ABANT IZZET BAYSAL UNIVERSITY

THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

DEPARTMENT OF CHEMISTRY

INVESTIGATION OF BENEFICIAL USE OF TURKEY'S MARINE DREDGED MATERIALS IN LANDSCAPING BY A CHEMICAL APPROACH:

MANUFACTURED TOPSOIL EXAMPLE

DOCTOR OF PHILOSOPHY

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BOLU, MARCH 2017

APPROVAL OF THE THESIS

INVESTIGATION OF BENEFICIAL USE OF TURKEY'S MARINE DREDGED MATERIALS IN LANDSCAPING BY A CHEMICAL APPROACH: MANUFACTURED TOPSOIL EXAMPLE submitted by **BARIŞ GÜZEL** in partial fulfillment of the requirements for the degree of Doctor of Philosophy in **Department of Chemistry, Abant Izzet Baysal University** by,

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TO MY FAMILY

DECLARATION

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Barış GÜZEL

ABSTRACT

INVESTIGATION OF BENEFICIAL USE OF TURKEY'S MARINE DREDGED MATERIALS IN LANDSCAPING BY A CHEMICAL APPROACH: MANUFACTURED TOPSOIL EXAMPLE

PHD THESIS
BARIŞ GÜZEL
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DEPARTMENT OF CHEMISTRY
(SUPERVISOR: PROF. DR. SERPIL YENISOY KARAKAŞ)
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BOLU, MARCH 2017

The purpose of this work is to investigate the usability of marine dredged materials (DMs) resulting from dredging activities carried out in our country's fifteen sampling points as manufactured topsoil (MT) in the landscaping applications in terms of technical, environmental and economical aspect and to provide the generalization of a limited number of beneficial use alternatives conducted on the national base. This doctoral work was performed in the framework of TÜBİTAK KAMAG 1007 program and under the TARAL 1007 project named "Marine Dredging Applications and Environmental Management of DMs" [DIPTAR, Project No. 111G036]. The related project was carried out from 01/10/2013 to 01/07/2016 in TÜBİTAK Marmara Research Center Environment and Cleaner Production Institute. The sustainable environmental management of DMs was undertaken in the context of dumping at sea, landfill disposal and beneficial use on the national base.

Within the context of the characterization of DMs collected from the fifteen different sampling points, physico-chemical, morphological and toxicological properties and leaching potentials were investigated. The analysis results were compared in accordance with "The Waste Management Regulation (AYY) App. 3B" and "The Regulation on the Landfilling of Waste (ADDDY)-App. 2" limit values. It is observed that DMs can be defined as "non-hazardous waste (17 05 06 (dredging spoil other than 17 05 05)) pursuant to AYY-App. 3B. It is also found that the eluate concentrations of F^-, Cl^-, SO_4^{2-}, Total Dissolved Solid (TDS), Mo, Cu, Ni, Mo and Sb were in accordance with the limit values of 2-B) Non-hazardous waste (Class II) landfill sites according to the ADDDY-App. 2. Besides, DMs were assessed in compliance with "The Regulation on Use of

Domestic and Urban Treatment Sludge in Soil (EKAÇTKY)-App. IIB", and, it is seen that there is no substantial risk for DMs to be used as a topsoil.

In the scope of the laboratory-scale studies carried out for the utilization of DMs as MT in municipalities' environmental landscaping works, soil quality improvement studies such as sieving, desalination (washing), dewatering, organic amelioration via peat and sheep manure and pH adjustment were conducted on DM samples in order to transform DMs into an alternative natural soil. Soil quality analyses were realized in a total of 33 MT samples prepared in three different mixture ratios (33%, 50% and 67%) by using improved DM, peat and manure. The plant growth performances were followed during six months period by planting lawn seeds into the related topsoil samples at first. It is observed that the entire harvested grasses have adequate amounts of macro and micronutrients, show healthy structure in terms of nitrogen and phosphorus. Mixture prescription showing the best grass growth performance is determined as the combination of $DM_{Mixture-C6}$ (washed) 67% + Peat 16.5% + Sheep manure 16.5%. The seasonal outdoor ornamental plants were also planted into MT samples at the end of six months period having good lawn seed growth performances. The plant growth performances were followed for three months at this time. The results of this study showed that improved DMs can be effectively and beneficially used as an alternative MT in order to cultivate grass in municipality's environmental landscaping applications without any adverse effects to the environment. On the other hand, it is seen that MTs prepared by DMs are technically not feasible for growing seasonal outdoor ornamental plants due to their physico-chemical structures.

