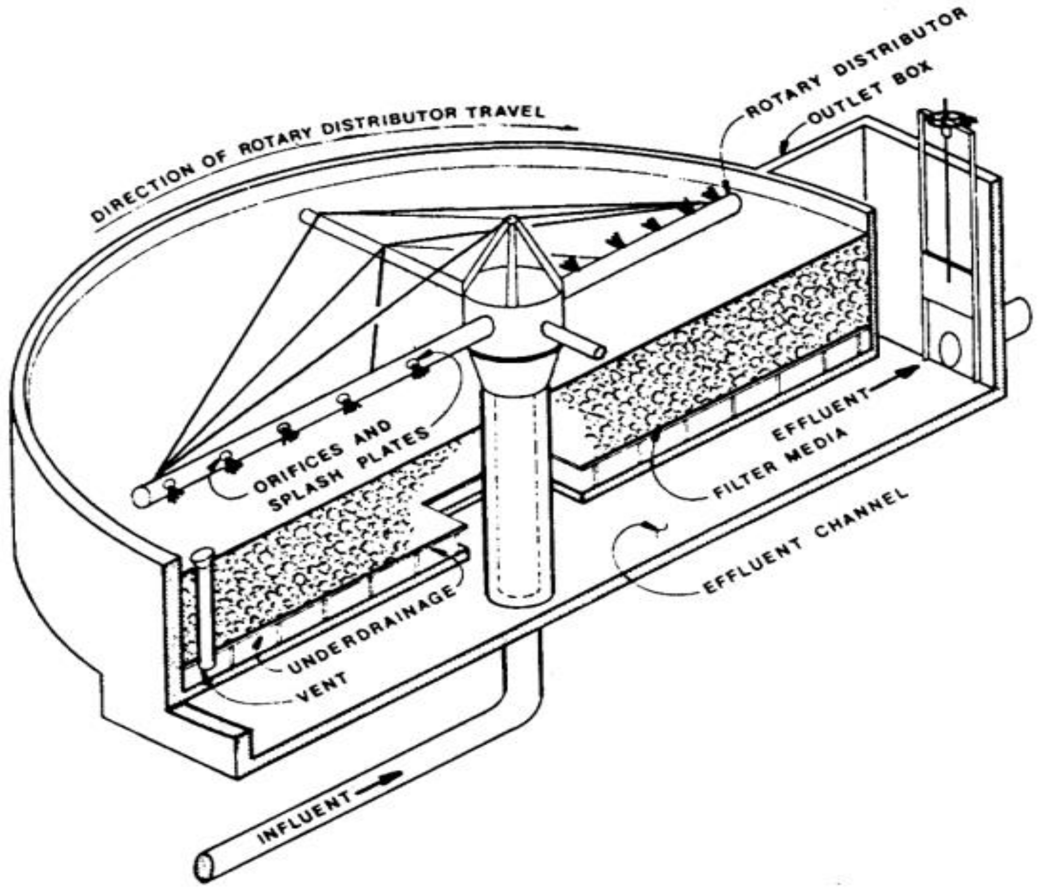

Figure 1.10 : Trickling biofilter in operation with PVC media and rotary arm, (US EPA, 2000).

Low rate trickling filter

BOD is stabilized aerobically by bacteria that grow attached to a support medium, which is commonly stones or plastic material. The sewage is applied on the surface of the tank through rotating distributors. The liquid percolates through the tank and leaves from the bottom, while the organic matter is retained and then further removed by the bacteria. Free spaces permit the circulation of air. In the low rate system there is a low availability of substrate (BOD) for the bacteria, which makes them undergo self-digestion and leave the system stabilized (M. Sperling, 2007).

High rate trickling filter

Similar to the low rate system but with the difference that a higher BOD load is applied to those systems. The bacteria (excess sludge) need to be stabilized within the sludge statement. The effluent from the secondary sedimentation tank is recirculated to the filter in order to dilute the influent and guarantee a homogeneous hydraulic load (M. Sperling, 2007).

Submerged aerated biofilter

Aerated-contact beds (also called submerged-contact aerators) were developed for more efficient continuous operation in the early 1900s. The submerged aerated biofilter is composed by a tank filled with a porous material (usually submerged), through which sewage and air flow permanently. The airflow is always upwards, while the liquid flow can be downward or upward. The biofilters with granular material stipulate, in the same reactor, removal of soluble organic compounds and particulate matter. Besides being a support medium for biomass growth, the granular material acts also as a filter medium.

Periodic backwashing is necessary to eliminate the excess biomass accumulated, reducing the head loss through the medium (M. Sperling, 2007). When a submerged-contact aerator is continuously operated, air is usually provided in sufficient volume to keep the water and slime surfaces aerobic and with sufficient intensity to tear away aging slime and solids accumulations for subsequent solid-water separation in a secondary settler (L. K. Wang et al., 1986).

Rotating biological contactor

The RBC was originally developed for wastewater streams as an alternative to standard sewage systems. Several discs, acting as biofilm carrier or attached growth surface, are mounted on a shaft at minimum 2 cm distances from each other. With the purpose of mass transfer increasement and adjustment of biofilm layer thickness, rotation speed must be stay in the range of 3 to 5 revolution per minute. Thanks to that rotation, friction forces occurs between wastewater and biolayer, which helps for the adjustment of the thickness of biomass layer that is attached on the high density polypropylene or PVC material disc surface.

Depending on the case specific design, RBCs are flat, channeled and ribbed structure which is submerged into the wastewater up to 40 to 60% of its disc volume (P.R. von Rohr et al., 2001). While these slow rotation, biomass on the rotating disc, get in contact with air and wastewater, as shown in Figure 1.11. Required oxygen for the metabolic activities of microorganisms during the wastewater treatment process is met from the air during this slow rotation move, and thanks to frequency speed control of electric motor of the RBC unit required rotation speed can be adjusted and necessary dissolved oxygen level in the wastewater can be maintained.

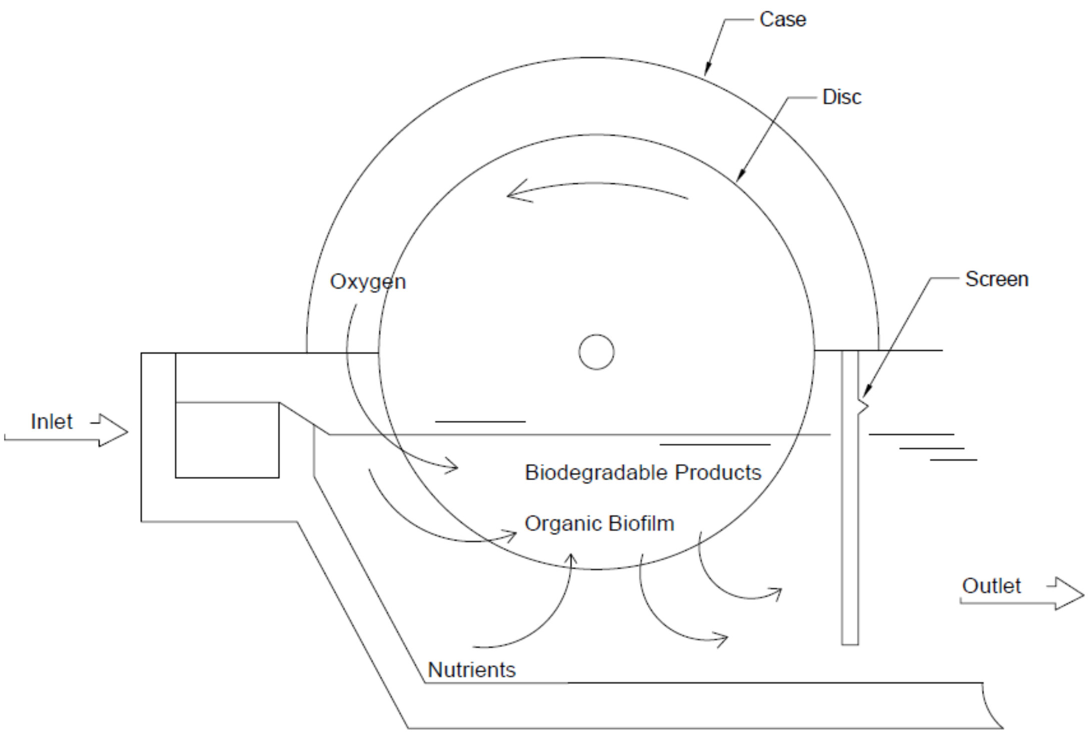

Figure 1.11 : Cross section drawings of RBC.

Thanks to their appropriate physical surface conditions, microorganisms can grow up on the surface of the rotating discs, which are resistant to corrosive effects of feed-in wastewater such as wood, PVC, HDPE, that are installed on a rotating shaft or they are cylindrical perforated drum structures and full of packing material (M. Scholz, 2016-a). On the surface of the discs, microorganisms create a biofilm layer. Oxygen requirement of microorganisms (biofilm layer) is met by air while their cycle through the atmosphere. Growth of the biomass on the inert surface, here in discs, occurs in the eight steps; Amassing of organic substances on the discs, cells reach the disc surface from the influent environment, cells fasten on the disc surface, some of the microorganisms desorb, some of the microorganisms fasten on the disc surface irreversibly and bind, microorganism cultivate through the nutrients in the influent wastewater and metabolic residuals exit from the system, microorganisms grow on the surface and make the biofilm thicker, some part of biofilm disengage from the discs and are accumulated in the effluent (Charaklis et al., 1990).

In general, basic elements of RBCs are main shaft with almost 8 meters, discs with applicable radius varies between 1.5 to 3 m and 20 or 30 discs can be located on each meter of the shaft with 2 cm gaps, drive system such as electric motor or mechanical drive unit which must be equipped with frequency control or variable speed control, influent tank with an enclosure and a final settling tank (M. Scholz, 2016-a). Total volume of the influent tank, or wastewater capacity, is optimized for 0.0049 m^3/m^2 disc surface ratio (Kincannon et at., 1982). With that ratio, hydraulic retention time 1.44 h can be achieved and hydraulic loading rate will be 0.08 m^3/m^2/day. In order to reach minimum 40% submerge of the discs, wastewater depth must be minimum 1.5 m. Influent tank needs to be covered with an enclosure in order to protect the discs and microorganisms from the external physical effects and avoid them from any extreme weather conditions, but the covering material must have enough space for the oxygene transfer from the air naturally. Final settling tanks are not the vital units of RBCs for the appropriate operation, but especially in the rural areas, where the operation has to be continued with minimum human assistance, these final settling tanks can be supportive during the operation control and sustainability.

Basically, there are two main types of RBCs, which are integral and modular (F. Hassard. et al., 2015). In the integral systems all the process, which are primary settlement, microorganisms attached on the surface of rotating biodiscs and biochemical reactions, and a final settling tank which can be both integrated or separated. Integral types are called as packed system in general, as seen in Figure 1.12.

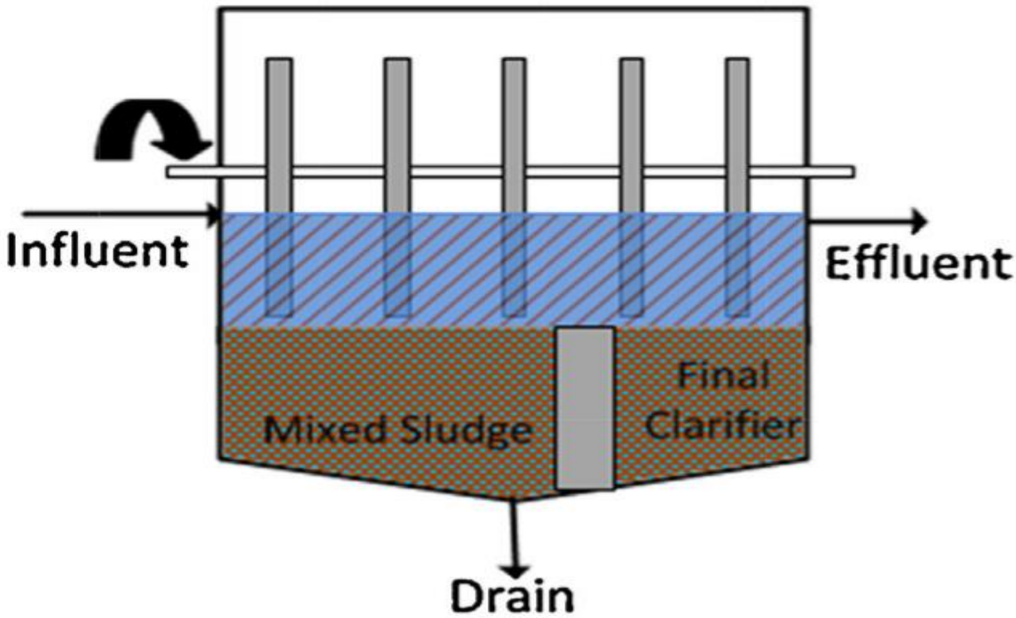

Figure 1.12 : Integral type of RBC (F. Hassard et al., 2015).

This packed type integral systems are worked for more than 250 people (Findlay, 1993). In the modular RBC systems, as seen in Figure 1.13, primary settling, final clarification and biological treatment process are continued in separately, and these systems are operated for up to 1000 people (Griffin, P., Findlay, G., 2000).

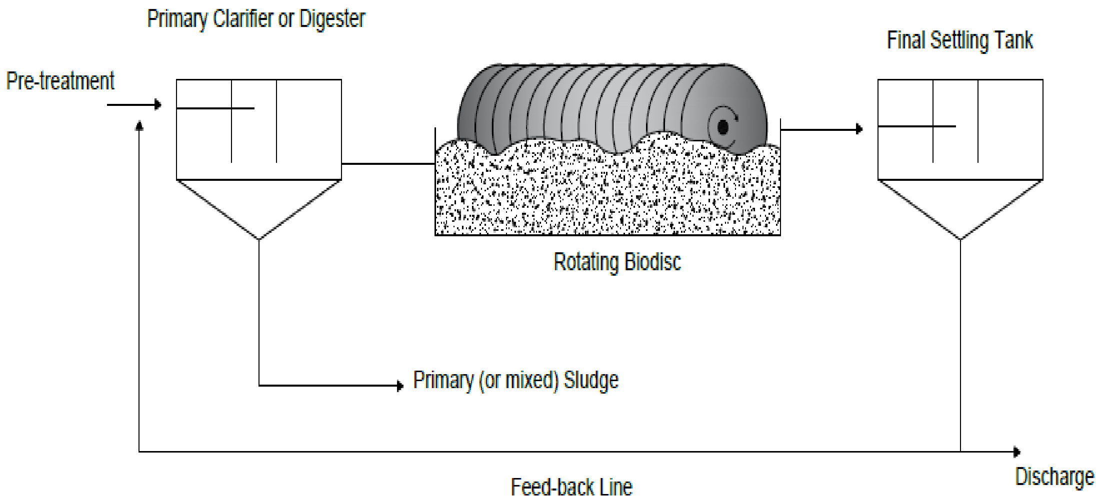

Figure 1.13 : Schematic Representation of RBC (TPA, 2010).

Thanks to that unit-based operation, modular RBC systems have more flexible operation opportunities. For instance, if the influent flow rate is the principal concern than modular RBCs can be operated in parallel form, or if the main concern is the effluent water quality than a number of modular RBCs can be connected in series and operated, as seen in Figure 1.14.

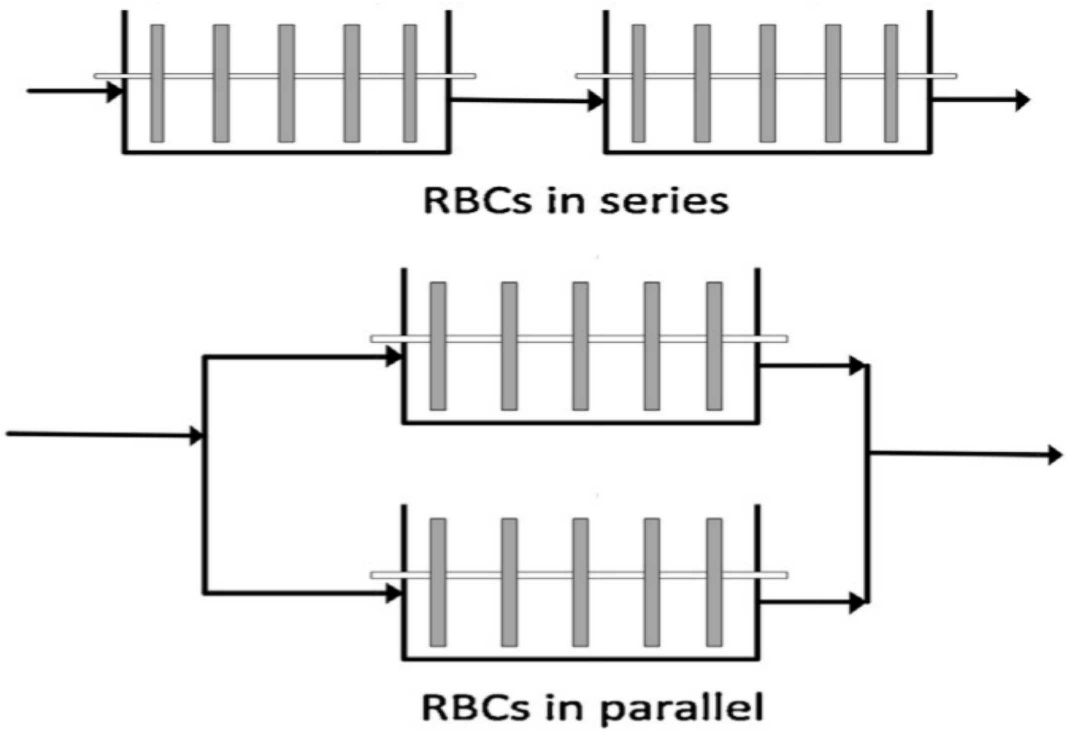

Figure 1.14 : Series and parallel type of modular RBC (F. Hassard et al., 2015).

Compared to conventional systems, the energy consumption of RBCs is reduced by 50% because of conventional activated sludge systems, energy consumption is relatively high (0.5-1.5 kWh/m^3) because of oxygen requirement is met by blowers or surface aerators, on the contrary, in rotating biological contactors energy consumption decreases down to 0.04-0.2 kWh/m^3 levels and the required space is reduced by 20 to 60% (P.R. von Rohr et al., 2001). Besides that low investment and maintenance costs, good buffering capacity and high reliability are the other main advantages of the RBCs in the wastewater treatment field (Bitton, 1994). In addition to advantages, there are major operation problems occurred since early stages of RBC technology, for instance shaft and bearing failures, biodisc crashes and odor problems. Among these operational risks, shaft failure is the major problem, which ends up with the unit loss and microorganism damage that is attached on the surface of the media or disc. In order to avoid any shaft damage selected metal type for the shaft manufacturing must be strong enough, bearings have to work properly and lubrication must be done correctly to avoid any buckling resistance, which causes metal fatigue on the shaft, and microorganism accumulation or biofilm thickness must kept under controlled. Furthermore, high organic loading rates causes insufficient organic degradation and results with odor problems.

In generally, RBC unites, which are utilized in small residential areas, used for treatment of domestic wastewaters, but in some cases, it can be used for elimination of organic substances of industrial wastewaters with low flow rate. Design criteria of rotating biological contactors are given in Table 1.1.

Table 1.1 : Basic design criteria of RBC Wastewater at 13°C (Metcalf&Eddy, 2003).

Parameter	Unit	Organic Substance Removal	BOD Degradation and Nitrification	Two Stage Nitrification
Hydraulic loading	m^3/m^2/day	0.08-0.16	0.003-0.08	0.04-0.1
Organic loading	g BOD/m^2/day	10-17.5	7.5-15	-
	g sBOD/m^2/day	3.7-10	2.5-7.5	5-15
Max. load on the first stage	g BOD/m^2/day	40-60	40-60	-
	g sBOD/m^2/day	24-30	24-30	-
NH_4-N	gN/m^2/day	-	0.75-1.5	1-4
HRT	days	0.7-1.5	1.5-4	1.2-2.9
Effluent BOD_5	mg/L	15-30	7-15	7-15
Effluent NH_4-N	mgN/L	-	< 2	1-2

Rotating biological contactors can undertake BOD removal and biological nitrogen removal for domestic wastewater (Hiras et al., 2004; Vlaeminck et al., 2009) and partial enhanced phosphorus recovery (Yun et al., 2004).