As a part of laboratory-scale washing-sieving experiments of DMs, the characterization and management of DM's washing wastewater resulting from the DM washing-sieving processes were performed. Besides, the design of "DM pre-treatment plant" to be stimulated to the laboratory scale DM washing-sieving experiments were made theoretically.

In the context of cost analysis, marine dredging cost, dumping cost at sea, landfill disposal cost, together with the beneficial use cost of DM as MT in landscaping applications were determined, the first investment and operating costs of DM pre-treatment plant plant were also actualized.

KEYWORDS: Beneficial Use, Characterization, Fertilizer, Manufactured Topsoil, Dredged Material, Peat

ÖZET

TÜRKİYE'NİN DENİZ DİP TARAMA MALZEMELERİNİN PEYZAJ DÜZENLEMESİNDE FAYDALI KULLANIMININ KİMYASAL BİR YAKLAŞIMLA İNCELENMESİ: İYİLEŞTİRİLMİŞ YÜZEY TOPRAĞI ÖRNEĞİ
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Bu çalışmanın amacı, ülkemizdeki deniz dibi tarama faaliyetleri sonucunda on beş farklı örnekleme noktasından alınan deniz dibi tarama malzemelerinin (DTM) çevre düzenlemelerinde iyileştirilmiş yüzey toprağı olarak kullanımının teknik, çevresel ve ekonomik açıdan araştırılması ve ulusal bazda yürütülen sınırlı sayıdaki faydalı kullanım alternatiflerinin yaygınlaştırılmasıdır. Bu doktora çalışması, TÜBİTAK KAMAG 1007 programı çerçevesinde "Deniz Dip Tarama Uygulamaları ve Tarama Malzemesinin Çevresel Yönetimi" [DİPTAR, Proje No. 111G036] adlı TARAL 1007 projesi kapsamında gerçekleştirilmiştir. Söz konusu proje 01/10/2013-01/10/2016 tarihleri arasında TÜBİTAK Marmara Araştırma Merkezi Çevre ve Temiz Üretim Enstitüsü'nde yürütülmüş ve DTM'lerin ulusal bazda sürdürülebilir çevresel yönetimi denize boşaltım, karada bertaraf ve faydalı kullanım seçenekleri kapsamında ele alınmıştır.

On beş farklı örnekleme noktasından alınan DTM'lerin karakterizasyonu kapsamında, fiziko-kimyasal, morfolojik ve toksikolojik özellikleri ile sızma (liç) potansiyelleri incelenmiş; analiz sonuçları "Atık Yönetimi Yönetmeliği (AYY)-EK 3B" ve "Atıkların Düzenli Depolanmasına Dair Yönetmelik (ADDDY)-EK 2" limit değerleri ile kıyaslanmıştır. Yapılan değerlendirmede, DTM'lerin AYY-EK3B'ye göre **"tehlikesiz atık"** (atık kodu 17 05 06 (17 05 05 dışındaki dip tarama çamuru)) olduğu sonucuna varılmıştır. ADDDY-EK2'ye göre ise, eluattaki F^-, Cl^-, SO_4^{-2}, Toplam Çözünmüş Katı Madde (TÇKM), Mo, Cu, Ni, Mo ve Sb konsantrasyonlarının, 2-**B) Tehlikesiz Atık (II. Sınıf)** depolama tesisleri için verilen sınır değerlere uygun oldukları saptanmıştır. Ayrıca, DTM'ler "Evsel ve Kentsel Arıtma Çamurlarının Toprakta Kullanılmasına Dair Yönetmelik (EKAÇTKY)-EK IIB 'ye göre değerlendirilmiş ve toprakta kullanımlarında herhangi bir risk olmadığı tespit edilmiştir.

DTM'lerin iyileştirilmiş yüzey toprağı olarak belediyelerin çevre düzenlemeleri işlerinde kullanımına yönelik yürütülen laboratuar ölçekli çalışmalarda DTM'leri alternatif doğal toprağa dönüştürmek için eleme, tuzluluk giderimi (yıkama), susuzlaştırma, torf ve koyun gübresi yoluyla organik içerik zenginleştirme ve pH

ayarı gibi toprak kalitesini iyileştirme aşamaları gerçekleştirilmiştir. İyileştirilmiş DTM'ler, torf ve doğal gübre kullanılarak üç farklı karışım reçetesinde (%33, %50, %67) hazırlanan toplam 33 yüzey toprağı örneğinde toprak verimlilik analizleri gerçekleştirilmiş, söz konusu toprak örneklerine ilk olarak çim tohumu ekilerek altı ay boyunca bitki gelişim performansları izlenmiştir. Tüm hasat edilen çimlerin yeterli miktarlarda makro ve mikro besin elementlerini içerdikleri, azot ve fosfor açısından sağlıklı bir yapı gösterdikleri gözlenmiştir. En iyi çim büyüme performansı gösteren karışım reçetesi %67 $DTM_{Karışım\text{-}C6}$ (yıkanmış) + %16,5 torf + %16,5 koyun gübresi olarak belirlenmiştir. Altı ay sonunda gelişim performansı iyi olan yüzey toprağı örneklerine mevsimsel dış mekân süs bitkisi tohumları ekilmiştir. Bu kez üç ay boyunca süs bitkilerinin gelişimleri takip edilmiştir. Yapılan değerlendirme sonucunda, DTM'lerin çevreye herhangi bir olumsuz etkisi olmadan verimli ve yararlı bir yüzey toprağı olarak belediyelerin çevresel düzenlemelerinde çim yetiştiriciliğinde kullanılabilecekleri saptanmıştır. Diğer taraftan, DTM'lerle hazırlanan yüzey topraklarının fiziko-kimyasal yapıları nedeniyle mevsimsel dış mekân süs bitkisi yetiştirilmesine teknik açıdan uygun olmadıkları sonucuna varılmıştır.

DTM'lerin laboratuvar ölçekli yıkama-eleme deneyleri kapsamında, DTM yıkama-eleme işlemleri sonucu ortaya çıkan yıkama atıksularının karakterizasyonu ve yönetimi gerçekleştirilmiştir. Ayrıca, laboratuar ölçekli DTM yıkama-eleme çalışmalarını yansıtacak şekilde teorik olarak "DTM ön işlem tesisi" tasarımı yapılmıştır.

Maliyet analizi kapsamında ise, deniz dibi tarama maliyeti, denize boşaltım maliyeti, karada bertaraf maliyetleri ile DTM'nin çevre düzenlemelerinde iyileştirilmiş yüzey toprağı olarak faydalı kullanım maliyeti belirlenmiş, DTM ön işlem tesisinin ilk yatırım ve işletme maliyetleri de saptanmıştır.

ANAHTAR KELİMELER: Dip Tarama Malzemesi, Faydalı Kullanım, Karakterizasyon, Gübre, İyileştirilmiş Yüzey Toprağı, Torf

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LIST OF ABBREVIATIONS AND SYMBOLS

ADDDY : The Regulation on the Landfilling of Waste
AYY : Waste Management Regulation
BOD : Biological Oxygen Demand
BS : British Standard
BTEX : Benzene, Toluene, Ethylbenzene and Xylenes
CEC : Cation Exchange Capacity
CEDA : Central Dredging Association
COD : Chemical Oxygen Demand
CEDY : Environmental Impact Assessment Regulation
DM : Dredged Material
DOC : Dissolved Organic Carbon
DUC : Dynamic Unit Cost
EC : Electrical Conductivity
EU : European Union
EDS : Energy Dispersive Spectrometer
EKAÇTKY : The Regulation on Use of Domestic and Urban Treatment Sludge in Soil
EPA : Environmental Protection Agency
ESP : Exchangeable Sodium Percentage
EWC : European Waste Catalogue
FT-IR : Fourier Transform-Infrared Spectroscopy
GC-ECD : Gas Chromatography-Electron Capture Detector
GC-FID : Gas Chromatography-Flame Ionization Detector
GC-HRMS : Gas Chromatography-High Resolution Mass Spectrometry
GC-MS : Gas Chromatography-Mass Spectrometry
GC-NPD : Gas Chromatography-Nitrogen Phosphorus Detector
GEF : Global Environment Fund
GES : Good Environmental Status
GIS : Geographical Information System
GLC : Great Lakes Commission
GHS : Globally Harmonized System
HDPE : High Density Polyethylene