Basic Components of Rotating Biological Contactors

A standard RBC system is basically consists of a coarse grid, wastewater pumping system, balance tank, fine grid, sand and grease trap, rotating discs, final settling tank and in some cases a disinfection unit.

Coarse grid

Works for physical separation of bulk material which can cause blockage of the treatment system units from wastewater. Grids installed with 30 to 75o angle to horizontal surface. Can be cleaned by hand or mechanically.

Pumping system

A pumping system required to meet load loss of wastewater between treatment process units and ensure its flow.

Balance tank

Especially in small residential areas, where the wastewater flow rate changes dramatically during the day and the seasonal changes. Biological treatment systems effect from flow rate variations and pollution load changes, and because of that fact, they must be fed steadily as much as possible. Utilization of balance tank is preferred to minimize the negative effects of changes in flow rates and load fluctuations on biological treatment process.

Fine grid

Compared with the coarse grids, has closer gaps (0.5 – 2 cm) and due to that they can capture smaller particles, which can escape from coarse grids. Likewise, coarse grids, fine grids are also installed with 30 to 75° angle to horizontal surface. Can be cleaned by hand or mechanically.

Sand and grease trap

Settleable solids like sand, gravel etc. must be eliminated from wastewater through sand traps because they can corrode pumps and create blockages in channels, pipelines, settling tanks and digestion tanks. There are different types of sand traps such as circular, longitudinal and longitudinal aerated sand traps. Main purpose is to catch particles bigger than 0.2 mm.

Rotating discs

Oxidation, nitrification and denitrification process of organic compounds is done by biofilm on the rotating discs, in principle. Biomass growth is achieved on rotating discs that is attached on a shaft. Shaft length can reach up to almost 8 m and biodiscs are attached on almost 7.5 m of it (Metcalf and Eddy, 2003).

Discs are partially sink under wastewater and can be adjusted according to required oxygen level. Generally, applicable radius to biodisc technology varies between 1.5 to 3 m. Surface area of regarding discs depends on density of disc material, texture of disc surface (fibrous etc.). For the medium dense and high dense surfaces, surface area can be reach up to 11.000 and 17.000 m^3. Each of the rotating disc or biodrum shafts are installed in different cylindrical channels as 40-70% of them sinks under water. 0.0049 m^3/m^2 for unit surface area is recommended for tank volume that contains rotating biodiscs. In addition, typical depth of side water wall is almost 1.5 m.

Final settling tank

In general, final settling tanks are the tanks, which separate treated wastewater from biomass via gravitationally, after the biological treatment. Design of inlet structure and sludge collection system must be done to avoid any failure in laminar flow in settling tanks and sludge characteristics. Separated water from sludge is collected from final settling tanks through penstocks. Additionally, sludge trap equipment must be maintained to collect foam on the surface and biological sludge at the bottom of tank. To increase settling performance of final settling tank lamella separators are used. Lamella separators are the plates, which are installed horizontally and in parallel with a certain angle.

Disinfection unit

Disinfection process is used for inactivation of any pathogenic microorganisms in wastewater to prevent spread of water origin diseases (V. Lazarova et al., 2013). Residual coliform bacteria amount after the disinfection process can be measured by coliform bacteria determination test kit. Especially, this issue will be much more important when treated wastewater utilized in agricultural irrigation activities. Disinfectant selection have to be done considering its toxicity on receiving environment and water sources, which is used by irrigation purposes. In generally, used chemicals for that disinfection purposes are liquid-gas chlorine, hypochlorite, chlorine dioxide and ozone (K. Verma et al., 2016).

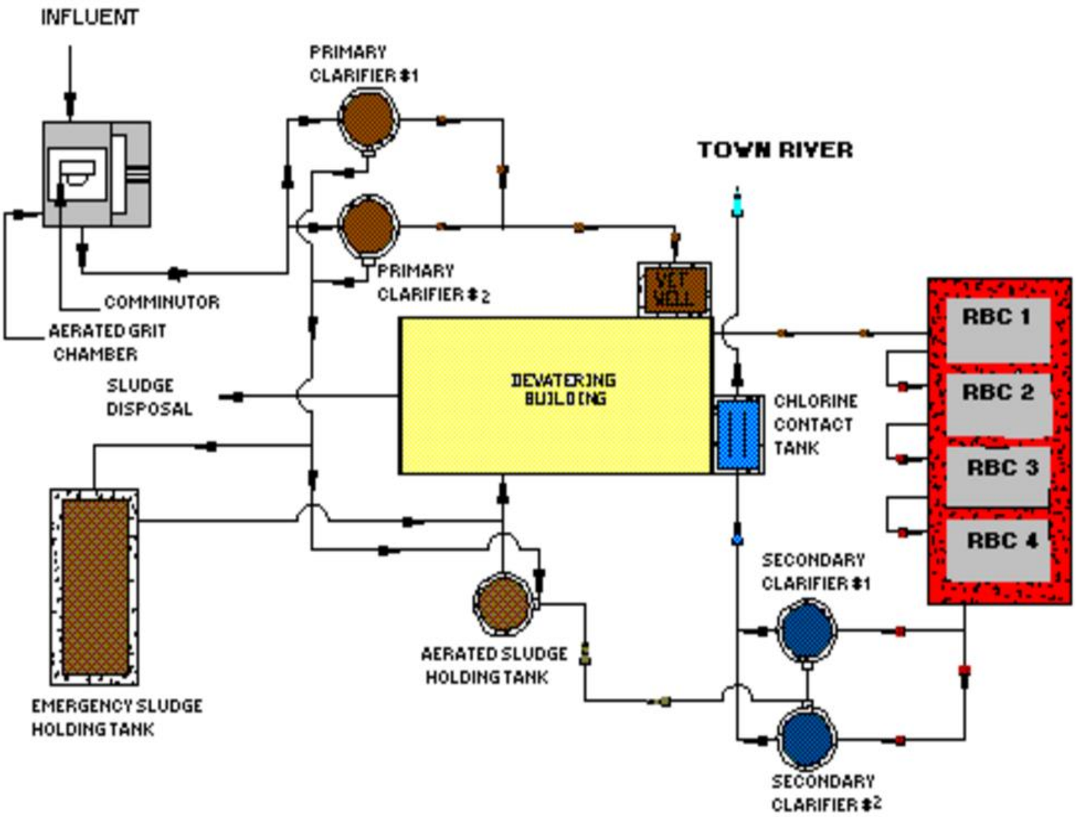

Figure 1.15 : Process flow diagram of RBC (Url-6).

1.2.2 Wastewater management under national regulations

Storm Valley and its water sources are evaluated under sensitive areas. Based on Notice of Selection Methods of Wastewater Treatment Plants, treatment plants must be designed according to wastewater amount and population. Regulation states that in the regions, where the sewer collection system is established and population is less than 84 habitants, on-site treatment units must be maintain. Similarly, independently from the population, regulation states that if a central sewer system is not established, than on-site treatment units must be maintain. When the population of the area stays between 84 and 2000, discharge limits, which are stated in the "Discharge Criteria for Domestic Wastewater to Receiving Environment – Table 21" of Water Pollution Control Regulation, must be met, as shown in Table 1.2.

Especially for the villages up to 500 habitants, subsurface flow constructed wetlands, surface flow constructed wetlands, and aerated lagoons can be considered some of the most applicable treatment technologies. Besides that, land application after septic tanks, overland flow or discharging to surface water sources after sand filtration methods can be considered some other applicable treatment technologies.

Table 1.2 : Discharge criteria (Water Pollution Control Regulation Table 21).

Parameter	Unit	Compost Sample for 2 hours	Compost Sample for 24 hours
BOD_5	mg/L	50	45
COD	mg/L	180	120
SS	mg/L	70	45
pH		6-9	6-9

Under this study, target community population is selected between 100 to 1000 people, and alternative treatment technologies, which will be served to those communities, were evaluated based on Notice of Selection Methods of Wastewater Treatment Plants, published in 20 March 2010.

1.2.3 Discharge water criteria for different wastewater treatment systems

Urban Wastewater Treatment Regulation will be applied for treated water discharge limitations of sensitive areas. Besides, in addition to wastewater discharge standards, in case of stabilization is required for the resultant sludge from treatment plants, sludge disposal technologies must be considered in parallel with the water treatment. Discharge water parameters are given in the Table 1.3, for the wastewater treatment system selection.

Table 1.3 : Discharge parameters for different treatment techniques (TPA, 2010).

Parameter	Unit	Untreated Water	AS	AS + filtration	BNR	BNR + filtration	MBR
SS	mg/L	120-400	5-25	2-8	5-20	1-4	< 2
BOD	mg/L	400-110	5-25	5-20	5-15	1-5	<1-5
COD	mg/L	250-800	40-80	30-70	20-40	20-30	<10-30
NH_4-N	mgNH_4	12-45	1-10	1-6	1-3	1-2	<1-5
Total N	mgTN/L	20-70	15-35	15-35	3-8	2-5	<10
Total P	mgTP/L	4-12	4-10	4-8	1-2	<2	<0.3-5
TDS	mg/L	270-860	500-700	500-700	500-700	500-700	

1.2.4 General Domestic Wastewater Characteristics

Domestic wastewater term is defined as wastewater streams arising from daily activities in the residence's baths, toilets, kitchen etc. Based on the current environmental regulations of Turkey, which named "Water Pollution Control Regulation", domestic wastewater is defined as wastewater stream originating from residential areas in general and mostly from places which domestic and daily human activities are very common such as school, hospital, and hotels etc. which have different pollutant loads, such as strong or weak wastewater streams.

Untreated wastewater streams that discharged directly to the receiving environment (such as river, lake or sea) causes significant damage on habitants via decreasing the oxygen levels. It is determined that when regarding contamination reaches up to the final link of food chain it will create significant negative effects on human health. Like all over the world, this environmental challenge is under controlled thanks to establishment of treatment plants, which became compulsory with regarding laws and regulations in Turkey. In the studies, which aim characterizing of domestic wastewaters and determination of their negative effects on ecosystem when they discharged to environment unrestrainedly, calculations are done by considering various parameters. The production of waste from human activities is unavoidable. A significant part of this waste will end up as wastewater. Wastewater types are classified in the Table 1.4. The quantity and quality of wastewater is determined by many factors. The amount and type of waste produced in households is influenced by the behavior, lifestyle, and standard of living of the inhabitants.

Table 1.4 : Wastewater types (Mogens Henze., 2008).

Wastewaters from society	Wastewater generated internally in treatment plants
Domestic wastewater	Thickener supernatant
Wastewater from institutions	Digester supernatant
Industrial wastewater	Reject water from sludge dewatering
Infiltration into sewers	Drainage water from sludge drying beds
Storm water	Filter wash water
Leachate	Equipment cleaning water
Septic tank wastewater	

The constituents in wastewater can be divided into main categories as seen in Table 1.5. The contribution of constituents can vary strongly.

Table 1.5 : Wastewater components (Henze et al., 2002).

Component	Province	Environmental Effect
Microorganism	Pathogenic bacteria, virus and worms eggs	Risk when bathing and eating shellfish
Biodegradable organic matters	Oxygen depletion in rivers, lakes and fjords	Fish death, odors
Other organic materials	Detergents, pesticides, fat, oil and grease, coloring, solvents, phenols, cyanide	Toxic effect, aesthetic inconveniences, bio accumulation in the food chain
Nutrients	Nitrogen, phosphorus, ammonium	Eutrophication, oxygen depletion, toxic effect
Metals	Hg, Pb, Cd, Cr, Cu, Ni	Toxic effect, bioaccumulation

Table 1.5 (continued): Wastewater components (Henze et al., 2002).

Component	Province	Environmental Effect
Other Inorganic Materials	Acids and bases	Corrosion, toxic effect
Thermal Effects	Hot water	Changing living conditions for flora and fauna
Odor (and taste)	Hydrogen sulphide	Aesthetic inconveniences, toxic effect
Radioactivity	Radioactive materials	Toxic effect, accumulation

Organic matter and nutrient levels of a typical domestic wastewater that can be originated from a dispersed settlement are listed in the Table 1.6 and Table 1.7.

Table 1.6 : Typical organic content of domestic wastewater (Henze et al., 2002).

Parameters	High	Medium	Low	Very Low
BOD				
Final	530	380	230	150
7 days	400	290	170	115
5 days	350	250	150	100
Dissolved	140	100	60	40
Dissolved, readily biodegradable	70	50	30	20
After 2 hours settlement	250	175	110	70
COD, with dichromate				
Total	740	530	320	210
Dissolved	300	210	130	80
Suspended	440	320	190	130
After 2 hours settlement	530	370	230	150
Inert, total	180	130	80	50
Dissolved	30	20	15	10
Suspended	150	110	65	40
Biodegradable, total	560	400	240	160
Rapidly degradable	90	60	40	25
Readily degradable	180	130	75	50
Recalcitrant	290	210	125	85
Heterotrophic biomass	120	90	55	35
Denitrify biomass	80	60	40	25
Eutrophic biomass	1	1	0.5	0.5
COD, with permanganate				
Total	210	150	90	60
TOC	250	180	110	70
Carbohydrate	40	25	15	10
Protein	25	18	11	7
Fatty acid	65	45	25	18
Fat and grease	25	18	11	7
Phenol	100	70	40	30
Phthalate	0.1	0.07	0.05	0.02
DEHP	0.3	0.2	0.015	0.07
DOP	0.6	0.4	0.3	0.15

Table 1.6 (continued): Typical organic content of domestic wastewater (Henze et al., 2002).

Parameters	High	Medium	Low	Very Low
NPE	0.08	0.05	0.03	0.01
PAH	2.5	1.5	0.5	0.2
Detergents	15	10	6	4

Table 1.7 : Typical nutrient levels of domestic wastewater (Henze et al., 2002).

Parameters	High	Medium	Low	Very Low
Total Nitrogen	80	50	30	20
Ammonia Nitrogen	50	30	18	12
Nitrite Nitrogen	0.1	0.1	0.1	0.1
Nitrate Nitrogen	0.5	0.5	0.5	0.5
Organic Nitrogen	30	20	12	8
Kjeldahl Nitrogen	80	50	30	20
Total Phosphorus	14	10	6	4
Ortho-phosphate	10	7	4	3

1.3 Renewable Energy Systems

Renewable energy generation is the key factor for a new kind of energy market, which targets to limit the greenhouse gases and energy insurance for the "uninterrupted availability of energy source at an affordable price" (IEA, 2014, b). Since the end of 2015, energy insufficiency and insecurity is rising for the people all over the world, and 1.2 billion people have not meet with the electricity power, besides that almost 3 billion people counts on the conventional biomass sources for the cooking.

Especially in China and other industrialized countries, health problems arisen from the greenhouse gases and other air pollutants caused by combustion of fossil fuels in the conventional power plants and factories. Because of these environmental and health problems became chronical issues, utilization of renewable energy sources, which are infinite and recuperative effects on the environment, became popular even in these developing countries which have electricity insufficiency. Besides the environmental and health problems of conventional energy sources, they are reaching of their economical productivity limits considering with the production costs and reserve limits. However, despite of that, in 2014, 78% of total consumed electricity is generated from the conventional energy sources (REN21, 2016).

Turkey is classified as developing country and based on the gross domestic product (GDP) figures 16th largest economy of the world and 6th in European Union countries, in 2013 (M. Melikoğlu, 2017). Based on the OECD GDP growth rate figures, Turkey is counted in the fastest growing countries, with 3.11% in 2015 and 3.94% in 2016.

It can be stated from the growth hypothesis that economic development increases electricity and other forms of energy consumption (Alper A. et al., 2016). Since 2007, development of Turkey's electricity consumption is shown in Table 1.8.

Table 1.8 : Development of installed power and consumption (TEİAŞ, 2016).

Year	Population (Million)	Installed Capacity (MW)	Net Electricity Consumption (GWh)	Net Electricity Consumption per capita (kWh)
2007	70.6	40,836	155,135	2198
2008	71.5	41,817	161,948	2264
2009	72.6	44,761	156,894	2162
2010	73.7	49,524	172,051	2334
2011	74.7	52,911	186,100	2490
2012	75.6	57,059	194,923	2577
2013	76.7	64,008	198,045	2583
2014	77.7	69,520	207,375	2669

It can be concluded from the table that when the population increased in a country, net electricity consumption is increased. Besides that, net electricity consumption increment is the key factor, which leads the development of a society.

Increasing electricity demand of Turkey is covered by the various type conventional and renewable electricity generation power plants as listed in Table 1.9.

Table 1.9 : Installed capacity of power plants based on energy source in Turkey at the end of 2015. (M. Melikoğlu, 2017).

Fuel Type	Installed Capacity (MW)	Share (%)	Number of Power Plants
Fuel oil, asphaltite, naphtha, diesel	851	1.2	18
Bituminous coal, lignite	9013	12.3	28
Imported coal	6064	8.3	8
Natural gas, LNG	21,222	29	233
Multiple fuels; solid + liquid	667	0.9	23
Multiple fuels; gas + liquid	3684	5	46
Geothermal	624	0.9	21
Hydro (dam type)	19,077	26.1	109
Hydro (river type)	6791	9.3	451
Wind	4498	6.1	113
Biomass	345	0.5	69
Unlicensed plants	310	0.4	395

1.3.1 Hydroelectric

Almost all kinds of the energy sources are occur from physical and chemical activity of solar irradiation on matter. Hydraulic energy is also occur indirectly from solar irradiation and hydraulic cycle is shown in Figure 1.16. Water evaporates from water sources such as sea, lake, river and regarding water vapor drags through wind effects and finally condenses, because of temperature decreases around the mountainside, in the form of snow and rain in order to feed the river streams. Thanks to that cycle hydraulic energy become a self-regenerating energy source. Electricity generation from those hydraulic sources is achieved through conversion of potential energy into the kinetic energy.

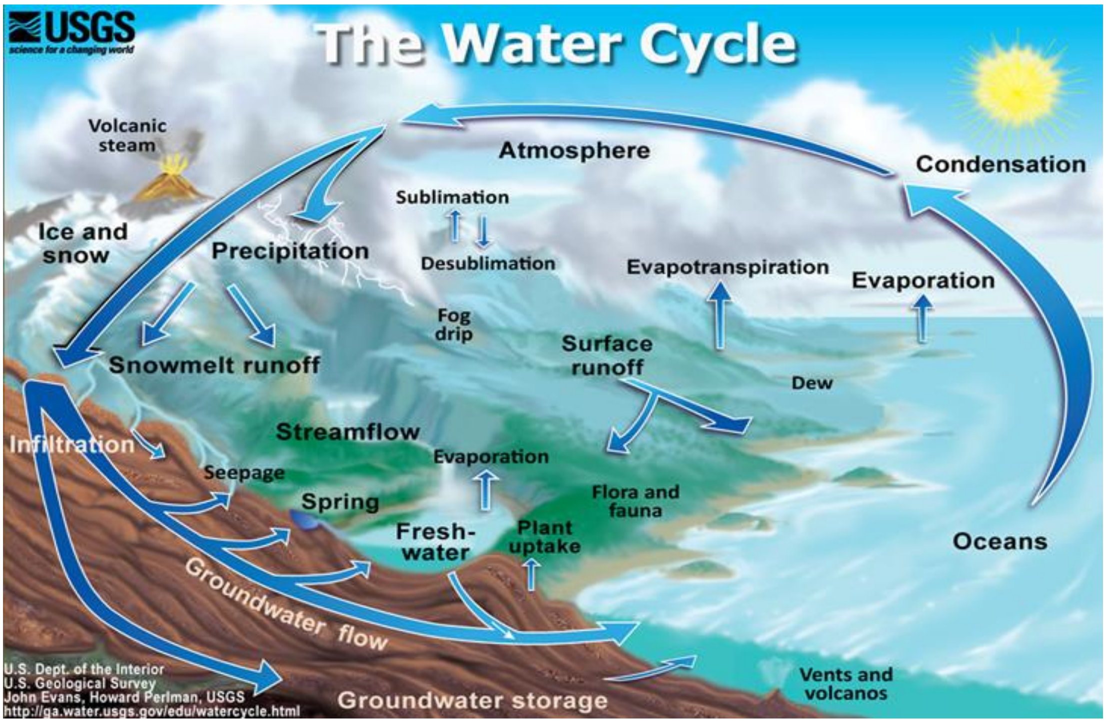

Figure 1.16 : Hydraulic cycle (Url-7).