HHV : High Heating Value
IADC : International Association of Dredging Companies
IC : Inorganic Carbon
ICP-MS : Inductively Coupled Plasma-Mass Spectrometry
ICP-OES : Inductively Coupled Plasma-Optical Emission Spectrometry
IMO : International Maritime Organization
LC-MSMS : Liquid Chromatography-Mass Spectrometry-Mass Spectrometry
LOI : Loss on Ignition
MAM : Marmara Research Center
MDCE : Marine Dredging Chief Engineering
MIP : Mersin International Port
MSFD : Marine Strategy Framework Directive
MT : Manufactured Topsoil
MTMAC : Ministry of Transportation, Maritime Affairs and Communication
NOAA : National Oceanic and Atmospheric Administration
NRCS : Natural Resources Conservation Service
NB : Net Benefit
NPV : Net Present Value
NTU : Nephelometric Turbidity Unit
OECD : Organisation for Economic Co-operation and Development
OG : Official Gazzette
OP : Osmotic Pressure
OSPAR : Oslo-Paris Commission
PAH : Polyaromatic hydrocarbons
PCB : Polychlorinated biphenyls
PCDD/F : Polychlorinated Dibenzodioxins (Dioxins and Furans)
SAR : Sodium Adsorption Ratio
SEM : Scanning Electron Microscope
SKKY : Water Pollution Control Regulation
SM : Standard Methods
SMOCS : Sustainable Manag. of Contaminated Sediments in the Baltic Sea
SOC : Soil Organic Carbon
SOM : Soil Organic Matter
SSDS : Soil Structure Soil Survey

TAMU : Texas Agricultural Extension Service
TBT : Tributyltin
TC : Total Carbon
TDF : Toxicity Dilution Factor
TDS : Total Dissolved Solid
TL : Turkish Lira
TKN : Total Kjeldahl Nitrogen
TOC : Total Organic Carbon
TP : Total Phosphorus
TSS : Total Suspended Solid
TÜBİTAK : The Scientific and Technological Research Council of Turkey
UNDP : United Nations Development Programme
UNEP : United Nations Environment Programme
VSS : Volatile Suspended Solid
VOC : Volatile Organic Compounds
WFD : Waste Framework Directive
WHC : Water Holding Capacity
WWTP : Wastewater Treatment Plant
XRD : X-Ray Diffraction Spectroscopy
XRF : X-Ray Fluorescence Spectrometer

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1. INTRODUCTION

1.1 CHAPTER I : DREDGING

1.1.1 Dredging Operation and Dredged Material (DM)

Dredging is a necessity to excavate or take away sediments from the bottom of marine or fresh waters in order to maintain navigation in channels and develop new ports/harbours (Figure 1.1) (Zentar et al., 2012; Cho et al., 2016).

Figure 1.1. Typical dredging equipment at the middle of the sea or lake (Pettersen et al., 2007)

Dredging operations have a vital role for the provision of marine transportation in ports, marinas and inland waterways, for the development of port facilities, for the prevention of flood risk, as well as the remediation of basins and water inlets by removing sediments (IMO London Protocol, 1996). This process consists of four phases:

a) Excavation,
b) Vertical transport,
c) Horizontal transport,
d) Placement or use of the material dredged (Bray and Cohen, 2010).

From the beginning of civilisation and the evolution of established communities, there has been a need to transport people, equipment, materials and commodities by water. Thus, the requirement for the increment and enlargement of the channels of many waterways has appeared in order to provide access to ports and harbours. Furthermore, these channels often require frequent and regular maintenance dredging. In the case of fluvial navigation, dredging is also required to construct and maintain vital links to inland ports and facilities (Bray, 2008). For example; economically and environmentally sound management and handling of dredged material (DM) is important in both The Netherlands and Germany due to huge amounts of DM emergence from maintenance, construction and remedial (clean-up) works within water systems. The national volumes of DM of the related countries are about 35 and 50 million m^3 $year^{-1}$, respectively (Netzband et al., 2002). In addition, approximately 50 million m^3 of DM is excavated per year in France (Alize, 1999; Boutin, 1999) where this amount is 400 million m^3 per year in USA.

In Turkey, Ministry of Transportation, Maritime Affairs and Communication (MTMAC), General Directorate of Shipyards and Coastal Structures is responsible to construct the port and fishery harbours, to finish the dredging works of already established maritime infrastructure facilities and also to provide the service of machinery and equipment. There are three Marine Dredging Chief Engineerings (MDCE) connected to MTMAC General Directorate of Shipyards and Coastal Structures. The assigned position of Samsun MDCE encompasses the ports from Kastamonu to Artvin, while İstanbul MDCE covers the ports from Bartın to Çanakkale (Küçükkuyu) (including Balıkesir Erdek-Bandırma) and İzmir MDCE includes the ports from Balıkesir to İskenderun (Figure 1.2) (URL-1).

Figure 1.2. MTMAC MDCE assigned positions (URL-1)

In our country, approximately 3 million m^3 DM per year were emerged as a result of routine dredging operations of the ports, marinas and fishery harbours (Özer-Erdoğan et al., 2016). 80% of this amount is thought to be dredged by MTMAC whereas 20% of the total DM by private dredging companies. MTMAC dredging quantities (m^3) on the basis of year arisen in Turkey are given in Table 1.1 and Figure 1.3 (MTMAC, 2016).

Table 1.1. MTMAC dredging quantities (m^3) on the basis of year in Turkey (MTMAC, 2016)

Year	MTMAC Dredging Quantities (m^3)			
	İstanbul MDCE	**Samsun MDCE**	**İzmir MDCE**	**Total**
2000	115,305	223,550	499,000	837,855
2001	162,250	492,950	448,800	1,104,000
2002	368,950	254,700	267,500	891,150
2003	519,300	361,700	836,000	1,717,000
2004	797,820	485,500	667,000	1,950,320
2005	641,370	741,200	447,250	1,829,820
2006	440,180	508,350	113,900	1,062,430
2007	659,460	719,100	121,500	1,500,060
2008	706,230	678,300	183,250	1,567,780
2009	684,830	417,710	174,950	1,277,490
2010	544,365	411,500	457,100	1,412,965
2011	527,750	434,150	914,500	1,876,400
2012	594,240	410,450	802,776	1,807,466
2013	507,384	193,350	534,562	1,235,296
2014	813,340	43,297	893,504	1,750,141
2015	824,837	117,814	462,282	1,404,933
2016	585,540	54,399	84,450	724,389