In the hydraulic systems or hydroelectricity plants, water derives to the hydraulic turbine through a penstock. Accelerated water coming through the penstock hits the turbine blades and transfers the kinetic energy of water to turbine in the form of moment of rotation. A generator connected to the hydraulic turbine via a shaft utilizes this torque and generates alternative or direct current during the rotation of rotor in a stator unit. Generated electricity energy can be used both directly or store in a battery. From that definition it can be concluded that generated energy from a hydro turbine is depended on elevation difference of penstock’s two mouths and flow rate.

1.3.1.1 Hydraulic potential of the World

According to the International Hydropower Association studies world's hydraulic potential is calculated as 14.2 trillion kWh/a. Economical hydraulic capacity is 8.1 trillion kWh/a. Distribution of that values can be shown in Table 1.10.

Table 1.10 : Technical and economical distribution of hydraulic potential of World (Sreenivas S, et al., 2016).

Continent	Technical Capacity		Economical Capacity	
	GWh (10^6)	%	GWh (10^6)	%
Asia	6.8	47.9	3.6	44.4
Europe	1.0	7.0	0.8	9.9
North America	1.7	12.0	1.0	12.3
South America	2.7	19.0	1.6	19.8
Oceania	0.3	2.1	0.1	1.2
Africa	1.8	12.7	1.0	12.3
TOTAL	14.3		8.1	

Technical capacity of the World is assumed as 48% or total potential and Asia has the biggest share of all. After Asia continent hydraulic potential distributes as, respectively, south America, Africa, north America, Europe and Oceanic. Today, only 33.8% of determined economical potential (8.1 trillion kWh/a) is utilized for the electricity generation purpose in the world (J. Araujo et al., 2010).

1.3.1.2 Hydraulic potential of the Turkey

Precipitation index of Turkey is quite irregular and unbalanced in terms of time and location, and it depends on meteorological conditions which varies significantly through years. Resulting from that it is inevitable to have significant variations in the hydroelectric generation potential.

According to the observed meteorological data of many years reflects that annual precipitation average is around 643 mm in Turkey and that equals to 501 m^3 water in total. Only 186 m^3 of this total water can derive to seas and lakes in closed basins through rivers with different sizes. According to the studies have been made, 720 numbers of different dams must be constructed in order to regulate the rivers in order to maximize the utilization of regarding water potential. When Turkey's topography and morphological structure considered it can be stated that Turkey has one of the largest hydroelectricity potential of the World in terms of flow rate and head height.

Before the evaluation of Turkey’s hydroelectric potential, technical feasibility and economic feasibility terms must be clarify. Technical feasibility is the fact that there is no eligible or significant engineering problem, which makes construction of the project impossible or extremely hard. Economic feasibility is the fact that annual operational costs of the project is lower than the annual incomes of the project.

Hydroelectricity potential of Turkey must be consider under three section, such as gross potential, technical potential and technical and economic potential. Gross Potential is the calculation of theoretical hydraulic sources considering existing total head height and average flow rate, and excluding technical and economic feasibility of hydroelectric generation potential. Turkey’s gross hydroelectric potential is around 430 billion kWh/a. Technical Potential is the total electricity generation potential from technically available hydraulic sources without any economic feasibility concern. Turkey’s technical hydraulic potential is around 430 billion kWh. Technical and Economic Potential is the total electricity generation potential can be achieved from both technically and economically doable hydraulic sources. Turkey’s technical and economical hydroelectricity potential is around 124.5 kWh (DSİ, 2015).

Today, Turkey utilizes only 48.5 billion kWh of its technical and economic hydroelectricity potential determined as 124.5 billion kWh. In most of the developed countries, utilization rate of technical and economic hydraulic potential is significantly high but when it comes to Turkey this rate is almost 39% of technical and economic hydraulic potential. Primary reason is hydroelectricity power plants, especially dam types, require higher investment unit costs comparing with the other energy sources.

Higher investment costs and longer construction periods can be counted as some of the disadvantages of hydroelectricity power plants. Besides that especially due to the negative effects on environment, most of the hydroelectricity power plant projects cannot be realized because of organized habitants by both non-governmental organizations and cancellation decision of related ministries to required permissions and reports etc. In parallel with their higher investment costs, hydraulic power plants has longer operation life compared with thermic power plants. Technical life span of thermic and natural gas fired power plants is almost 25 years, but when it comes to hydroelectric power plants this increases up to 40 or even 50 years. These values are for feasibility studies, of course thanks to some rehabilitation studies technical operation life of hydroelectricity power plants can be increase up to even 100 years.

Biggest technical advantage of hydroelectricity power plants is short start-up times comparing with the other power plant types, especially during the peak hours. In generally, hydroelectricity power plants needs only a couple of minutes, besides that when it comes to thermic power plants this time period increases up to hours.

1.3.1.3 Classification of hydroelectricity power plants

Hydroelectricity power plants are classified under four main topic according to their installed power; large scale, medium scale, small scale and micro scale.

Hydroelectricity power plants with 50 MW and bigger installed power are considered under Large Scale plants. Energy requirement for illumination of one resident is almost 200 W, from that point electricity demand for illumination of 50,000 residents can be met from a large scale hydroelectricity power plant with 50 MW installed capacity.

Hydroelectricity power plants which has minimum 10 MW, maximum 50 MW installed capacity can be classified under medium scale hydraulic power plants.

Hydroelectricity power plants which have installed capacity between 101 kW to 10 MW are classified under small scale hydraulic plants and has less contribution to national electricity grid.

In generally micro scaled hydroelectricity power plants has no contribution to national electricity grid. Utilization of these micro scale plants can be observed generally rural areas, which have no grid connection. Installed power of these system is designed as enough as to meet the electricity demand of a house or farm. Power scale is varies between 200 W to 100 kW enough to meet the energy requirement for illumination, cooking and heating purposes. Electricity generation is not the main target for micro hydraulic systems always, in some cases, such as mills, energy derived from water flow can be utilize in the mechanical form.

In the energy literature big hydroelectricity power plants, especially dam types, are considered under the conventional energy systems, besides that small hydroelectricity power plants, especially river types, are considered under renewable energy systems.

Another classification is related with the water storage, defined as dam type and river type projects. In the Figure 1.17, main parts of dam type hydraulic systems can be seen. In the storage type systems water stream is blocked via a dam. This system has two main advantage; excessive water during the rainy months can be stored in order to utilize it during the dry season. Another advantage of storage can be achieved via a successful reservoir management and thanks to that energy generation can be shift to "peak time" in order to sell electricity from the most expensive price.

Dam type hydroelectricity power plants are generally complex to operate and they have higher investment costs relatively. Especially during the operation, dam type power plants have various problems. For instance, reservoir area is get full due to sand and clay in a time. Discharge of related alluvial deposit from the reservoir area is both expensive action and very complex. Due to get full with the alluvial material dams finally complete their life cycle in time.

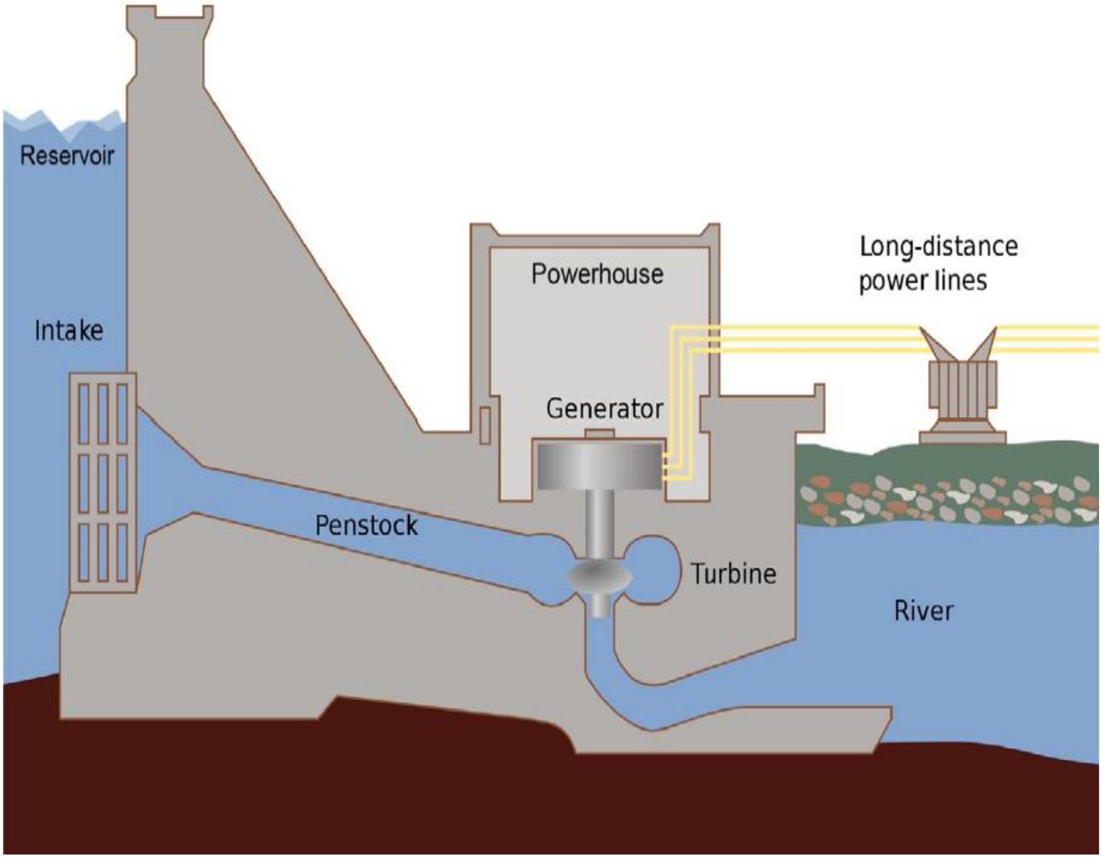

Figure 1.17 : Dam type hydroelectricity plant (Url-8).

In the river type projects main equipment and units are regulator unit, power tunnel, forebay, penstock and turbine, as seen in Figure 1.18. Water is collected from river stream by regulator unit and derived to forebay via power tunnel. Forebay has several purposes such as buffer stock in order to achieve smooth power generation and a settling point to eliminate excessive sand and gravel in the derived water from the stream. In addition, residual water that cannot be utilize electricity generation purpose is derived from spillway especially during flood seasons and maintenance periods.

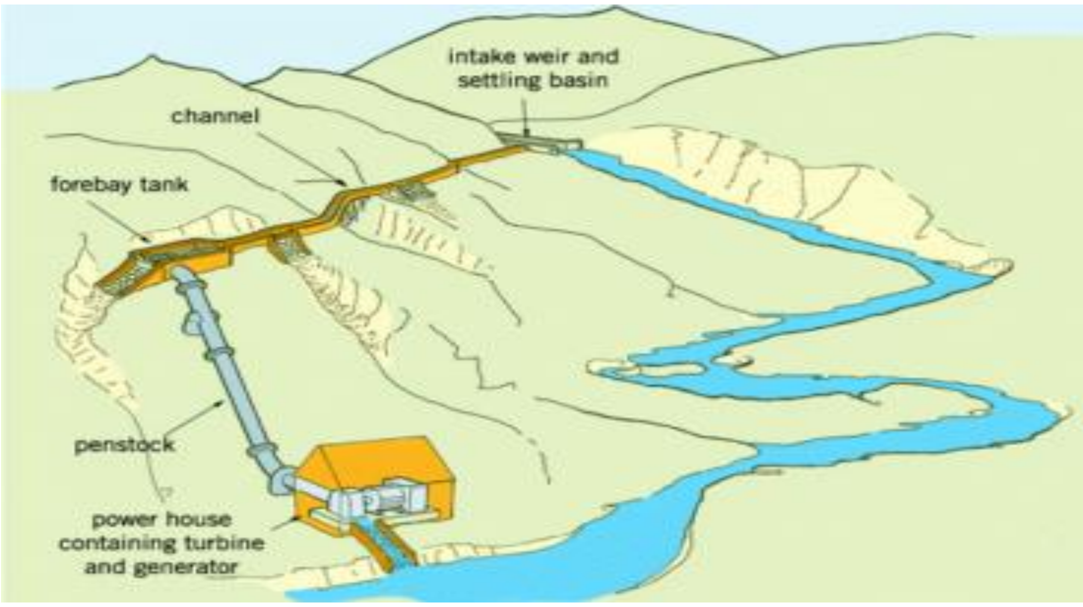

Figure 1.18 : River type hydroelectricity plant (Url-9).

From forebay, stored water is derived to hydraulic turbine and generator set via a penstock. Potential energy of water is transferred in to the kinetic energy and finally that energy creates moment of rotation on the turbine shaft.

One of the biggest disadvantage of these systems is that they cannot achieve minimum flow rate to operate a turbine in a dry season. Besides that, biggest advantage is their relatively low investment costs. In addition, for the environmental point of view, they have relatively low negative effect on riverbed.

1.3.1.4 General design concerns of a hydroelectricity plant

Capacity and demand research

When energy demand is occurred then one must answer the question “how many kWh electricity for what purpose”. In addition, unit demand level of each consumer must be determined. In general, micro hydraulic systems are designed for rural areas in order to meet the energy requirements of residents, which have not complex devices. Required investment cost for design and construction works are met by habitants themselves.

Source potential research

For that step, hydraulic potential of project site is determined. Flow rate and deviations of water stream is monitored annual bases, location of regulator structure is confirmed considering efficiency and cost. In addition, water utilization for irrigation purpose from the water stream must be considered.

Pre-feasibility study

In that stage project cost can be calculated roughly. A pre-feasibility study is generally comparison of different alternatives in order to meet the regarding electricity requirement and reveals their advantages and disadvantages clearly. In addition, in that step, comparison of electricity demand and hydraulic specifications of regarding basin is executed.

For the electricity generation, one of the most important design parameter is head height of the plant. Based on the classification to head height, hydraulic plants by which head height varies between 2 to 20 m named “low head height”, 20 to 150 m named “medium head height” and more than 150 m named “high head height”. In generally, due to their low unit cost medium and high head height systems are preferred (B. Towler, 2014). Relation between head height, flowrate and power is defined with the following Equation 1.1;

$$P_e = \rho . g \cdot Q \cdot H_o \cdot \eta_{turbine} \tag{1.1}$$

In the equation P_e power derived from turbine shaft (W), ρ water density (1.000 kg/m^3), g gravitational acceleration (9.81 m/s^2), H_o net head height (calculated from elevation difference of penstock, m), Q flow rate (m^3/s), $\eta_{turbine}$ total efficiency.

1.3.1.5 Hydraulic turbines

A hydraulic turbine can be defined as a machine that converts hydraulic energy of a fluid into mechanical energy. Every project has its own characteristics and turbine selection must be done according to those case specific characteristics, such as head level and flow rate. Specific speed of a turbine “n_s” defines as “revolution per minute” of a turbine, which generates 1 HP from its shaft with its best performance and 1 m head level, H_o net head height (calculated from elevation difference of penstock, m). In the Table 1.11, turbine types vs. specific speed can be seen.

Table 1.11 : Turbine classification based on specific speed (S. Murthy et al., 2016).

Turbine Type	Specific Speed
Pelton turbine	12-30
Turgo turbine	20-70
Cross-flow turbine	20-80
Francis turbine	80-400
Uskur or Kaplan turbine	340-1000

Specific speed calculation is depends on the Equation 1.2;

$$n_s = n \cdot p_e^{0.5} / H_s^{1.25} \tag{1.2}$$

During the turbine selection speed parameter of turbine and generator has a great importance. Another selection criteria is either turbine can be operated under partial flow rate or not. Generally, it must be avoid from 3:1 ratio, at least 2.5:1 and less must be selected (J. Araujo et al., 2010). If the generator rotation is 1500 RPM then turbine revolution per minute value must be 500 or higher. In case of turbine speed and generator shaft rotation speed are equal than turbine is connected directly to generator shaft through a grip. In general, micro turbine system units are purchased in separate.

Hydraulic turbines are classified according to the head height such as high, medium and low head machines. Turbines can be classified according to their operation principals. In impulse turbines inlet and outlet pressure of hydraulic turbine is equal to atmospheric pressure. In that case, kinetic energy of water is utilized. When it comes to reaction turbines, there is a pressure difference between runner inlet and outlet area. Impulse and reaction turbine head range is given in Table 1.12.

Table 1.12 : Head range of impulse and reaction turbines (O. D. Thapar, 2010).

Turbine Runner	Head		
	High	Medium	Low
Impulse	Pelton	Cross flow	Cross flow
	Turgo	Turgo	
	Pelton	Pelton	
Reaction		Francis	Uskur
		Pump turbine	Kaplan

In general, impulse turbines are cheaper than reaction turbines. Turbines that are designed to use in micro systems are not suitable for variable flow rates. In the big hydraulic systems that kind of adjustment units are existent, in general. For instance in the multi nozzle Pelton turbines flow rate adjustment can be done through shutting down some of the nozzles.

In the large hydraulic systems, Pelton turbines can be used when the gross head is bigger than 150 m. Also for the micro hydraulic systems, Pelton turbines can be use. For instance, a Pelton turbine can be used places where have 20 m head in order to generate 1 kW power. In the Figure 1.19 main parts of a Pelton turbine can be seen. When the installed power increased runner radius of these turbines also increases and turbine rotation rate is decreases. If radius of runner and low speed are not generates problem than a Pelton turbine can be used for the projects with the low head levels.

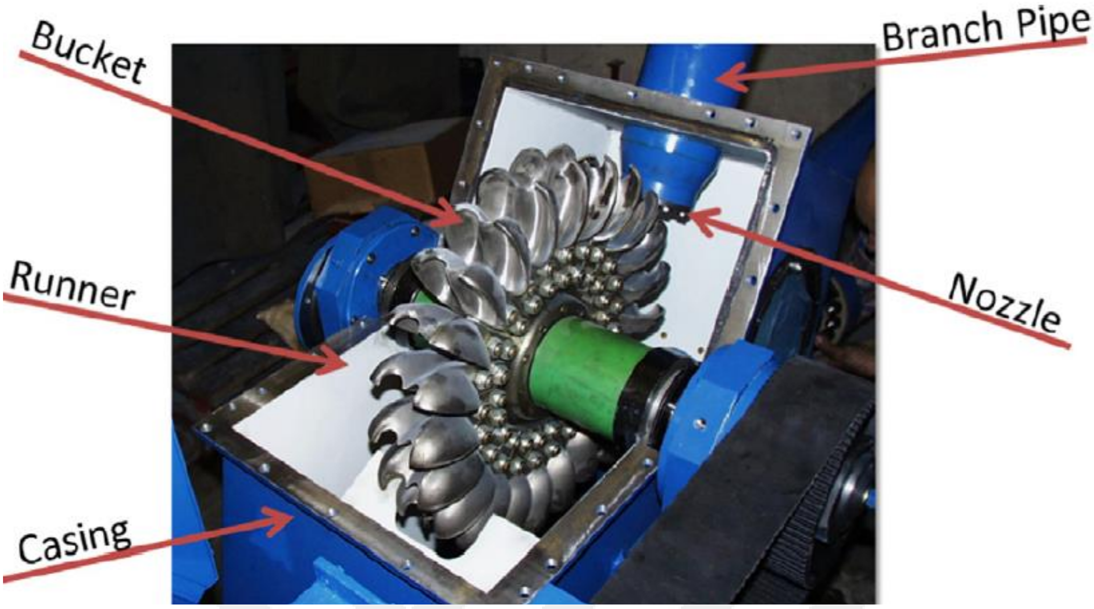

Figure 1.19 : Main parts of a Pelton turbine (A. ŽIDONIS et al., 2015).

Turbines that will be utilized for the planned pilot projects, which have low head and small installed power, must have a simple and cheap operation and maintenance characteristics because of necessity to operate by the local sources. On the other hand, main structures of the turbine unit can be found through local market. From that point, cross-flow turbines have a major advantage in that kind of rural areas. Construction of those turbines are also very simple compared with the others.