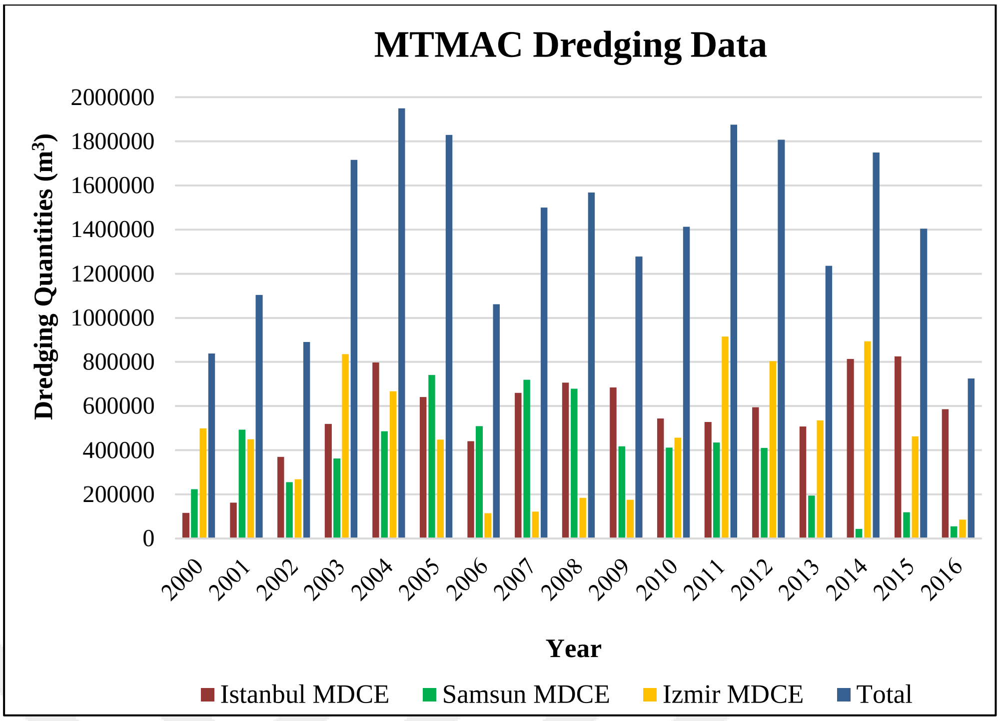


Figure 1.3. The graphical representation of MTMAC dredging quantities (m^3) on the basis of year (including August 2016) (MTMAC, 2016)

It is obvious that high volumes of DMs arise as a result of dredging of waterways like ports, marinas and waterways (Bray, 2008). Although this material is mostly dumped at sea due to economical, logistical and environmental constraints national and international field in the current situation, it is a useful and valuable resource. Most of the DM is relatively uncontaminated and it is suitable for reuse directly or after pre-treatment as raw material in other fields. Generally, a small amount of material dredged in the region of industrial areas or exposed to industrial discharges in the past may become contaminated with chemical pollutants. This type of DMs just needs the treatment applications or removal/stabilization of contaminants. The majority of the DM excavated in worldwide, by its nature, is similar to the structure of intact sediment in inland and coastal waters. However, a small portion of the DM was contaminated as a result of human activities in such size; the disposal option of these sediments must be assessed because of major environmental precautions (PIANC, 2009).

1.1.2 The Purpose of Dredging Operations

The dredging operations are carried out for different purposes and are outlined below:

- **a) Navigation:** If the dredging operation is performed for the creation of new harbours/ports, basins, canals, marinas and other facilities, it is called "capital dredging". But, if it is carried out in order to maintain the existing waterways, harbours/ports and channels; it is called as "maintenance dredging" (OSPAR, 2004; NOAA, 2011).
- **b) Construction and reclamation:** Dredging is also a process to provide the supply of construction aggregates such as clay, sand, gravel, and DMs can be used in the construction of industrial areas, residential areas, highways, dams, airports and the landfill areas as resource (OSPAR, 2004, Mymrin et al., 2016).
- **c) The beach nourishment:** DM can also be used as a filler material in the preservation and restoration of beaches in recreational purposes (OSPAR, 2004).
- **d) Environmental remediation:** Dredging can be conducted in order to remove (clean-up) the contaminated material from the marine environment for the human and environment health protection purposes and to remediate pollutants under water and to improve the water quality (OSPAR, 2004; NOAA, 2011).
- **e) The flood control:** The dredging process is also applied for the flood control via improving or maintaining the discharge or flow capabilities of rivers, canals or natural waterways and for the construction of dams and ditches.
- **f) The recovery of minerals:** Dredging can be realized for the recovery of minerals, gemstones and metals.
- **g) General:** Other reasons include excavating for underwater foundations and for the emplacement of oil, gas or other pipelines or tunnels, and providing flood control in swampy or lowland areas, where environmentally acceptable. Dredging is also used for maintaining irrigation canals and reservoirs, infrastructure that will become even more important as the world seeks to conserve and use scarce fresh water supplies (Bray and Cohen, 2010).

1.1.3 Dredging Equipments

The dredging operation can be actualized with specialized dredging equipment which varies widely, coming in many sizes and types, and including mainly water-based and sometimes land-based machines. Dredging equipment (dredger) can be grouped into four main categories according to the methods of excavation and operation. These categories are as follows:

a) Mechanical dredgers,
b) Hydraulic dredgers,
c) Mechanical/Hydraulic dredgers (utilizing both basic elements in some combination)
d) Hydrodynamic dredgers (Cohen, 2005).

Production rates for dredgers vary widely depending on the circumstances, the material to be dredged and the transport and disposal methods employed. Other factors, such as weather and sea forecast, ship traffic, depth and thickness of material being removed, also affect dredging production rates (Bray et al., 1997).