1.3.2 Wind

Since the ancient times people use wind energy in order to convert it into the mechanical energy. For instance, 1700 B.C. King of Babylonia used wind energy to irrigate agricultural lands in Mesopotamia (Url-10). However, the electricity generation through wind power is relatively young technology. Until recent years, wind technology has not a significant development because of low fossil fuel prices, but especially during the petroleum crisis in 1970s, it was remembered again. After the developments in 1980s, wind power plants become engineering products from the point of economy, environment and energy view. Investments in wind energy generators turbine technology are increased exponentially through mass production of wind turbines with different technologies and installations that are spread all over the world. Wind power plants, which are installed on the ground, gave place to offshore wind turbines that are installed on the ocean surface (C. Ng et al., 2016). Detailed studies are in progress for mechanic, electrical, electronical, aerodynamic and control algorithms field of wind turbine technology.

In 1958, Poul la Cour from Denmark, developed a wind turbine model which generates direct current. Johannes Juul, one of students of Poul la Cour, modelled an alternative current concept named “Danish Concept” for the grid feed. Almost half of the wind turbines under operation today are based on that concept (Url-10).

End of 1970s, small-scale wind turbine generators, compared with other alternative energy technologies, catch investor’s remarkable attention because of their relatively low investment costs and developed technologies. Between 1979 – 1985 thanks to governmental credits and subventions more than 4500 wind turbines are installed which have various installed power 1 to 25 kW. Today, 3 to 5 MW onshore turbines and 10 MW offshore wind turbines can be found in the commercial turbine market (Url-11).

In parallel with the small-scale wind turbines, some of the countries decided to make investments on large-scale wind turbines in order to meet the market demand. Especially in Germany significant amount of money was spent for the development of large-scale turbines but due to technical problems were faced in governmental subventions were cut off. Second large scale wind turbine manufacturing trial was also failed because of indifference of investors, even it was successful in terms of cost end performance (S.L. Dixon et al., 2014).

In August 1992, first 500 kW installed power wind turbine were started to operate manufactured by Tacke Windtechnik. Following that, E40 by Enercon and other European manufacturers’ turbines released to the wind market. After that blade manufacturing with 37m and 46m rotor diameters were started by the turbine companies in order to develop 500 kW turbines and thanks to that increment in rotor diameters 600 kW turbines were able to manufactured, especially for the areas where the wind speed is low (S.A. Kalogirou, 2014).

For the high-energy potential compared with the inland areas offshore wind power plant constructions are initiated on the surface of oceans (C. Ng et al., 2016). Because of they are installed on the ocean surface installation, operation and maintenance costs are significantly higher than on land turbines. Extreme weather conditions makes the routine maintenance works of these turbines very difficult, and sometimes transportation of maintenance team to the turbine location becomes impossible.

1.3.2.1 Global potential for wind energy

It is focused here on the potential energy that could be intercepted and converted to electricity by a globally distributed array of wind turbines, the distribution and properties of which were described above. The distribution of potential power is illustrated in Table 1.13.

Table 1.13 : Installed power of Europe and World total by the end of 2015 (Url-12).

Region	End of 2014 (MW)	End of 2015 (MW)
Africa and Middle East	2,536	3,489
Asia	141,973	175,831
Europa	134,251	147,771
Latin America and Caribbean	8,568	12,220
North America	77,935	88,749
Pacific Region	4,442	4,823
World Total	369,705	432,419

1.3.2.2 Wind energy potential in Turkey

Wind energy potential map of Turkey is prepared by General Directorate of Renewable Energy, as shown in Figure 1.22, and this map has a great importance and valuable database especially for the wind power project investors.

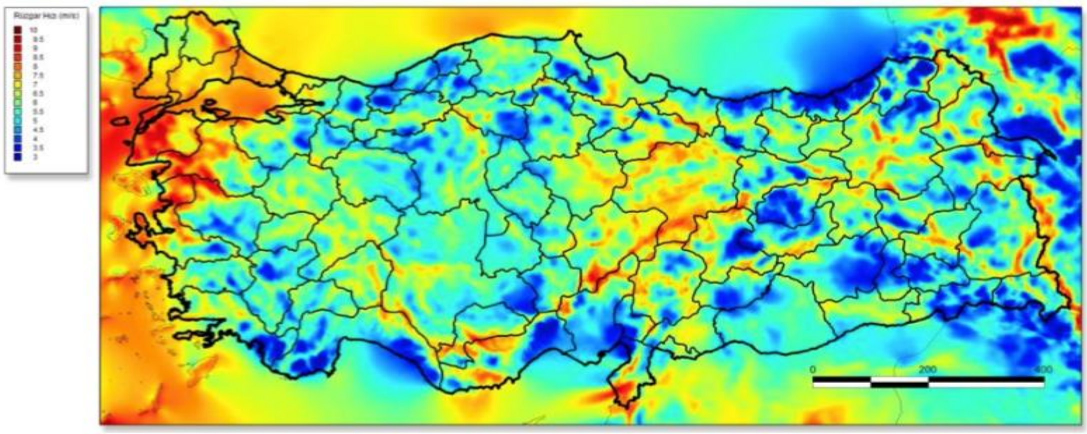

Figure 1.20 : Wind energy potential map of Turkey (EIE, 2016).

It is indicated that in Turkey total installed wind power capacity is 2.312 MW in 2012; it is rising for upcoming years as 2.958 MW in 2013, as 3.762 MW in 2014, as 4,718 MW in 2015. By the end of 2016, when total wind energy installed has been reaching to 5.146 MW, and 1.868 MW new capacity will be added from continued wind power plants (TUREB, 2016). Aegean and Marmara Regions have the largest wind energy potential with the 74.82 % of installed wind power plants of Turkey. The ranking on the basis of cities does not change this year. Balıkesir is the first city within 923 MW wind power installed capacities; Izmir and Manisa take second and third places respectively with 807 MW and 574 MW, as shown in Figure 1.23.

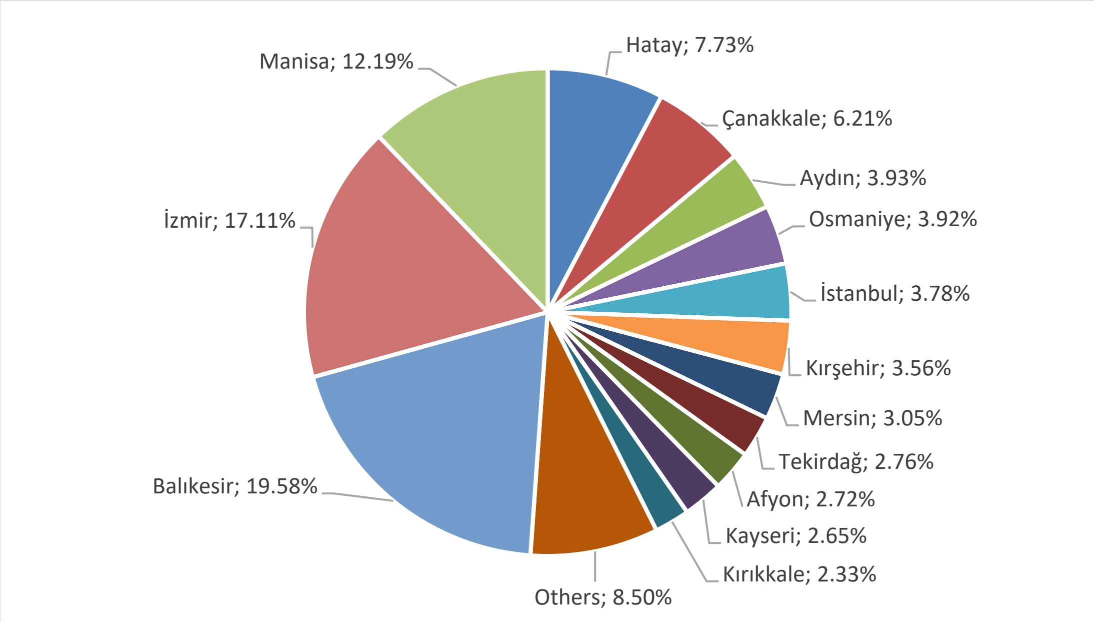

Figure 1.21 : Cities according to the operational wind power plants (G. Köktürk et al. 2017).

1.3.2.3 Wind energy and electricity generation

Wind energy can be defined as kinetic energy of air stream, which forms wind. Wind turbines are the mechanical systems, which convert kinetic energy of wind stream to mechanical energy first, and then to electrical energy, and energy conversion calculations are depends on the Equation 1.3;

$$E = \frac{1}{2} \cdot m \cdot V^2 \qquad (1.3)$$

In the equation, m reflects mass of air, and V velocity of air. To calculate the mass of air Equation 1.4 is required;

$$m = g \cdot V_h \qquad (1.4)$$

In the equation, g reflects air density and V_h for volume of air. To calculate the volume of air Equation 1.5 is required;

$$V_h = V \cdot S \cdot t \tag{1.5}$$

In the equation, V reflects air velocity, S for swept area and t for unit time. From the definition of power, which says kinetic energy per unit time, power Equation 1.6 can be found;

$$P = \frac{1}{2} \cdot g \cdot S \cdot V^3 \tag{1.6}$$

Wind power is directly proportional with the cube of wind speed (S.A. Kalogirou, 2014).

1.3.2.4 Types of wind turbines

Wind turbines are categorized according to their rotation axis; horizontal axis wind turbines and vertical axis wind turbines (P. Breeze, 2016).

Horizontal axis wind turbines

Rotation axis of these wind turbine generators are in parallel with the wind direction, and blades are vertical to wind direction. Total mechanical efficiency of these turbines can be reach up to 45%. Hub height of a horizontal axis wind turbine must be minimum 20 m from the ground and 10 m higher than any obstacles around. There are three types of horizontal axis wind turbines; single, two and three bladed turbines.

The basic motivation of manufacturing a single bladed wind turbine is higher rotation speed of turbine shaft and thanks to that rotational speed decrease in total mass of the machine and torque. In additional to that rotor blade must be balanced with a balance weight in order to maintain a smooth rotation movement and to decrease structural loads on the surface of blade. One of the biggest disadvantage of this single bladed wind turbine is very high noise levels because of 120 m/s tip speed of blade. Due to this disadvantage single bladed turbines could not became commercially popular.

In order to decrease the rotor cost two bladed wind turbines are manufactured. In many countries, these two bladed wind turbines with 10 to 100m rotor diameter are designed as prototypes and operated in Europe and USA. Balance of two bladed turbine is more accurate than a single bladed turbine but to prevent the dynamic loads additional technical efforts are required and this increases the system costs. Compared with the three bladed turbines biggest advantage is the higher tip speed, which makes these turbines applicable to low wind speed areas. On the other hand, this high tip speed creates significant noise levels.

Three bladed modern wind turbine generators are used all over the world. Main reason of utilization three-blade concept is a stable torque compared with the others. Because of low tip speed, 70 m/s, they have limited noise problems and that makes them commercially feasible.

Vertical axis wind turbines

Rotation axis and blades of these wind turbines are vertical to wind direction. Vertical axis wind turbines can accept wind streams from any directions and thanks to that, they do not need any yaw mechanism, which turns the turbine according to wind direction, but the cut in operations are not reliable. General efficiency of these turbines is almost 35%. Generators and gearbox units can be established on the ground level and because of that, they do not need high tower structures compared with the horizontal axis turbines. In generally, these turbines are manufactured for the areas with low wind speeds and water pump purpose. For the higher wind speed, these turbines are became inefficient. 500 kW power can be obtained from a turbine with 5m rotor diameter.

1.3.2.5 Comparison of wind turbines

Wind turbine specifications have a great importance during a wind energy power plant construction in order to avoid significant losses during energy generation. Wind turbine generators (WTG) can be manufactured according to blade types, rotation axis, wind speed, terrain and energy utilization area (Y. Yu et al., 2016). In the Table 1.14, wind turbines are compared considering their installed power.

Table 1.14 : Comparison of WTGs according to installed power.

Type	Utilization Area	Unit Power (kW)	Feed-in Point	Storage	Maintenance Cost	Installation Cost
Large	Industrial	500-2000	Grid	No	High	High
Medium	Industrial	50-500	Grid	No	Low	Low
Small	Domestic	5-50	Off-grid	Yes	Very Low	Low

When it comes to comparison according to the blade types, considering with the cost, aesthetical concerns, noise, cut-in speed etc. details can be seen in the Table 1.15.

Table 1.15 : Comparison of WTGs according to blade types.

	Horizontal Axis				Vertical Axis	
	Single Blade	Two Blade	Three Blade	Multi Blade	Savonius	Darrierus
Cost	High	High	Low	Low	Low	Low
Aesthetical	Bad	Bad	Good	Good	Good	Good
Noise	High	High	Low	Low	Low	Low
Cut-in Speed	High	Low	High	Low	Low	Low
Tower	Yes	Yes	Yes	Yes	No	No
Commercial Application	No	No	Yes	Yes	Very Limited	Very Limited

Terrain structure, plantation and high-rise structures are considered significant negative effects on wind speed. For the hills, wind turbines are installed on the highest point, but when it comes to natural passages such as valley or canyons turbines must be installed considering with the wind direction.

1.3.3 Solar

In 1839, Becquerel was observed conversion of solar irradiation into the electricity, which is nominated photovoltaic effect in generally (Parida et al., 2011). In United States 1954, Bell Phone Laboratories invented first photovoltaic solar cells (L.A. Lamont, 2012). Nevertheless, the utilization of solar energy for the electricity generation purpose was very limited because of significantly high investment cost requirement compared with the petroleum and natural gas. However, with the petroleum crisis between 1974 and 1978 energy shortages became known and that conjuncture became an opportunity for solar energy researches (C. Binz et al., 2016).

World energy crisis effected technological developments and future of solar energy and two major application area dominated researches and solar market, which are HVAC of residential areas with solar energy and environmental friendly electricity generation with photovoltaic or thermal technologies (P. Sampaio et al., 2017).

1.3.3.1 Global potential for solar energy

Photovoltaic market expanded almost 40% during last decade. Total PV installed power increased from 4 GW in 2005 to 228 GW in 2015, and by the end of 2009, 70%

of total PV installed power is established in Europe, as seen in Figure 1.24 (A.J. Waldau, 2013).

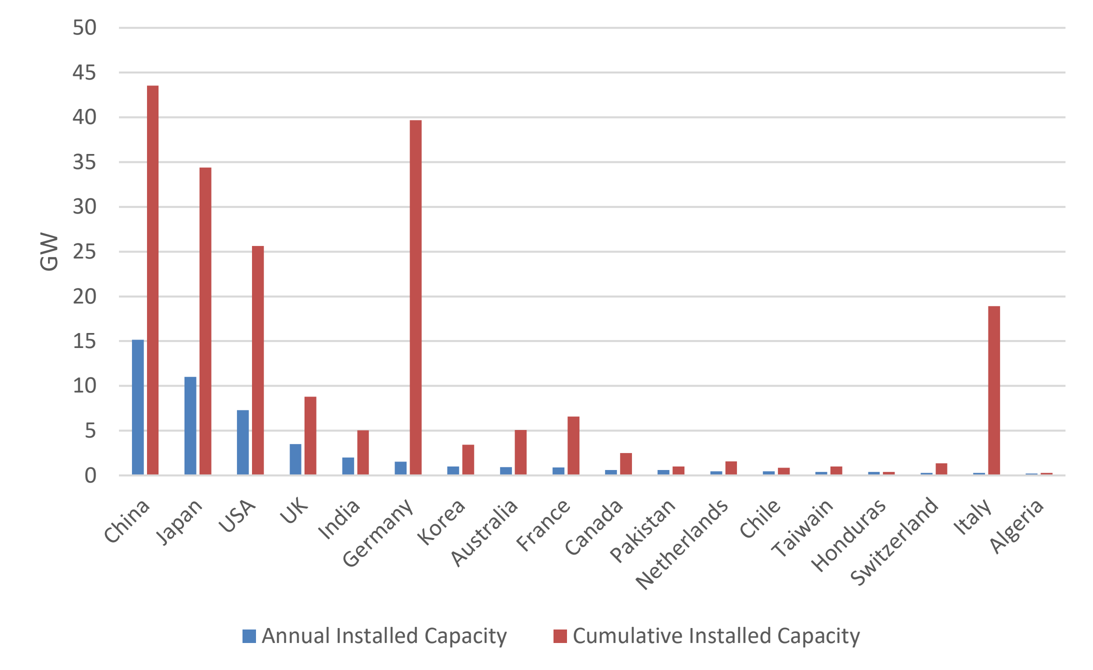

Figure 1.22 : Annual PV installed and cumulative installed power of countries, 2015.

World's PV market expended 15% in 2009 in spite of global economic crisis. By the end of 2009, global PV installed capacity reached up to 22.9 GW. Almost 10 GW of this installed capacity comes from Germany and it became world's largest PV market. The 24 IEA-PVPS countries represented 123.2 GW of cumulative PV installations together, mostly grid-connected, at the end of 2013 (IAE, 2014, a).

Other than European solar market, Japan and USA are the second two major PV market with their 484 MW and 475 MW installed power. According to the scenario that considers additional subventions that are come into play, in 2014, World's PV installed power expected to reach up to almost 30 GW (H. Zou, et al. 2016).

According to the International Energy Agency's ETP BLUE Map scenario it is expected that by the end of 2050 solar energy will be responsible of 11% of global electricity generation and total installed power will be 3,000 GW and 4,500 TWh annual electricity generation will be executed. According to that report, cumulative PV capacity will increase up to 200 GW in 2020, and 900 GW in 2030. In parallel with that thanks to the 4,500 TWh electricity generation from solar power annually 2.3 Gt CO_2 emission will be able to prevent (IEA, 2010).

1.3.3.2 Solar energy potential of Turkey

Studies in the field of solar energy technologies are began in 1960s. Istanbul Technical University, Middle East Technical University and Ankara University are the pioneers of scientific studies performed. First local manufactured solar thermal water heaters are manufactured in these times.

In Turkey, studies on theoretical and practical sciences of solar technologies are performed in various fields. Especially local manufacturing of solar thermal heaters are become widespread. By the end of 2012, in Turkey, total solar thermal collector area is calculated as 18,640,000 m^2 (D. Eryener et al. 2016). Annual production capacity of flat solar collector system in Turkey calculated as 1,164,000 m^2 and solar thermal collector with vacuum tube system production capacity calculated as 57,600 m^2 (Bulut H. et al., 2006).

Turkey has a geographical advantage for the solar energy compared with the other countries. Turkey's average sunshine duration is calculated as 2640 h (7.2 h per day) and average global solar irradiation level is 1311 kWh/m^2-a according to the studies made by EIE based on the measurements for the sunshine duration and radiation level data collected by General Directorate of Meteorology between 1966 and 1982 (A. Batman et al., 2012). Monthly basis solar energy potential and sunshine duration values are given in Table 1.16.

Table 1.16 : Solar energy potential and sunshine duration of Turkey (Url-13).

Months	Monthly Solar Irradiation		Sunshine Duration
	kcal/cm^2-month	kWh/m^2-month	Hours/month
January	4.45	51.75	103
February	5.44	63.27	115
March	8.31	96.65	165
April	10.51	122.23	197
May	13.23	153.86	273
June	14.51	168.75	325
July	15.08	175.38	365
August	13.62	158.40	343
September	10.60	123.28	280
October	7.73	89.90	214
November	5.23	60.82	157
December	4.03	46.87	103
Total	112.74	1311	2640

Southeastern part of Turkey has the highest sunshine duration time of the whole country and Mediterranean region is in the second position (F. Dinçer, 2011). Solar energy potential and sunshine duration of Turkey based on the regions are listed in Table 1.17.

Table 1.17 : Regional distribution of solar energy potential of Turkey (Url-13).

Region	Global Solar Energy kWh/m^2-year	Sunshine Duration Hours/year
Southeastern Anatolia	1460	2993
Mediterranean	1390	2956
Eastern Anatolia	1365	2664
Central Anatolia	1314	2628
Aegean Region	1304	2738
Marmara Region	1168	2409
Black Sea Region	1120	1971

Besides that according to the studies and measurements were performed locally proved that Turkey's real solar potential higher than the calculated data above. Based on the collected measurement data since 1992 it was assumed that on site solar potential of Turkey will be almost 25% higher than the calculated one. According to the latest measurement data and satellite data Solar Energy Potential Map of Turkey is generated by general directorate of electrical power resources survey and development administration department of Turkish Ministry of Energy and Natural Resources, as seen in Figure 1.25.