1.1.3.1 Mechanical Dredgers

Mechanical dredgers are used for excavation – dislodging the material and then raising it to the water surface – in a way similar to dry land excavation methods. Mechanically dredged sediments are generally transported by barges. Cohesive sediments dredged and transported by this way usually remain intact, with large pieces retaining their in-situ density and structure through the whole dredging and placement process (Cohen, 2005). Grab (or clamshell) and dragline dredgers, backhoe dredgers, dipper dredgers, bucket-ladder dredgers are the examples of mechanical dredgers, respectively (Figure 1.4) (Bray and Cohen, 2010).


a)
b)
c)
d)

Figure 1.4. Mechanical dredgers; a) grab (or clamshell) dredgers, b) backhoe dredgers, c) dipper dredgers and d) bucket-ladder dredgers (Bray and Cohen, 2010)

1.1.3.2 Hydraulic Dredgers

These dredgers use hydraulic centrifugal pumps to provide the excavating force, without mechanical cutters, and hydraulic transport in order to carry solid/water slurries from the digging site through a pipeline to the surface and from there to the discharge site. In some special cases, hydraulic dredgers pump into barges for subsequent transport to the placement site (Bray and Cohen, 2010). In hydraulic dredging and transportation methods large amounts of process water was added to sediments where the original structure of sediments has changed (Cohen, 2005). Plain suction dredgers and dustpan can be given as the examples of hydraulic dredgers, respectively (Figure 1.5).

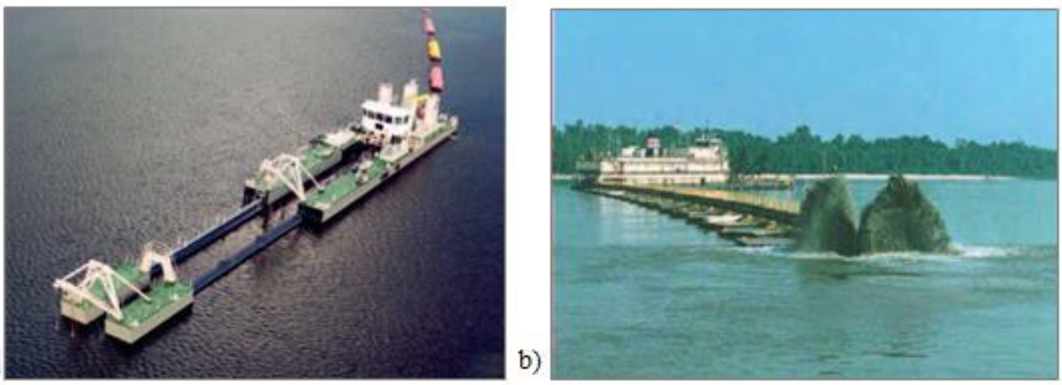

a)
b)

Figure 1.5. Hydraulic dredgers; a) plain suction dredgers, b) backhoe dredgers (Bray and Cohen, 2010)

1.1.3.3 Mechanical/Hydraulic Dredgers

They include the real workhorses of the dredging industry. These dredgers are often employed on construction and maintenance projects. The cutter suction or cutter-head dredger, bucket-wheel dredger and trailing suction hopper dredger are the examples of mechanical/hydraulic dredgers, respectively (Figure 1.6) (Bray and Cohen, 2010).

Figure 1.6. Mechanical/Hydraulic dredgers; a) cutter suction or cutter-head dredger, b) bucket-wheel dredger, and c) trailing suction hopper dredger (Bray and Cohen, 2010)

1.1.3.4 Hydrodynamic Dredgers

Hydrodynamic dredgers mobilize material underwater and then use the bed slopes, natural water currents and density gradients at the dredging site to move the material to a different location. They may be mechanical or hydraulic. The water injection dredger (Figure 1.7) is an example of hydrodynamic dredgers (Bray and Cohen, 2010).

Figure 1.7. A water injection dredger (Bray and Cohen, 2010)

Before dredging operation, the port area of interest should be carefully reviewed. The distribution and depth of sampling; the size and depth of field to be dredged, variability in the amount of dredging and the horizontal and vertical distribution of contaminants should be reflected, respectively. Core samples should be taken for this purpose. In other cases, grab (surface sediment) sampling is usually sufficient. Sampling of DMs from barges is not recommended (OSPAR, 2014).