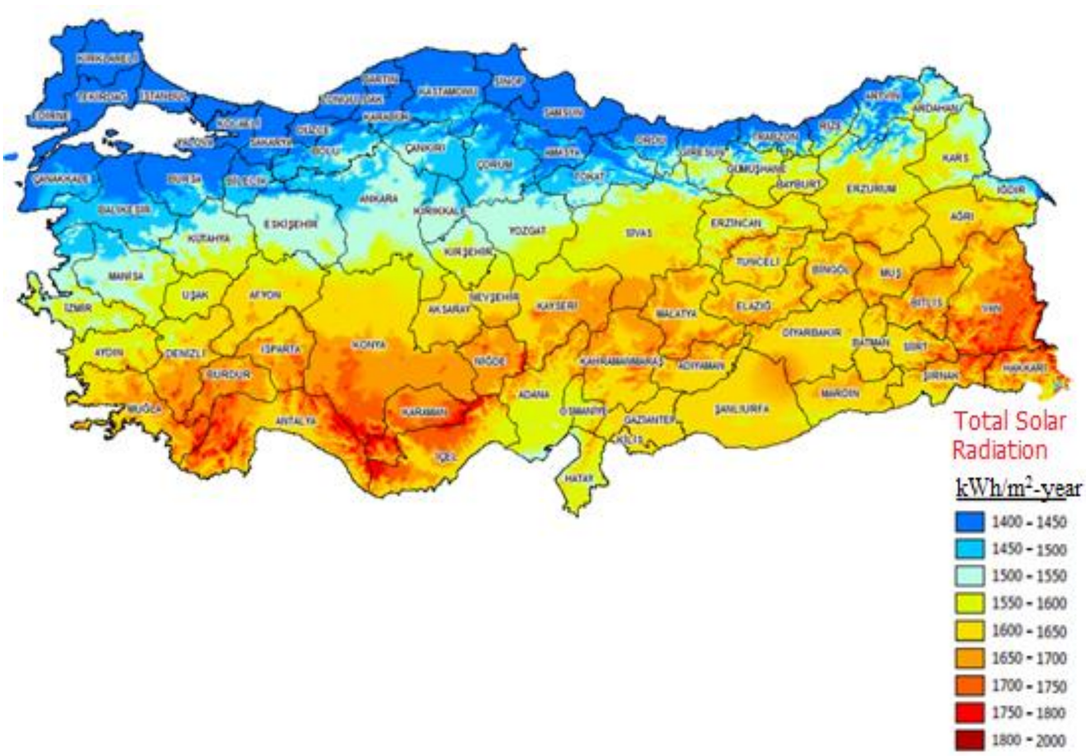

Figure 1.23 : Solar energy potential map – GEPA (Url-14).

1.3.3.3 Solar energy technologies

Solar energy technologies are divided into two main sections, which are photovoltaic systems and solar thermal systems.

Photovoltaic systems

Photovoltaic systems converts sunlight into direct current electricity through a chemical reaction in the semi-conductor material. Because of its modular structure, quite operation and simple installation procedure this renewable electricity generation method is suited to wide range of application area both in domestic and also commercial applications. Thanks to their modular structure these photovoltaic modules can be connected each other in series or in parallel and a certain level of current and voltage range can obtained. Because of its chemical nature, photovoltaic modules generate direct current (DC) electricity. Generated electricity can be used directly illumination purpose, can be converted into mechanical energy via a DC motors, can be stored in batteries or can be converted into the alternative current (AC) via inverters. Major PV technologies are crystalline silicon systems, thin film systems and the new generation type solar cells which are dye-sensitized solar cells, organic solar cells etc. (H. Zou et al., 2016).

Crystalline silicon systems

Crystalline silicon cells are the first generation solar cells and have been dominated the solar market in all over the world because of their low cost and relatively high conversion efficiency (P. Sampaio et al., 2017). In opposition to the efficiency increases in the PV systems, their thickness decreases as the time passed by. Thickness of the wafers was 0.32 mm, but 0.15 mm in 2010. Average efficiency of commercial poly-crystalline modules varies between 12% and 14%, however mono-crystalline' varies between 15% and 17.5% (M.K. Hairat, 2017). Recently, average efficiency is 15.5% and wafer thickness is around 0.13 mm. Average efficiency of mono-crystalline modules is expected as around 23% by the end of 2020 and in the long term it is expected as around 25%. Polycrystalline silicon modules are relatively cheap and has lower efficiency compared with the monocrystalline silicon modules due to their less stable atomic structure. It is expected that in the long term efficiency of polysilicon modules will be increased up to 21% (Kato K. et al., 2011).

Conventional polysilicon price was around 400 $/kg in 2008, however it was decreased dramatically to 23 $/kg in 2014 (R. Fu, et al. 2015). Global polysilicon production increased from 193,910 metric tons in 2009 to 375,970 metric tons in 2013. Silicon manufacturing has a very complex and expensive production procedure, and requires a deep expertise. In order to manufacture 1 MW solar cell almost 5.3 tons of polysilicon material is required in 2014, but this was 6 tons in 2008. When it comes to 20 GW that requirement raises up to 106,000 tons of polysilicon material (R. Fu, et al. 2015).

In 2008 seven largest polysilicon manufactures are Hemlock Semiconductor (USA), Wacker Chemie (Germany), OCI Chemical (Korea), REC (Holland), Tokuyama (Japan), MEMC (USA), GCL Poly (China), LDK Solar (China), Mitsubishi (USA), Sumitomo (Japan), and the total manufacturing capacity of these companies is 50,000 tons and 94,000 tons in 2010. Also in 2008, manufacturing capacity of new entrants to the market is increased from 24,000 tons to 125,000 tons in 2010 (Url-15).

Thin film technology

Thin film solar cells are comprised of an elastic material, which makes them available to use integrated solar systems (H. Zou et al., 2016). There are three main branch of thin film technology, which are Amorphous silicon (a-Si) and Micro-morph silicon (μc-Si), Polycrystalline semiconductors – cadmium telluride (CdTe) and Indium selenide “Copper indium selenide (CIS) – Copper indium gallium selenide (CIGS)” (P. Sampaioa, et al. 2017).

Considering the manufacturing and installation, among these technologies, a-Si is the most important and promising one in terms of both technical applicability and economic feasibility (Gangopadhyay U, et al. 2013). The principal advantages of thin film modules are relatively low raw material consumption, high automation for the manufacturing process, high efficiency, applicable for building integrated projects, esthetical appearance due to frameless structure, high performance where the high ambient temperatures and resistivity to module temperature (P. Sampaioa, et al. 2017).

CdTe technology is the most successful one among the other thin film technologies in terms of efficiency levels. Because of that, CdTe technology is dominated the thin film market and it is market leader for unit manufacturing price per Watt. Even the amorphous silicon thin film modules have almost half of efficiency level compared with the others but its production cost is almost three time less. That makes them commercially preferable (D. Bonnet, 2003). When it comes to thin film production capacity Europe leads the way with their 30% market share, and following that China, USA, Japan and Malaysia can be count with their production share varies between 10% and 20%. In 2015 global PV production reached 63.2 GWp, 6.6% of this comes from thin film production, 69.5% of this polycrystalline silicon and almost 23.9% of this monocrystalline silicon technology (IHS, 2016).

Thermal systems

Although significant improvements in photovoltaic systems for the electricity generation since past 20 years, due to relatively low efficiency rates of cell technologies these systems are incompatible for the large-scale electricity generation plants especially considering tremendous land requirements. For that fact, solar energy which is utilized for the electricity generation purpose, through focusing solar irradiation by the concentrated units and hot steam generation to operate steam turbine (A. Dowling, et al. 2017).

Solar thermal systems are the power plants, which use solar irradiation as the primary power source. There are three main types of solar thermal power plants, which are parabolic trough, heliostats and dish receivers. These systems generate electricity with the same principals but only harvesting or collection of solar irradiation method is differs from one to another (C. Kalathakis et al., 2017).

Three different solar thermal system, for the renewable electricity generation purpose, can be seen in Figure 1.26. In the solar thermal power plants, which parabolic trough collectors are in used as solar collector, working fluid is circulating in the adsorbing pipes that are installed on the collector focusing line. From the heated working fluid, which can be such as direct water or synthetic oil, hot steam is produced thanks to the heat transfer within the heat exchangers and from that generated hot and pressurized steam electricity generation will be available through the steam turbines and generator sets, which is incorporate with the turbine shaft.

For the parabolic dish collector systems, either the same principal is used or direct electricity generation occurs thanks to the Stirling engine, which is basically a steam engine, installed on the focal point of the dish unit, which is covered with the mirrors. In the solar tower systems solar light is reflected on a heat exchanger unit, where installed on the top of a tower, by the heliostat mirrors. Electricity is generated from the steam turbines or steam engines by heated and pressurized working fluid through the focusing of the solar light on the surface of the focusing point (R.A. Mayers Ed, 2001).

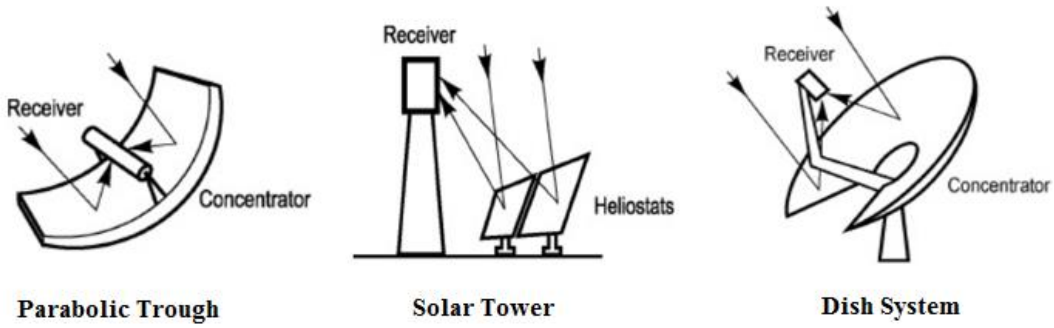

Figure 1.24 : Schematic of three main optical configurations for solar thermal systems (R.A. Mayers Ed, 2001).

Besides the solar tower systems, in the solar energy field, concentrated collector systems are used in order to make the working fluid to reach up the higher temperatures and generate electricity from steam turbines or Stirling engines. Concepts and descriptions made for the heliostat units are similar to concentrated solar units. However, concentrated solar systems need some other terminologies because of their complexity (V. Kumar et al., 2015).

One of the most important concept in the concentrated solar power systems is the “solar concentration ratio” which means non-dimensional ratio of the solar flux intensity (e.g., in “suns”) achieved after concentration to the normal insolation of incident beam (R.A. Mayers Ed, 2001). Concentration ratio is considered as 200 for two dimensional systems such as parabolic trough units, but almost 40,000 for three dimensional systems such as parabolic dish units. Solar light can be focused as linear or spot through reflectors or refractors.

Another title is “sun farm” which can be defined as integration of standalone parabolic trough units in parallel with each other. In those systems, solar light is collected and focused on a receiving pipe, which contains and transfers the working fluid, with 4 mm thickness and very high reflection rate. Parabolic trough collector units are supported by the metal structures, which allow them to rotate around the horizontal axis. There is also a tracking unit, which maintains the tracking of solar movement in the sky (J.P. Bijarniya, 2016).

“Heat receiving unit” is also one of the most important part of a solar thermal system which is mainly consist of steel pipes, that have 97% heat conductivity, glass tubes covering the metal pipes and glass-metal connectors. Air between steel pipe and glass tube is vacuumed in order to reduce the heat losses on the surface of steel pipe. Vacuum pressure is almost 0.1 atm. Heat resistant glass tube's light transmittance is significantly high due to very low iron content in the glass raw material and has an antireflective specification to reduce irradiation losses. In order to reduce the heat losses from the connection points of vacuum tubes, due to expansion and contraction of material, bendy glass-metal connectors are used (Srilakshmi G. et al., 2015).

"Control System" of the power plant is considered as brain of the system. It consists of main control system and local control system that is located on every collector group. Main control system measures and tracks the location of Sun and according to the receiving information, it can partially or completely opens or closes the system. This operation is continued incorporation with the local control system. Local control units drive each collector group separately and ensure the sun tracking (Omar Z. et al., 2015).

"Steam Production Unit" is consist of mainly pre-heaters, steam generators and super heaters. Pressure and temperature levels of steam, which passed from these sections, is increased to 371 °C and 100 bar levels and sent to steam turbine in order to generate electricity. Exhaust steam coming out from the steam turbine is sent to condenser units in order to transform into the water phase. Main purpose of this phase transformation is that pumping of steam requires significantly more energy than pumping of water. In case of loss of solar power in these power plants, additional heaters are used in order to maintain the continuous energy generation. These additional heaters can be operate with petroleum or natural gas and thanks to that burners required energy can obtained (C.S. Turchi, et al., 2017).

A parabolic solar dish collector focuses incoming solar irradiation on its focal point. Surface of these collectors are covered with the reflective material, similar with the parabolic trough collectors. Incoming solar irradiation is concentrated on the Stirling engines through this reflective material. Stirling engine can convert heat energy to mechanical energy and thanks to that mechanical energy a generator is driven in order to generate electricity.

Besides electricity generation these collectors are used for steam or heated air production also. In addition, these solar thermal systems are utilized in the industrial for steam generation, underground injection and taking out the petroleum. They can operated in the places, where the energy requirement is occur with the limited capacity.

Main obstacle of usage of these solar dish systems is their price, but even they are not commercially applicable recently, research and development studies are continuing in order to decrease the unit price and increase the efficiency (A. Dowling, et al. 2017).

1.4 Aim and Scope of This Study

Storm Valley is home to a substantial ecosystem and now it is faced with misplace this legacy because of uncontrolled discharge of domestic wastewaters of habitants living around the Storm Valley. Based on the studies performed, from Ardeşen and Çamlıhemşin dispersed settlements of Storm Valley, almost 4 million m^3 domestic wastewater is directly discharge into the water basins of Storm Valley. It is concluded that untreated discharge of domestic wastewaters into the Storm Valley has a significant negative effects on human health, socioeconomic structure, ecology and also on tea agriculture. Because of the important role of tea agriculture in the region, soil quality decrease in the farmlands effects directly social and economic conditions of habitants living in the area.

Unfortunately, it is observed that, throughout the years leaked wastewater from septic tanks, which were cursorily buried near the tea farms, has significant effects on physical, chemical and biological quality of soil, especially soil acidification cause pH decrease and in time it shorten the life cycle of tea plant. As a result, regarding soil pollution negatively effects sustainable tea agriculture and in parallel with that economic losses within the habitants.

This economical losses also triggers the deviations on the demographical structure of the region. In order to eliminate these negative effects where they occure, distributed wastewater treatment plants with appropriate treatment technologies has a great importance for this region to protect regarding unique and fragile ecosystem. Through the elimination of the negative effects of domestic wastewaters with appropriate treatment technology, cultural and economic legacy would be protected. Besides with the protection of this unique natural heritage, spreading of waterborn contagious diseases such as typhus, hepatitis, cholera and dysentery from utilization or consumption of contaminated water sources would be eliminated. And at the end of all these environmental and human health problems, they all end-up with the sustainability of tea agriculture and economic development of region, which can be accomplished through efficient tea farming.

Uniqueness of the proposed system is utilization of renewable energy sources for the treatment of domestic wastewater originated from dispersed settlements of Ardeşen and Çamlıhemşin districts of black sea region in order to achieve zero or minimum energy consumption from grid. In this context utilization possibilities of renewable energy potentials of the eastern black sea region, such as wind, solar and hydraulic potential, is aimed in order to meet the energy requirement of planned pilot scale wastewater treatment plant. Thanks to utilization of local renewable energy sources for the electricity generation purpose with free of charge, sustainable distributed wastewater treatment concept would be achievable.

2. MATERIAL AND METHODS

Within the scope of this study, Rize Çamlıhemşin and Ardeşen were visited, documents and information, which reflect population structure of the area, were obtained from the local officials and authorities, and also amount and characteristics of wastewaters generated and discharged to Storm Valley unrestrainedly was observed pursuant to examinations and analysis.

During the site studies, local community was informed about the negative effects of discharging of domestic wastewaters, which are originated from Ardeşen – Çamlıhemşin region, into the natural water sources of Storm Valley, on bio-diversity and agricultural lands. Besides that local residents were informed about the details of elimination methods of regarding negative effects through economical, applicable and site specific compact wastewater treatment plant technologies that utilize renewable energy sources for required electricity. As the first step, dispersed settlements were determined and targeted as Topluca, Çayırdüzü, Muratköy ve Dikkaya villages of Çamlıhemşin and Aşağıdurak, Yeşiltepe, Bayırcık, Şendere, Tunca villages of Ardeşen, which have priority with regard to environmental pollution. During these studies, dispersed settlements are determined by taking into consideration of their population density, settlement characteristics and negative effects on Storm Valley which is the most important water catchment basin of the region. Regarding dispersed settlements are shown in detailed on satellite photo as Figure 2.1, as it can be seen in generally the region is divided in to two region, such as western part and the eastern part of the Storm Valley.

In order to determine the total amount and characteristics of domestic wastewaters generated from regarding dispersed settlements from Ardeşen and Çamlıhemşin, wastewater samples were taken after the site studies. The samples were analyzed by TÜRKAK accredited laboratories under the TS EN ISO/IEC 17025 standard, which defines general requirements for the competence of testing and calibration laboratories.

Population data was obtained from the district governorship and during the site studies, these population data were cross checked with the habitants for the purpose of determination of seasonal variations of domestic wastewater generation from these dispersed settlements.

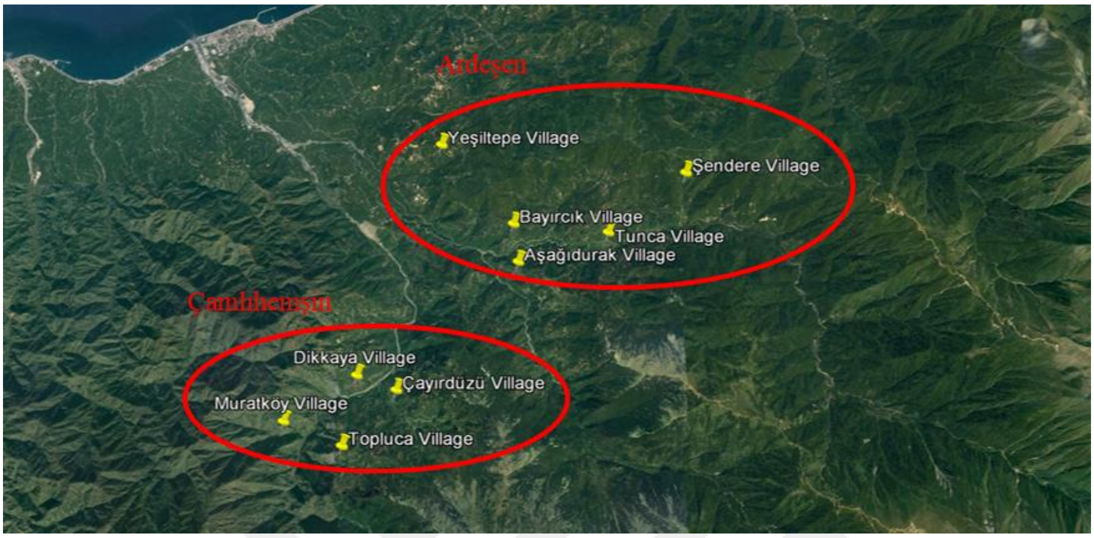

Figure 2.1 : Selected Dispersed Settlements of Ardeşen and Çamlıhemşin (Google Earth, 2016).

2.1 Study Area

Within the scope of this project, current situation and environmental problems are revealed by the interviews with the habitants after the site studies have been done to selected dispersed settlements of Ardeşen and Çamlıhemşin districts. Visited dispersed settlements are categorized as large, medium and small residences according to their population and in order to reveal existing situation site studies had been made to villages with various population.

2.1.1 Çayırdüzü village

According to TÜİK 2015 data, population of the village was recorded as 633 people but after the site visit and interviews with the habitants have been done, it understood that there was a significant population difference between summer and winter, almost three times and especially in winter times population decreases dramatically. After the site visit it was observed that due to elevation profile of the terrain, village separated into the sections, in itself. In the “Düz Mahalle” area, which is accepted as the center of the village, it was observed that there were sewer pipe infrastructure and this system serves for almost 15 residences during the winter times, but the population increases up to almost 60 residences during the summer times. Domestic wastewater and rainwater are drained altogether via this sewer system to a cesspool, which is located on the edge of Storm Valley. However, it was observed that there were some leakage problems and fecal contaminations in the river.

Figure 2.2 : Location of Çayırdüzü Village to Storm Valley and Streams (Google Earth, 2016).

2.1.2 Muratköy village

According to TÜİK 2015 data, population of the village was recorded as 214 people and compared to region standards this village is accepted as medium size in terms of population point of view.

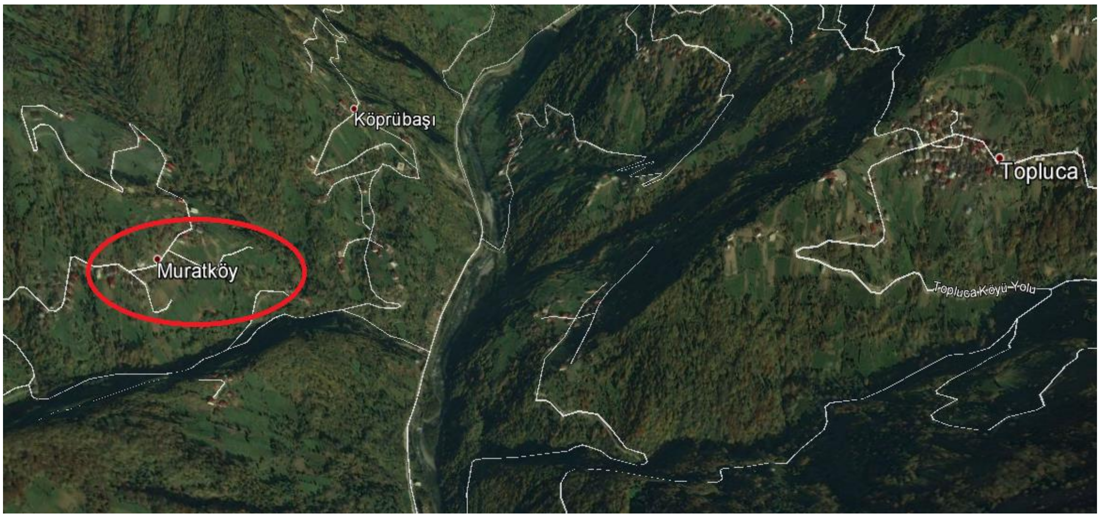

Figure 2.3 : Location of Muratköy Village to Storm Valley and Streams (Google Earth, 2016).

During site visit it was observed that there was a main sewer system passing through the center of the village made by habitants themselves. Collected wastewater by this sewer system was drained into cesspool located at the entrance of village and from there collected wastewater was discharging to Fırtına River without any precaution and any control. Based on the information, obtained from habitants, collected wastewater in the cesspool causes significant odor problems especially during the summer times. In addition, habitants declared that, as a common practice, kitchen wastewater outlets and sewer systems are constructed separately in the region. In parallel with that, it was declared that after completion of construction of sewer system, new residents migrating into this village, constructed their own cesspool instead of connecting their wastewater pipelines into existing sewer system.

Figure 2.4 : Cesspool Discharge Structure at Muratköy Village.

2.1.3 Dikkaya village

According to TÜİK 2015 data, population of the village was recorded as 1,001 people and is referred as biggest village in the region. According to the observations, it can be stated that village has three main sections with 300 residents almost. In generally, it was observed that during the summer times, habitants were moved to city center or other areas in order to work seasonally, but when the winter has come, habitants were move back to village again.

Figure 2.5 : Location of Dikkaya Village to Storm Valley (Google Earth, 2016).

An existing sewer system was observed under the village. In the village, wastewater was collecting in two main locations and drained into the river directly, without any control. At the discharge point, it can be seen that there was a clean water inlet, which feeds village’s water supply. Besides that, there was another sewer discharge line, which ends up in a septic tank, but septic tank was not functioning and collected sewer was discharged directly into the river. Habitants complained about their sufferings from corrupted ecosystem in time and arisen odor problems around the discharge point.

Figure 2.6 : Sewer Pipes and Discharge Point to River at Dikkaya Village.

2.1.4 Bayırcık village

According to TÜİK 2015 data, population of village was recorded as 291 people. In the village there are almost 50 residences observed during the site visit.

Figure 2.7 : Location of Bayırcık Village to Storm Valley and Streams (Google Earth, 2016).

Collected wastewater in the region is drained into the septic tanks, which is constructed very close to the river. Due to lack of any wastewater treatment system, grey water is drained into the river directly, without any treatment. Significantly high flow rate of the river was also remarked as a potential energy source of the wastewater treatment system.

2.1.5 Aşağıdurak village

According to TÜİK 2015 data, population of the village was recorded as 390 people with almost 90 residents. For the existing infrastructure, a sewer system was observed, which is passing through under the village, and it drained the sewer to septic tank with a concrete bottom, which is constructed 50 m below from the village and very close to the river. It was observed that there are some leakages from this tank, which have almost 250 m^3 total volume, and contaminations of the river currently.

Figure 2.8 : Location of Aşağıdurak Village to Storm Valley and Streams (Google Earth, 2016).

High flow rate of the river and sunshine duration of the area were also remarked as a potential energy source of the wastewater treatment system.

2.2 Population Data of Ardeşen and Çamlıhemşin Dispersed Settlements

Population data of the dispersed settlements of regarding regions were collected from the TÜİK 2015 data, in order to determine the population ratio of visited areas to total of region. Under the scope of these studies, inhabitant data of Topluca, Çayırdüzü, Muratköy and Dikkaya villages of Çamlıhemşin district is listed in it the Table 2.1 below.

Table 2.1 : Population data of dispersed settlements of Çamlıhemşin.

Settlement	Population	%
Çayırdüzü	633	10.2
Dikkaya	1,001	16.1
Muratköy	214	3.5
Topluca	1,059	17.1
Others	1,702	27.4
Center of District	1,594	25.7
Total of District	6,203	100.0

In parallel with that, inhabitant data of Yeşiltepe, Bayırcık Dobira and Tunca villages of Ardeşen district is listed it the Table 2.2.

Table 2.2 : Population data of dispersed settlements of Ardeşen.

Settlement	Population	%
Aşağıdurak	390	1.0
Bayırcık	291	0.7
Tunca	2,828	7.0
Yeşiltepe	194	0.5
Others	9,112	22.6
Center of District	27,463	68.2
Total of District	40,278	100.0

There are 43 dispersed settlements in total in Ardeşen district and every dispersed settlements require specific treatment technology based on its own characteristics. Following to the pilot scaled application, it would be a permanent solution with the construction of wastewater treatment plants to the other dispersed settlements, which were already studied in the area.

It will be possible to prevent regional pollution, which is resulted from uncontrolled discharge of wastewater into the Storm Valley, through establishment of a sustainable environmental plan and application of 64 small-scaled wastewater treatment plants in total.

2.3 Wastewater Characteristics of Ardeşen-Çamlıhemşin Dispersed Settlements

In order to determine wastewater parameters of Ardeşen and Çamlıhemşin dispersed settlements, samples were sent to a laboratory, which is accredited by TÜRKAK, and through these analysis region specific wastewater characteristics are determined. Analysis results are listed in the Table 2.3, 2.4 and 2.5.

Table 2.3 : Wastewater parameters of Aşağıdurak village, Ardeşen.

Sample No: Wastewater – N-5094/13		
Parameter – Unit	Test Result	Test Method
pH	7.05	TS 3263 ISO 10523
TDS (mg/L)	335	SM 2540 C
TS (mg/L)	530	SM 2540 B-E
TD (volatile) (mg/L)	255	SM 2540 E
SS (mg/L)	232	TS EN 872
SS (volatile) (mg/L)	148	SM 2540 E
Settleable Solids (mL/L)	0.9	TS 7092

Table 2.3 (continued) : Wastewater parameters of Aşağıdurak village, Ardeşen.

Sample No: Wastewater – N-5094/13		
Parameter – Unit	Test Result	Test Method
BOD (mg/L)	149.9	SM 5210 B
COD (mg/L)	294	SM 5220 B
TOC (mg/L)	22.4	SM 5310 B
TKN (mg/L)	34.7	SM 4500 N_{org} B
Nitrate Nitrogen (mg/L)	<0.1	EPA 352-1
Nitrite Nitrogen (mg/L)	0.018	SM 4500 NO_2 B
Total Phosphorus (mg/L)	5.68	SM 4500 P B E
Organic Phosphorus (mg/L)	0.9	SM 4500 P B E
Inorganic Phosphorus (mg/L)	4.78	SM 4500 P B E
Chloride (mg/L)	52	SM 4500 Cl^- B
Sulphate (mg/L)	21.9	SM 4500 SO_4^{-2} E
Alkalinity (mg $CaCO_3$/L)	268	SM 2320 B
Oil and Grease (mg/L)	72	TS 8312
Total Coliform (CFU/100 mL)	45,000	TS EN ISO 9308-1
VOC (mg/L)	<0.008	EPA5021A, 8015 D

Table 2.4 : Wastewater parameters of Çayırdüzü village, Çamlıhemşin.

Sample No: Wastewater – N-5095/13		
Parameter – Unit	Test Result	Test Method
pH	7.43	TS 3263 ISO 10523
TDS (mg/L)	508	SM 2540 C
TS (mg/L)	866	SM 2540 B-E
TDS (volatile) (mg/L)	381	SM 2540 E
SS (mg/L)	352	TS EN 872
SS (volatile) (mg/L)	253	SM 2540 E
Settleable Solids (mL/L)	0.8	TS 7092
BOD (mg/L)	207	SM 5210 B
COD (mg/L)	520	SM 5220 B
TOC (mg/L)	7	SM 5310 B
TKN (mg/L)	33.6	SM 4500 N_{org} B
Nitrate Nitrogen (mg/L)	5.08	EPA 352-1
Nitrite Nitrogen (mg/L)	0.055	SM 4500 NO_2 B
Total Phosphorus (mg/L)	5.1	SM 4500 P B E
Organic Phosphorus (mg/L)	0.6	SM 4500 P B E
Inorganic Phosphorus (mg/L)	4.5	SM 4500 P B E
Chloride (mg/L)	7	SM 4500 Cl^- B
Sulphate (mg/L)	14.5	SM 4500 SO_4^{-2} E
Alkalinity (mg $CaCO_3$/L)	50	SM 2320 B
Oil and Grease (mg/L)	54.2	TS 8312
Total Coliform (CFU/100 mL)	18,000	TS EN ISO 9308-1
VOC (mg/L)	<0.008	EPA5021A, 8015 D

Table 2.5 : Wastewater parameters of Dikkaya village, Çamlıhemşin.

Sample No: Wastewater – N-5096/13		
Parameter – Unit	Test Result	Test Method
pH	8.48	TS 3263 ISO 10523
TDS (mg/L)	393	SM 2540 C
TS (mg/L)	558	SM 2540 B-E
TDS (volatile) (mg/L)	299	SM 2540 E
SS (mg/L)	160	TS EN 872
SS (volatile) (mg/L)	125	SM 2540 E
Settleable Solids (mL/L)	1	TS 7092
BOD (mg/L)	283.2	SM 5210 B
COD (mg/L)	590	SM 5220 B
TOC (mg/L)	35	SM 5310 B
TKN (mg/L)	57.7	SM 4500 N_{org} B
Nitrate Nitrogen (mg/L)	0.17	EPA 352-1
Nitrite Nitrogen (mg/L)	0.021	SM 4500 NO_2 B
Total Phosphorus (mg/L)	7.26	SM 4500 P B E
Organic Phosphorus (mg/L)	1.1	SM 4500 P B E
Inorganic Phosphorus (mg/L)	6.16	SM 4500 P B E
Chloride (mg/L)	78	SM 4500 Cl^- B
Sulphate (mg/L)	55.4	SM 4500 SO_4^{-2} E
Alkalinity (mg $CaCO_3$/L)	322	SM 2320 B
Oil and Grease (mg/L)	75	TS 8312
Total Coliform (CFU/100 mL)	40,000	TS EN ISO 9308-1
VOC (mg/L)	<0.008	EPA5021A, 8015 D

Based on the analysis have been made by the accredited laboratory it was determined that wastewaters from regarding dispersed settlements are matched with the medium strength wastewater characteristics, which have negative effects on human life and existing ecosystem, and when they discharge to environment directly without any treatment, within a certain period of time, absorbing limits of receiving environment will be exceeded and at the end regarding wastewater contamination into the water sources will decrease the water and soil quality of receiving environment. Finally create chronical effects on environment, ecology and the human health while utilization of these water sources for the agricultural irrigation purpose or daily usage through the years.

2.3.1 Organic pollution

There are three major effects of organic pollution on the environment; one is on the human health cause from decreased water quality, waterborne diseases such as typhoid, cholera and hepatitis and odor problems. Another one is on the ecosystem arises from habitat degradation, aquatic degradation and poisonous effect on the food chain. Moreover, the last one is on the sustainability derive from agricultural land degradation, collapse in sustainable tea farming and product qualities.

Considering components or organic pollution, it can be concluded from direct discharging of wastewaters to receiving environment causes both surface water pollution and underground water sources pollution, which conclude with quality problems with the general water sources that directly linked in tea farming areas. This phenomenon creates irreversible results within both short term as acute and long term as chronical.

In order to prevent these consequences, required engineering solutions must be established in the region immediately. In the contrary case, it can be state that required actions for the purpose of enhancing water and soil quality, which had already be degraded, was going to be extremely high priced, and it will be impossible to brought back the site specific endemic animal and plant species.

Wastewater specifications of Çamlıhemşin and Ardeşen district show typical domestic wastewater characteristics. Organic pollutions from that wastewater on receiving environment are summarized in Table 2.6 and Table 2.7. Water consumption per capita is considered as 0.2 m^3/day and pollutant load per capita 60 g/day (Henze et al., 2002).

Table 2.6 : Wastewater amounts and pollutant loads of Çamlıhemşin.

	Population	Water Consumption per capita m^3/day	Pollutant Load Per Capita (BOD) g/cap-day	Total Wastewater Amount m^3/day	Total Organic (BOD) Pollutant Load kg/a
Çayırdüzü	633	0.2	60	126.6	13,863
Dikkaya	1,001	0.2	60	200.2	21,922
Muratköy	214	0.2	60	42.8	4,687
Topluca	1,059	0.2	60	211.8	23,192
Other	1,702	0.2	60	340.4	37,274
Center	1,594	0.2	60	318.8	34,909
Total	6,203	0.2	60	1,240.6	135,846

Considering the data and calculations in Table 2.6, it can be concluded that wastewater streams generated in Çamlıhemşin district and its dispersed settlement areas have 74 percentage comparing with the total amount in district, in spite of that district center has almost only 26 percentage of wastewater generation by itself. In another words, generated wastewater in one year, which is 453,000 m^3 in total, with 136,000 kg organic pollution, is discharge directly into the receiving environment of Storm Valley, such as water resources or soil.

Table 2.7 : Wastewater amounts and pollutant loads of Ardeşen.

	Population	Water Consumption per capita m^3/day	Pollutant Load Per Capita BOD gr/cap-day	Total Wastewater Amount m^3/day	Total Organic (BOD) Pollutant Load kg/a
Aşağıdurak	390	0.2	60	78	8,541
Bayırcık	291	0.2	60	58.2	6,373
Tunca	2,828	0.2	60	565.6	61,933
Yeşiltepe	194	0.2	60	18.8	2,059
Other	9,112	0.2	60	1,822.4	199,553
Center	27,463	0.2	60	5,492.6	601,440
Total	40,278	0.2	60	8,055.6	882,088

Considering data and calculations in Table 2.7, it can be concluded that generated wastewater in dispersed settlements of Ardeşen has 32% share in total, and district center has 68% in total. In other words, 2,940,000 m^3 domestic wastewater amount, with its 882,000 kg of organic pollutant load, is discharge directly in to the water sources of Storm Valley.

It can be state that these uncontrolled discharges may cause significant negative effect on human life, farmlands and of course tea farms. Required engineering precautions must be taken and tailor made engineering applications must be brought in to the region immediately in order to decrease environmental pollution problems. Otherwise, it may create significant costs to recover damaged water and soil quality, and also make it impossible to return site specific endemic plants and animal species living in existing ecology.

2.3.2 Microbial pollution

The data for microorganism species and concentrations of microorganisms (number of microorganisms per 100 ml) for domestic wastewater can be seen in the Table 2.8.

Table 2.8 : Microorganism in domestic wastewater (Henze et al., 2001).

Microorganism (num./100 ml)	High	Low
E. Coli	$5x10^8$	10^6
Coliforms	10^{13}	10^{11}
Cl perfringen	$5x10^4$	10^3
Fecal streptococcus	10^8	10^6
Salmonella	$3x10^2$	50
Campylobacter	10^5	$5x10^3$
Listeria	10^4	$5x10^2$
Staphylococcus aureus	10^5	$5x10^3$
Coliphage	$5x10^5$	10^4

Table 2.8 (continued) : Microorganism in domestic wastewater (Henze et al., 2001).

Microorganism (num./100 ml)	High	Low
Giardia	10^3	10^2
Roundworms	20	5
Enterovirus	10^4	10^3
Rotavirus	10^2	20

Because of domestic wastewater discharge to receiving environment, significant amount of pathogenic microorganism will contaminate the water sources and carry various diseases to people who use or in contact with these contaminated water sources. Calculations, which have been made for determination of microbial pollution loads of wastewaters that are originated from districts and dispersed settlements of Ardeşen and Çamlıhemşin region, are given in Table 2.9 and 2.10.

Table 2.9 : E.coli amount in Çamlıhemşin wastewater samples.

	Population	Water Consumption per capita m^3/day	Untreated Wastewater E.coli/m^3	Total Wastewater Amount m^3/day	Total E.coli/a
Çayırdüzü	633	0.2	10^6	126.6	$4.6x10^{10}$
Dikkaya	1,001	0.2	10^6	200.2	$7.3x10^{10}$
Muratköy	214	0.2	10^6	42.8	$1.6x10^{10}$
Topluca	1,059	0.2	10^6	211.8	$7.7x10^{10}$
Other	1,702	0.2	10^6	340.4	$1.2x10^{11}$
Center	1,594	0.2	10^6	318.8	$1.2x10^{11}$
Total	6,203	0.2	10^6	1240.6	$4.5x10^{11}$

Table 2.10 : E.coli amount in Ardeşen wastewater samples.

	Population	Water Consumption per capita m^3/day	Untreated Wastewater E.coli/m^3	Total Wastewater Amount m^3/day	Total E.coli/a
Aşağıdurak	390	0.2	10^6	81.2	$3.0x10^{10}$
Bayırcık	291	0.2	10^6	36.8	$1.3x10^{10}$
Tunca	2,828	0.2	10^6	475.2	$1.7x10^{11}$
Yeşiltepe	194	0.2	10^6	26	$9.5x10^9$
Other	9,112	0.2	10^6	1,826.4	$6.7x10^{11}$
Center	27,463	0.2	10^6	5,622.6	$2.1x10^{12}$
Total	40,278	0.2	10^6	8,068.2	$2.9x10^{12}$

When the data given in Table 2.9 and Table 2.10 considered, it can be concluded that microbial pollution level in wastewater from Çamlıhemşin and Ardeşen region carry a significant threat for human health. In other words, in case of consumption of these contaminated water sources for the purpose of irrigation or utility water, which would have potential vital consequences on human life through occurrence of contagious diseases such as typhoid, cholera, hepatitis. Every year, in all over the world, almost 20 million of people suffers from contagious diseases like typhoid, cholera which arise from contamination of utility and drinking water sources, and significant amount of regarding illness result in death.

In Ardeşen district, there are 40 dispersed settlements and in Çamlıhemşin there are 24 dispersed settlements with totally 64. In that dispersed settlements 64 wastewater treatment system, which are integrated with existing habitat, must be established and they must be operated according to receiving environment limits, which are defined in Water Pollution Control Regulation. According to the site observations, population characteristics of regarding dispersed settlements varies seasonally and in summer times population increases almost double compared with winter times. When routines of habitants are examined, it observed that kitchen wastewater and toilet wastewater are collected separately in some villages. Besides that, during the construction of main sewer system of the village, seasonal habitants were not taken into consideration and because of that, these residents have needed to collect their wastewater in their own septic tanks. However, collected wastewater through sewer system, which is constructed by habitants themselves, are derived into the septic tanks or cesspools and collected are drained to the receiving environment directly without any treatment. And due to that existing septic tanks are worked just as collection pits. Especially during the summer times, habitants complained about heavy odor problem occurs in the septic tank area, around the cesspools or in the streambeds, where the discharge points.

Wastewater stream originated from dispersed settlements of Çamlıhemşin district have 74% of total wastewater in the regions, and after all district center have 26% of total. In Çamlıhemşin, it is calculated that almost 453,000 m^3 domestic wastewater is generated, and that can fill almost 350 Olympic size pool, with 136 tons total organic pollution load and it is discharged in to the water sources of Storm Valley directly. Wastewater stream originated from dispersed settlements of Ardeşen district have 32% of total wastewater in the regions, and after all district center have 68% of total. In Ardeşen, it is calculated that almost 2,940,000 m^3 domestic wastewater is generated, which can fill almost 2,500 Olympic pool, with 882 tons total organic pollution load and it is discharged in to the water sources of Storm Valley directly. Annually 3,393,000 m^3 domestic wastewater originated from Ardeşen and Çamlıhemşin region. Almost 1,250,000 m^3 of this wastewater, generated by dispersed settlements of regarding districts, is discharged directly into the Storm Valley without any treatment. Result of these uncontrolled discharges without any treatment, it can be envisaged that this will have a negative effect primarily on human health and also on ecology, biodiversity, water quality, treatment costs and sustainable agriculture.

It is observed and foreseen that with the consumption and utilization of these contaminated water sources with the wastewaters from regarding dispersed settlements will cause contagious diseases such as typhus, cholera, hepatitis and become a direct threat on human life. Microbial pollution causes quality degradation of surface and underground water sources, and via that pollutes tea-farming lands that utilize regarding contaminated water sources.

2.4 Score Card and Treatment System Selection

Ten important parameters are taken in to consideration for the evaluation of multi criteria analysis of treatment plant technology alternatives for wastewater management of dispersed settlements of Çamlıhemşin and Ardeşen region, which are meeting discharge standards, flexibility for flow rate and load deviations, sensitivity to climate, land requirement, upgradable/modularity, investment costs, staff requirement, maintenance costs, energy requirement and noise level.

Considering regional aspects, evaluation of regarding ten critical parameters according to treatment technologies are summarized in Table 2.11. For treatment alternatives, 5 to 10 points are given to each parameters, 10 for best, and 5 for least. It is assumed that each ten factors have same weight. Treatment alternative that have the highest score is determined as the most applicable technology.

Table 2.11 : Evaluation of treatment technology alternatives.

Parameter	AS System	SBR	MBR	Aerated Lagoon	RBC	Constructed Wetlands
Meeting Discharge Standards	9	9	10	8	9	7
Flexibility for Flow Rate and Load Deviations	8	7	6	9	8	7
Sensitivity to Climate	7	7	9	8	7	8
Land Requirement	6	8	9	5	8	5
Upgrade / Modularity	8	8	7	5	10	6
Investment Cost	7	8	5	7	6	8
Staff Requirement	8	8	7	9	10	7

Table 2.11 (continued) : Evaluation of treatment technology alternatives.

Parameter	AS System	SBR	MBR	Aerated Lagoon	RBC	Constructed Wetlands
Maintenance Cost	7	8	5	6	10	8
Energy Requirement	7	7	5	6	9	10
Noise	6	6	7	6	9	10
TOTAL SCORE	73	76	70	69	86	76

As a result, after the evaluation of alternatives, rotating biological contactors are come to the forefront as the most convenient treatment technology for regarding project region in terms of modularity, staff requirement, maintenance costs, energy demand and noise.

2.5 Score Card and Renewable Energy Source Selection

In order to maintain sustainable wastewater management, where dispersed settlements of Çamlıhemşin and Ardeşen districts of Eastern Black Sea Region, seven major criteria, which are renewable energy potential of region, continuous electricity generation, land requirement, extendibility or modularity, investment cost, maintenance cost and noise level, were considered very carefully for the establishment of planned RBC wastewater treatment unit and electricity generation system to feed the required energy of regarding treatment units.

Considering the renewable energy potential of the region and internal electricity consumption of the planned treatment unit, comparison can be seen in the Table 2.12 specified below. According to energy source and/or technology scores are given between 5 to 10 points for each parameters. In the table, 5 points reflects the worst and 10 points reflects the best. Each seven factors have equally weighted. Energy alternative that have the highest score in total is considered as the most feasible option.

Table 2.12 : Renewable energy score table.

Parameter	Hydroelectricity	Wind Energy	Solar Energy
Energy Potential of Region	10	7	5
Stable Electricity Generation	6	7	7
Land Requirement	5	10	6
Extendibility/Modularity	5	5	10
Investment Cost	9	5	7
Maintenance Cost	8	5	10
Noise Level	7	5	10
TOTAL	50	44	55

As a result, according to the comparison table, solar energy has the highest score and because of that, it is selected as the most applicable technology in order to meet the electricity requirement of wastewater treatment system, considering the parameters.

3. RESULTS

Following to observation of existing conditions, studies have been done to find out the applicable wastewater treatment technologies and alternative renewable energy sources. The most applicable wastewater treatment technology and energy source was determined through analyzing of each alternatives by taking into consideration of various parameters such as cost, efficiency, design, site specificity, land requirement and extensibility.

3.1 Calculations for Rotating Biological Contactor Unit

Capacity calculations have been made for 100, 200, 400, 600, 800 and 1.000 population equivalent, to determine the most applicable treatment plant alternative, which utilize site-specific renewable energy source. In addition, for determined wastewater treatment technology and energy source, plant design and cost analysis have been done for 200, 400 and 800 individual capacities.

3.1.1 Capacity calculation of planned RBC Unit

Design of rotating biological contactor is made considering residential areas are inhabited by 100, 200, 400, 600, 800 and 1,000 people. Main aspects during the design and operation phase are daily wastewater generation per capita is considered as 130 L, BOD_5 and SS loads per capita is considered as 45 and 50 g/day respectively, after the primary clarifier BOD_5 and SS removal performance from wastewater is taken as 35% and 60%, respectively (Metcalf and Eddy, 2003).

Rotating biological contactor is located after the primary clarifier and design is made base on characteristics of settled wastewater in the primary, secondary and balancing tank. Elimination of suspended solids remain from rotating biological contactor process is achieved in final settling tank, which is lamella separator type, and generated sludge will be taken out from the system, in certain period, and sent to the final sludge drying lands.

For the project designing, Equation 3.1 is used (Grady et al.1999). Based on that dissolved BOD_5 concentration in effluent, which depends on influent concentration, can be calculated via Equation (3.1).

$$S_n = \frac{-1+\sqrt{1+(4\cdot 0.00974)\cdot(\frac{A_S}{Q})\cdot S_{n-1}}}{2\cdot 0.00974\cdot(\frac{A_S}{Q})} \quad (3.1)$$

In Table 3.1, design criteria are summarized for different population equivalent. In general, influent and effluent soluble BOD/BOD_5 rate remains in between 0.5 to 0.75 (Metcalf and Eddy, 2003; MOP-35, 2010). This rate is considered as 0.5 during the calculations typically. Required biodisc area is calculated as 390 m^2 for Aşağıdurak village and 780 m^2 for Dikkaya village. It is calculated that with these biodisc area effluent water quality will be almost 38 mg BOD_5/L. In addition, selected final settling tank ensures project criteria for 200 and 400 habitants (MOP-8, 2005).

Table 3.1 : Design parameters of RBC based on population.

Parameter	Unit	100	200	400	600	800	1000
Min. Temperature	°C	15	15	15	15	15	15
Influent flowrate	m^3/day/cap	0.13	0.13	0.13	0.13	0.13	0.13
Total flowrate (Q)	m^3/day	13	26	52	78	104	130
BOD_5 load (q_{BOD})	g/day/cap	45	45	45	45	45	45
Unit Nitrogen load (q_N)	gN/day/cap	7	7	7	7	7	7
BOD concentration	g/m^3	346	346	346	346	346	346
Soluble BOD_5	g/m^3	173	173	173	173	173	173
BOD_5 load, (L_{BOD})	$gBOD_5$/day/10^3	4.5	9	18	27	36	45
Nitrogen load, (L_N)	gN/day/10^3	0.7	1.4	2.8	4.2	5.6	7
Total Kjeldahl N	mgN/L	54	54	54	54	54	54
Primary Settling							
Retention time	hours	20	10	5	3	3	3
BOD_5 removal efficiency	%	35	35	35	35	35	35
SS removal efficiency	%	60	60	60	60	60	60
N removal efficiency	%	11	11	11	11	11	11
Effluent BOD_5 load	$gBOD_5$/day/10^3	2.9	5.9	11.7	17.6	23.4	29.3
Effluent nitrogen load	gN/day/10^3	0.6	1.2	2.5	3.7	5.0	6.2
RBC							
BOD load rate	$gBOD_5$/day/m^2	15	15	15	15	15	15
Required biodisc area	$m^2.10^3$	0.2	0.4	0.8	1.2	1.6	1.2
Total area per shaft	m^2/shaft	700	700	700	700	700	700
Shaft amount	#	1	1	2	2	3	3
Nitrogen load rate	gN/m^2/day	1.5	1.5	1.5	1.5	1.5	1.5
Actual N loading	gN/m^2/day	11.5	5.7	2.9	1.9	1.4	1.1
A_s/Q	m^2/m^3/day	12	12	12	12	12	12
Effluent soluble BOD_5	$mgBOD_5$/L	31	31	31	31	31	31

Table 3.1 (continued) : Design parameters of RBC based on population.

Parameter	Unit	100	200	400	600	800	1000
Effluent SS	mg/L	<10	<10	<10	<10	<10	<10
Effluent BOD_5 (< 50 mg/L)	$mgBOD_5/L$	35	35	35	35	35	35
Final Settling Tank							
Lamella separator area	m^2	15	15	15	15	15	15
Peak Factor, (PF)	-	3	3	3	3	3	3
Flow Rate, (Q_p)	m^3/hour	2	3	7	10	13	16
Net surface area, (A)	m^2	2	2	2	2	2	2
HRT, Q_H<10	m^3/m^2/hour	1	2	3.5	5	7.5	8

3.1.2 Basic design of planned RBC unit

Design, equipment specification, investment cost and capital expenditures of a rotating biological contactor is given for 200, 400 and 800 people capacity, as seen in Table 3.2 and 3.3.

Table 3.2 : Physical Treatment Units of Planned RBC Design.

Parameter	No.	Screen Opening (mm)	Capacity	Material	Type
200					
Coarse and Fine Grid	1	10/25		Epoxy covered St-37	Manuel Cleaning, bar grid
Sand and Grease Trap	1		1 m^2	Polyethylene or concrete	
Primary Settling Tank	1		10 m^3	Polyethylene	
Seconder Settling Tank	1		3 m^3	Polyethylene	
Pump	1+1		6 m^3/h - 8 m		Submerged type
400					
Coarse and Fine Grid	1	10/25		Epoxy covered St-37	Manuel Cleaning, bar grid
Sand and Grease Trap	1		1 m^2	Polyethylene or concrete	
Primary Settling Tank	1		20 m^3	Polyethylene	
Seconder Settling Tank	1		6 m^3	Polyethylene	
Balance Tank	1		12 m^3	Polyethylene	
Pump	1+1		6 m^3/h - 8 m		Submerged type
800					
Coarse and Fine Grid	1	10/25		Epoxy covered St-37	Manuel Cleaning, bar grid
Sand and Grease Trap	1		1.6 m^2	Polyethylene or concrete	
Primary Settling Tank	1		53 m^3	Polyethylene	
Seconder Settling Tank	1		14 m^3	Polyethylene	
Balance Tank	1		23 m^3	Polyethylene	
Pump	1+1		6 m^3/h - 8 m		Submerged type

Table 3.3 : Biological Treatment Units of Planned RBC Manufactured by CTGPlanetTEK®Environmental Technologies.

Parameter	No.	Disc Diameter (m)	Area (m^2)	Disc No.	Total Area (m^2)	Motor (kW)	RPM	Diameter (W/D/H)	Capacity	Material			Brand /Type	
										Rotor Cover	Disc	Shaft	Motor	Reducer
200														
RBC Unit	1	2	6.5	80	520	0.37	3-5	3.5/3/3		FRP	HDPE	CK45 Cr	Gamak	Yılmaz
Final Settling Tank (L.Separator)	1		15		15					Polyethylene, fiber or epoxy painted carbon steel			Planet TEK	
Sludge Pump	1					0.55			6 m^3/h - 11.5 m				Ebara	
Chlorine Tank	1								100 L					
Chlorine Pump	1+1					0.05			4.8 m^3/h - 6.3 m				Submerged type	
400														
RBC Unit	1	2	6.5	100	700	0.37x2	3-5	3.5/3/3		FRP	HDPE	CK45 Cr	Gamak	Yılmaz
Final Settling Tank (L.Separator)	1		15		15					Polyethylene, fiber or epoxy painted carbon steel			Planet TEK	
Sludge Pump	1					0.55			6 m^3/h - 11.5 m				Ebara	
Chlorine Tank	1								100 L					
Chlorine Pump	1+1					0.05			4.8 m^3/h / 6.3 m				Submerged type	
800														
RBC Unit	2	2	6.5	110	1560	0.37x3	3-5	3.5/3/3		FRP	HDPE	CK45 Cr	Gamak	Yılmaz
Final Settling Tank (L.Separator)	1		25		25					Polyethylene, fiber or epoxy painted carbon steel			Planet TEK	
Sludge Pump	1					0.55			6 m^3/h - 11.5 m				Ebara	
Chlorine Tank	1								100 L					
Chlorine Pump	1+1					0.05			4.8 m^3/h / 6.3 m				Submerged type	

Besides that P&I diagram and layout plan of proposed pilot plant is also given in the Figure 3.1.

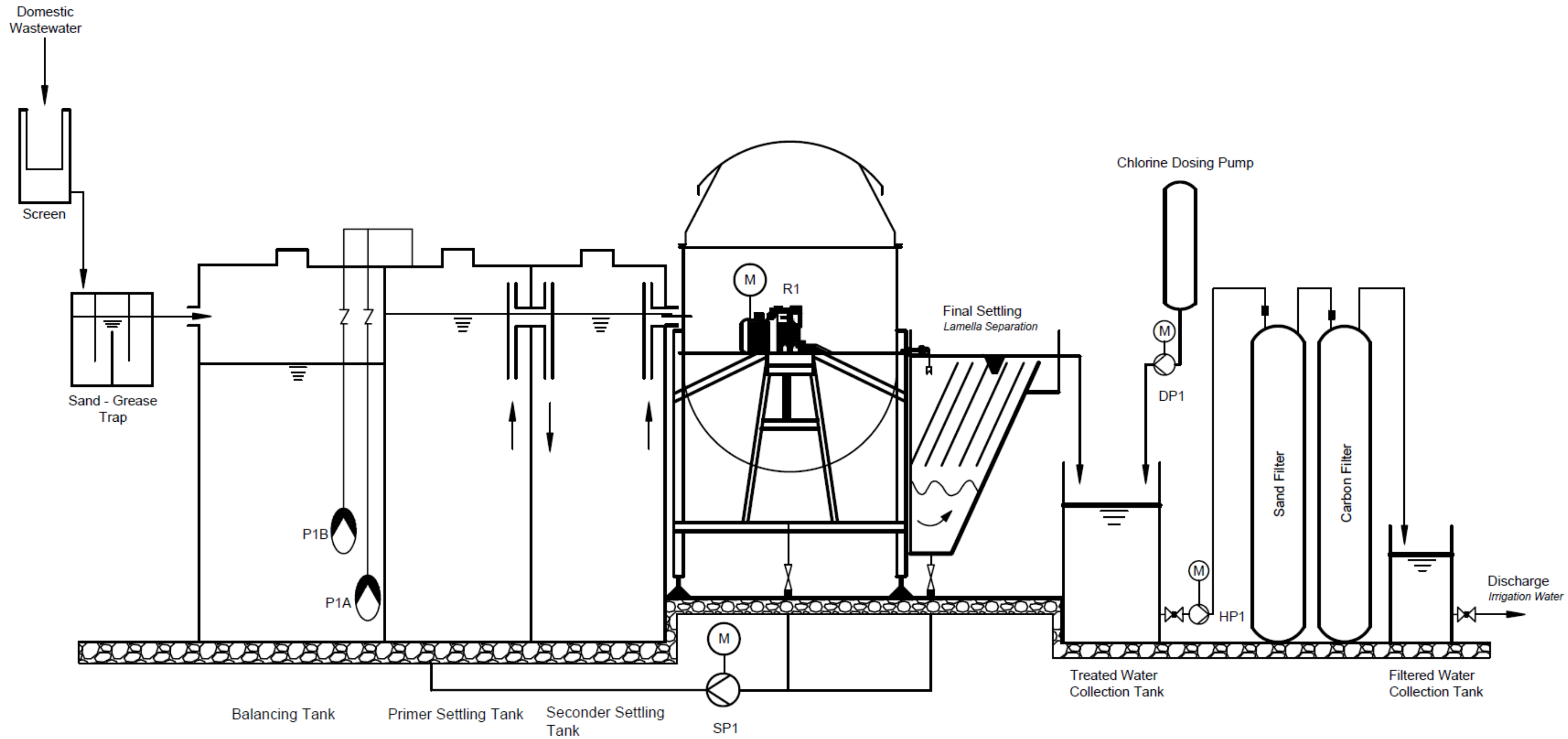

Figure 3.1 : P&I Diagram for Designed RBC Unit.

During the design, as discharge criteria, Water Pollution Control Regulation-2004 is considered with the parameters as BOD: 5 – 120 kg/day and Population: 84-2,000. Defined discharge limits for the effluent wastewater are given in Table 3.4.

Table 3.4 : Treated wastewater characteristics from designed RBC unit.

Parameter	Unit	2 Hours Composite Sample	
		Regulation Limits	Effluent Analysis
BOD_5	mg/L	50	50
COD	mg/L	180	126.6
SS	mg/L	70	25
pH		6-9	7.32

3.1.3 Investment and operation costs of RBC serving to 200 inhabitants

Investment cost of the plant is summarized in Table 3.5. Land improvement costs of treatment plant are excluded. During the operation, energy consumption of the plant for per m^3 flowrate is 0.9 kWh/m^3. From that value, annual electricity consumption and annual energy cost of plant is calculated as 8,497 kWh/a and 1,020 €/a. Energy unit price is considered as 0.12 €/kWh.

Table 3.5 : Investment and operation costs of RBC for 200 inhabitants.

Cost Center	Cost (€)
Investment Cost	28,000
Annual operation cost	1,020

In case of treatment plant designed as an Activated Sludge System, during the operation, unit energy consumption for per m^3 flowrate will be around 4 kWh/m^3. This value can be assumed as 4 times more than rotating biological contactor. Comparing with the conventional activated sludge system, rotating biological contactors needs larger investment costs but based on the economic analysis have been made it is determined that after 2 years operation regarding investment cost difference is compensate. Besides that, with regard to relatively low operation costs, sustainability is achieved in years, and become an economically preferable technology.

3.1.4 Investment and operation costs of RBC serving to 400 inhabitants

Investment cost of the plant is summarized in Table 3.6. Land improvement costs of treatment plant are excluded. During the operation, energy consumption of the plant for per m^3 flowrate is 0.45 kWh/m^3. From that value, annual electricity consumption and annual energy cost of plant is calculated as 8,497 kWh/a and 1,100 €/a. Energy unit price is considered as 0.12 €/kWh.

Table 3.6 : Investment and operation costs of RBC for 400 inhabitants.

Cost Center	Cost (€)
Investment Cost	32,000
Annual operation cost	1,100

In case of treatment plant designed as an Activated Sludge System, during the operation, unit energy consumption for per m^3 flowrate will be around 3 kWh/m^3. This value can be assumed as 7 times more than rotating biological contactor. Comparing with the conventional activated sludge system, rotating biological contactors needs larger investment costs but based on the economic analysis have been made it is determined that after one and a half years operation regarding investment cost difference is compensate. Besides that, with regard to relatively low operation costs, sustainability is achieved in years, and become an economically preferable technology.

3.1.5 Investment and operation costs of RBC serving to 800 inhabitants

Investment cost of the plant is summarized in Table 3.7. Land improvement costs of treatment plant are excluded. During the operation, energy consumption of the plant for per m^3 flowrate is 0.395 kWh/m^3. From that value, annual electricity consumption and annual energy cost of plant is calculated as 14,980 kWh/a and 1,798 €/a. Energy unit price is considered as 0.12 €/kWh.

Table 3.7 : Investment and operation costs of RBC for 800 inhabitants.

Cost Center	Cost (€)
Investment Cost	51,500
Annual operation cost	1,798

In case of treatment plant designed as an Activated Sludge System, during the operation, unit energy consumption for per m^3 flowrate will be around 3 kWh/m^3. This value can be assumed as 8 times more than rotating biological contactor. Comparing with the conventional activated sludge system, rotating biological contactors needs larger investment costs but based on the economic analysis have been made it is determined that after ten months operation regarding investment cost difference is compensate. Besides that, with regard to relatively low operation costs, sustainability is achieved in years, and become an economically preferable technology.

3.1.6 Return of investment analysis of RBC systems with different capacities

Project design of rotating biological contactors, which are served for 100, 200, 400, 600, 800 and 1000 population equivalent, have been done and detailed investment and operational cost analysis are performed for the systems serving to 200, 400 and 800 population equivalent. Based on the calculations it is concluded that compensation period of a rotating biological contactors unit serving to 200 inhabitants is 24 months and this time period decreases to 10 months when the systems scaled up to 800 inhabitant capacity.

Table 3.8 : Cost analysis of RBC unit with different capacities.

Conventional Systems	200 People	400 People	800 People
Investment Cost	22,500	25,000	37,700
Annual Operation Cost	3,250	4,400	16,700
Rotating Biological Contactor			
Investment Cost	28,000	32,000	51,500
Annual Operation Cost	550	550	825
Compensation Period			
Month(s)	24	20	10

3.2 Calculations for Solar Energy Power Unit

3.2.1 System parameters and design

Design criteria is summarized for a photovoltaic electricity generation system, which generates electricity for rotating biological contactors with 100, 200, 400, 600, 800 and 1,000 population equivalent as seen in Table 3.9.

Table 3.9 : Design criteria for population equivalent.

Parameter	Unit	Population Equivalent 100	200	400	600	800	1000
Global Horizontal Irradiation	kWh/m^2.a	1,344					
Specific Production	kWh/kWp.a	1,200					
Installed Power	kWp	6			13		
Electricity Generation	kWh/a	7,200			13,200		
Electricity Demand	kWh/a	8,500			15,000		
PV Module	Amount	24			52		
PV Module	Brand	Yingli 250Wp Polycrystalline					
Inverter	Brand	SunnyBoy 5000			2xSunnyBoy 5000		
Inverter Nominal Power	Wp	5,000			10,000		
Construction	Brand	Schletter PVMax3					

Considering the design parameters of the planned wastewater treatment plant, it is considered that PV power plant is established with two different installed power, 5 kWp and 13 kWp, as synchronous with the national electricity grid, in order to maintain continuous electricity supply to the treatment system.

3.2.2 Basic design of solar power unit of RBC serving to 200 and 400 inhabitants

In order to meet the required electricity of treatment system serving to 200 and 400 population equivalent; 24 PV modules, one SMA SunnyBoy with 6 kWp and one set of Schletter PVMax3 aluminum construction with three concrete foundations are planned. Equipment and work items related with the treatment plant's investment cost are summarized in Table 3.10.

Almost 8,500 kWh/year annual electricity demand of the treatment plant, which is design for 200 and 400 population equivalent, is met annually but especially during the winter times, because of insufficient solar energy, surplus energy demand will be met from both inverter battery system and the national grid, thanks to on-grid inverters.

Table 3.10 : Investment costs of solar system served for up to 400 people.

Equipment	Definition	Amount	Unit Price (€)	Total Price (€)
PV Module	Yingli 250Wp	24	182.8	4,387
Inverter	SMA SunnyBoy 5000	1	2,707	2,707
Construction	Schletter PVMax	1	2,925	2,925
Cabling	AC&DC cables		1,529	1,529
Installation	Electromechanical		6,801	6,801
TOTAL				18,349

3.2.3 Basic design of solar power unit of RBC serving to 800 inhabitants

In order to meet the required electricity of treatment system serving to 800 population equivalent; 52 PV modules, two SMA SunnyBoy 5000 with 13 kWp and one set of Schletter PVMax3 aluminum construction with six concrete foundations are planned. Equipment and work items related with the treatment plant's investment cost are summarized in Table 3.11.

Almost 15,000 kWh/year annual electricity demand of the treatment plant, which is design for 800 to 1000 population equivalent, is met annually but especially during the winter times, because of insufficient solar energy, surplus energy demand will be met from both inverter battery system and the national grid, thanks to on-grid inverters.

Table 3.11 : Investment costs of solar system served for up to 800 people.

Equipment	Definition	Amount	Unit Price (€)	Total Price (€)
PV Module	Yingli 250Wp	52	182.8	9,506
Inverter	SMA SunnyBoy 5000	2	2,707	5,414
Construction	Schletter PVMax	1	4,875	4,875
Cabling	AC&DC cables		2,382	2,382
Installation	Electromechanical		6,801	6,801
TOTAL				28,978

When small-scale modular PV system is required, especially for the remote areas, instead of pile foundation or piling concrete foundation is preferred, as seen in the Figure 3.2. In addition, detailed drawings of these construction tables can be seen the Figure 3.3.

Figure 3.2 : Aluminum construction of a PV system.

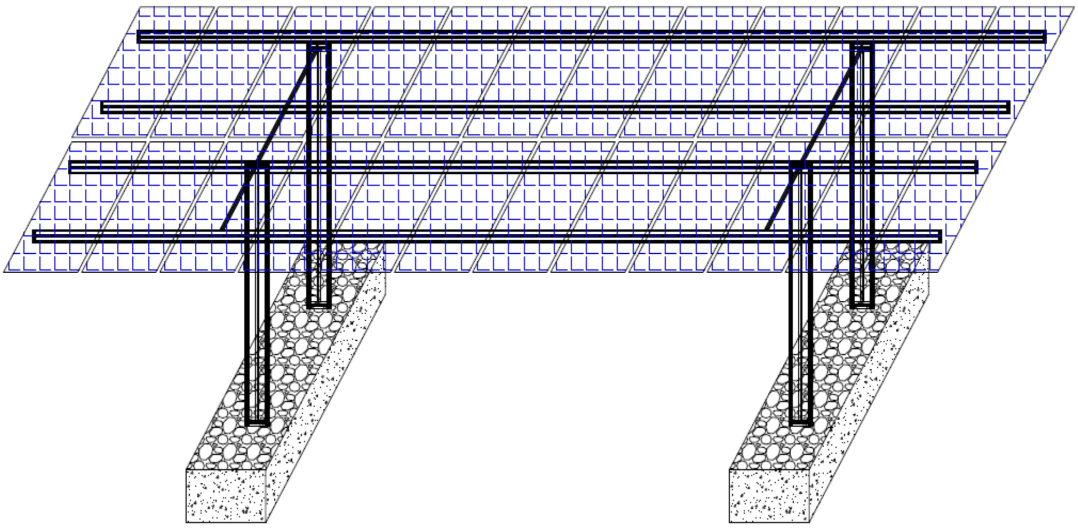

Figure 3.3 : Aluminum construction and concrete foundation cross sectional drawings.

3.3 Calculations for Wind Energy Power Unit

Considering the design parameters of the planned wastewater treatment plant, it is considered that wind power plant is established with two different installed power, 5 and 10 kW, as synchronous with the national electricity grid, in order to maintain continuous electricity supply to the treatment system.

3.3.1 Basic design of wind power unit of RBC serving to 200 and 400 inhabitants

In order to meet the required electricity of treatment system serving up to 400 population equivalent; one SWT-5kW wind turbine generator is planned with 5.6 m rotor diameter, 3 fiberglass blades. Cut-in speed of turbine is 3 m/s, cut-out speed is 30 m/s and nominal speed is 10.5 m/s. Turbine generator is direct drive type with three phase permanent magnet alternator, without any gearbox unit. Wind turbine speed control is made through variable pitch control and frequency control unit. Average electricity generation of planned turbine is 11,800 kWh/a with 5 m/s average wind speed. For the steady electricity generation, turbine is equipped with battery unit, which is fully charged within 8 hours. Generated DC electricity is transformed into the AC electricity via one invertor unit, which is on-grid three-phase type with 5.4 kW power capacity. Equipment and work items related with the treatment plant's investment cost are summarized in Table 3.12.

6,480 kWh/year annual electricity demand of the treatment plant, which is design for 200 and 400 population equivalent, is met annually but especially during the autumn and spring months, because of very low average wind speed, surplus energy demand will be met from the national grid, thanks to on-grid inverters.

Table 3.12 : Investment costs of the wind system served for up to 400 people.

Equipment	Definition	Amount	Unit Price (€)	Total Price (€)
Wind turbine	SWT-5kW	1	13,770	13,770
Inverter	Grid Connected	1	2,450	2,450
Cabling	AC&DC		345	345
Installation	Electromechanical		5,980	5,980
TOTAL				22,545

3.3.2 Basic design of wind power unit of RBC serving to 800 inhabitants

In order to meet the required electricity of treatment system serving up to 400 population equivalent; one SWT-10kW wind turbine generator is planned with 8 m rotor diameter, 3 fiberglass blades. Cut-in speed of turbine is 3 m/s, cut-out speed is 35 m/s and nominal speed is 10.8 m/s. Turbine generator is direct drive type with three phase permanent magnet alternator, without any gearbox unit. Wind turbine speed control is made through variable pitch control and frequency control unit. Average electricity generation of planned turbine is 20,000 kWh/a with 5 m/s average wind speed. For the steady electricity generation, turbine is equipped with battery unit, which is fully charged within 8 hours. Generated DC electricity is transformed into the AC electricity via one invertor unit, which is on-grid three-phase type with 12.5 kW power capacity. Equipment and work items related with the treatment plant's investment cost are summarized in Table 3.13.

9,721 kWh/year annual electricity demand of the treatment plant, which is design for 800-population equivalent, is met annually but especially during the autumn and spring months, because of very low average wind speed, surplus energy demand will be met from the national grid, thanks to on-grid inverters.

Table 3.13 : Investment costs of the wind system served for up to 800 people.

Equipment	Definition	Amount	Unit Price (€)	Total Price (€)
Wind turbine	SWT-10kW	1	19,680	19,680
Inverter	Grid Connected	1	2,950	2,950
Cabling	AC&DC		370	370
Installation	Electromechanical		5,980	5,980
TOTAL				28,980

3.4 Calculations for Hydroelectricity Power Unit

Considering the design parameters of the planned rotating biological contactor treatment plant, it is considered that hydroelectricity power plant is established with two different installed power, 1 and 2 kW, operating as island mode, which means independent from the national electricity grid. Turkish Electromechanical Industry Company (TEMSAN) made the measurements in three different locations and the results are listed in Table 3.14 below.

Table 3.14 : Flow rate measurements performed by TEMSAN.

Location	Flow Rate (L/s)	Net Head (m)	Penstock (m)	Electricity Line (m)
Dikkaya Village	4	27	35	20
Aşağıdurak Village	8	10	20	80
Murat Village	50	18	250	10

Based on the measurements on site, TEMSAN team performed a simulation in order to calculate seasonal variations of flow rate for regarding streams as seen in Table 3.15.

Table 3.15 : Relative flow rates predicted by TEMSAN.

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dikkaya	2	2	2	4	4	6	4	6	3	2	2	2
Aşağıdurak	4	4	4	8	8	10	8	10	7	4	4	4
Murat	50	50	50	50	50	60	50	60	50	50	50	50

According to the Equation 1.1 maximum and minimum hydroelectric power generation potentials of Dikkaya, Aşağıdurak and Murat streams were calculated and listed in Table 3.16.

$$P_e = \rho \,.\, g \cdot Q \cdot H_o \cdot \eta_{turbine} \tag{3.2}$$

In the equation P_e power derived from turbine shaft (W), ρ water density (*1,000 kg/m*^{3}), g gravitational acceleration (*9.81 m/s*^{2}), H_o net head height (calculated from elevation difference of penstock, m), Q flow rate (*m*^{3}*/s*), η_g total efficiency (0.90).

Table 3.16 : Maximum and minimum hydroelectricity potential of streams.

Location of Stream	P_e (kW)	ρ (kg/m^3)	*g* (m/s^2)	*Q* (m^3/s)	H_o (m)	$\eta_{turbine}$
Dikkaya Village	0.95	1000	9.81	0.004	27	0.9
	0.48	1000	9.81	0.002	27	0.9
Aşağıdurak Village	0.71	1000	9.81	0.008	10	0.9
	0.35	1000	9.81	0.004	10	0.9
Murat Village	9.54	1000	9.81	0.06	18	0.9
	7.95	1000	9.81	0.05	18	0.9

3.4.1 Basic design of hydroelectricity unit serving to 200 and 400 inhabitants

In order to meet the required electricity of treatment system serving up to 400 population equivalent; two Pelton turbine manufactured by TEMSAN is planned with 500 W installed power each one. Generated DC electricity is transformed into the AC electricity via one invertor unit, which is on-grid mono phase type with 0.5 kW power capacity. For the stable electricity generation, a concrete fore bay pool, which is served for water collection structure, is designed with the 1 m width, 1 m length and 0.5 m depth dimensions. In addition, a fine grid must be applied in order to trap the sands and gravels. In order to direct collected water from the fore bay pool to turbine unit, a penstock is designed considering local conditions. Net head of this penstock must be minimum 20 m in order to reach up the nominal operation conditions of hydraulic turbine. Regarding penstock is made through PVC pipes and will be fixed to the ground via concrete clamps with 5 m intervals. Equipment and work items related with the treatment plant's investment cost are summarized in Table 3.17.

Table 3.17 : Investment costs of the hydro system served for up to 400 people.

Equipment	Definition	Amount	Unit Price (€)	Total Price (€)
Turbine	TEMSAN	2	1,050	2,100
Inverter	TEMSAN	2		
Fore Bay Pool	Concrete	1	200	200
Penstock	PVC	30m	10	300
Cabling and installation			1,400	1,400
TOTAL				4,000

6,480 kWh/year annual electricity demand of the treatment plant, which is design for 200 and 400 population equivalent, can totally be met annually from the hydraulic sources but if any surplus energy demand occurs, especially between October and March, because of dry season of Turkey, it will not be met from the national grid because of off-grid mode operation of the generator. In order to maintain continuous electricity generation to treatment plant and prevent any power outage during the dry season, it is planned to install two small unit instead of one single unit.

3.4.2 Basic design of hydroelectricity unit serving to 800 inhabitants

In order to meet the required electricity of treatment system serving up to 800 population equivalent; one Banki turbine manufactured by TEMSAN is planned with 5.5 kW installed power. Generated DC electricity is transformed into the AC electricity via one invertor unit, which is on-grid mono phase type with 6 kW power capacity. For the stable electricity generation, a concrete fore bay pool, which is served for water collection structure, is designed with the 3 m width, 1 m length and 0.5 m depth dimensions. In addition, a fine grid must be applied in order to trap the sands and gravels. In order to direct collected water from the fore bay pool to turbine unit, a penstock is designed considering local conditions. Net head of this penstock must be minimum 10 m in order to reach up the nominal operation conditions of hydraulic turbine. Regarding penstock is made through PVC pipes and will be fixed to the ground via concrete clamps with 5 m intervals.

Equipment and work items related with the treatment plant's investment cost are summarized in Table 3.18. 9,721 kWh/year annual electricity demand of the treatment plant, which is design for 800 population equivalent, can totally be met annually from the hydraulic sources but if any surplus energy demand occurs, especially between October and March, because of dry season of our Country, it will not be met from the national grid because of off-grid mode operation of the generator.

Table 3.18 : Investment costs of the hydro system served for up to 800 people.

Equipment	Definition	Amount	Unit Price (€)	Total Price (€)
Turbine	TEMSAN	1 set	7,752	7,752
Inverter	TEMSAN	1 set		
Fore Bay Pool	Concrete	1 set	450	450
Penstock	PVC	200 m	8	1,600
Cabling and installation			950	950
TOTAL				10,752

3.4.3 Return of investment analysis of renewable energy generation units

Within the scope of performed studies, multi-criteria decision analysis have been done based on criteria such as renewable energy potential of the region, land requirement, investment cost, operation and maintenance cost, noise level etc. After the detailed comparison of each three different renewable electricity generation options, it can be concluded that hydroelectricity power plant is the most appropriate technology for the economical point of view, as seen in Table 3.19.

Nevertheless, because of the fragile ecological balance of the Storm Valley water basin, hydroelectricity power plant was not considered as a primary energy solution. Because of that, establishment of an off-grid solar energy power plant supported with batteries is evaluated as a better option in order to meet the continuous electricity requirement of planned wastewater treatment plant.

Table 3.19 : Cost comparison of different renewable energy plants.

Investment Cost	200 People	400 People	800 People
Hydroelectricity	3,550	3,550	7,372
Wind	22,545	22,545	28,980
Solar	18,349	18,349	28,978

4. CONCLUSIONS AND RECOMMENDATIONS

In this thesis, dispersed settlements of Çamlıhemşin and Ardeşen region was examined, wastewater amount and characteristics coming out from these settlements were determined. In consequence of studies performed in the region shows that annually more than 3 million cubic meters of domestic wastewater coming from Ardeşen and Çamlıhemşin dispersed settlements is discharging directly into the water streams of Storm Valley.

4.1 Practical Application of This Study

According to the Notice of Selection Methods of Wastewater Treatment Plants, the most applicable treatment technology alternatives, for the regarding region, are scored according to their ability of meeting discharge standards, flexibility to variations in flow rate and load changes, sensitivity to seasonal variations, land requirements, extensibility, investment cost, staff requirement, maintenance cost, energy consumption and noise level parameters are compared. In this context, when other treatment alternatives are evaluated, rotating biological contactors gets the highest score and become prominent technology for this region.

RBC plants do not require any qualified personnel during their operation and this is regarded as one of the biggest advantage of that system. For the operation and maintenance works of the planned RBC unit, basic maintenance training must be maintain to the selected persons and for required controls to be done must be secured at least one day per week. RBC investment cost is relatively higher than the other systems, but in consequence of detailed cost analysis have been done, regarding investment cost surplus is liquidate and in the forthcoming years, thanks to its low operational costs.

Project design of rotating biological contactors, which are served for 100, 200, 400, 600, 800 and 1000 population equivalent, have been done and detailed investment and operational cost analysis are performed for the systems serving to 200, 400 and 800 population equivalent. Based on the payback term calculations it is concluded that return of investment time of a RBC unit serving to 200 inhabitants is 24 months and this time period decreases to 10 months when the systems scaled up to 800-inhabitant capacity.

Within the scope of this thesis, it is planned to establish a solar energy power unit in order to meet the continuous electricity requirement of rotating biological contactor unit. Detailed cost and equipment analysis have been done in order to determine the most feasible renewable energy sources in consideration of energy potential of the region.

Thanks to that project, a series of innovations will be gained to region such as biological contactor type wastewater treatment plant constructed in a dispersed settlement of Storm Valley and Turkey’s first solar powered wastewater treatment system will be established, planned system will be the first one which is operated with sustainable wastewater management concept, it will be the first environmental project that contributes sustainable tea agriculture and it will be the first project that contributes protection of biodiversity of Storm Valley.

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