1.1.4 National and International Legislation Relating to the Management of DMs

1.1.4.1 National Legislation

"Environmental Law (No: 2872)", "Environmental Impact Assessment (EIA) Regulation" and "Water Pollution Control Regulation (SKKY)" are fundamental laws and regulations need to be considered in terms of our national legislation in the dredging/dumping operations because of the ongoing studies about the new regulation related to the management of DM, currently.

1.1.4.1.1 Environmental Impact Assessment Regulation (25.11.2014-O.G.29186)

In our country, the only national legislation governing the decision on the management of DM has been "EIA Regulation" up till now. According to this regulation; the dredging of ≥ 3,000,000 m^3 material projects and port-built projects are considered as EIA Report desired projects (EIA Regulation Annex. 1) (25/11/2014 - O.G.29186). Also, the dredging of ≥ 300,000 m^3 material dredging projects is situated in Selection/Elimination Criteria to be implemented in accordance with EIA Regulations in Annex 2. However, EIA Regulation does not contain any specific provisions and criteria for characterization and management of DM. In addition, there is no national criterion for dumping at sea and selection of dumping areas.

1.1.4.1.2 Environmental Law (Law No 2872) (11.08.1983-O.G.18132)

All kinds of substances discarded or released into the environment as a result of any activity are defined as "**waste**" within the scope of Environmental Law No. 2872. Furthermore, according to Article 8; "All kinds of waste and residues are forbidden contrary to the standards and procedures specified in the regulations relating to harm to the environment directly and indirectly” (09.08.1983-Law No: 2872).

1.1.4.1.3 The Water Pollution Control Regulation (SKKY) (31.12.2004-O.G.25687)

It is necessary to receive the opinion of The Ministry in the scope of "The Water Pollution Control Regulation (SKKY)" for dredging and dumping activities that are not covered within the "EIA Regulation". Besides, other national legislation concerned to the protection of natural areas, fisheries and water pollution must be taken into account (Article 24 - Control of Dredging Operations).

1.1.4.1.4 Draft Regulation on the Dredging and Environmental Management of Dredged Material

"***Draft Regulation on the Dredging and Environmental Management of DM***" was prepared by the Ministry of Environment and Urbanization General Directorate of Environmental Management in the context of DIPTAR Project with the help of Project Partners in order to regulate the disposal/dumping activities and beneficial use alternatives of DM caused from dredging operations. The Regulation of concern will entry into force at the end of 2016. Draft regulation covers with the dredging operations carried out in the marine and coastal waters of our country, the criteria for the selection of dumping areas, evaluation of dumping at sea, landfill disposal and beneficial use opportunities, the receipt of necessary permits, issues relating to the monitoring of impacts of operations on the marine environment and reporting to be performed to the Ministry of Environment and Urbanization/Provincial Directorate of Environment and Urbanization. Pursuant to the Draft Regulation, The Ministry of Environment and Urbanization has the authority for $\geq$ 300,000 m^3 material dredging operations while the Provincial Directorate of Environment and Urbanization possess the authority for dredging operations < 300,000 m^3 material. In addition, the minimization of DM dumped at sea was brought to the forefront primarily by investigating the beneficial use methods in land or coastal areas for the purpose of diminishing the impacts of the material resulting from dredging operations to be caused on the marine environment.

1.1.4.1.5 The Waste Management Regulation (AYY) (02.04.2015 O.G.29314)

The objective of AYY is to determine the general principles for providing of waste management without damaging the environment and human health from formation to the disposal of waste. Accordingly, waste management is a form of management including the reduction of waste in the source, separation to the nature, collection, temporary storage, intermediate storage, recycling, transportation, disposal and control after disposal operations and similar operations, respectively.

In the Waste Management Pyramid (Figure 1.8), the first stage is to prevent the generation of waste. If this situation is not achieved, it is intended to reduce the amount of waste. The next steps are the re-use, recycling and energy recovery of waste. Disposal (such as landfilling, incineration) is the latest action to be taken for the remaining waste which is not assessed by above methods.

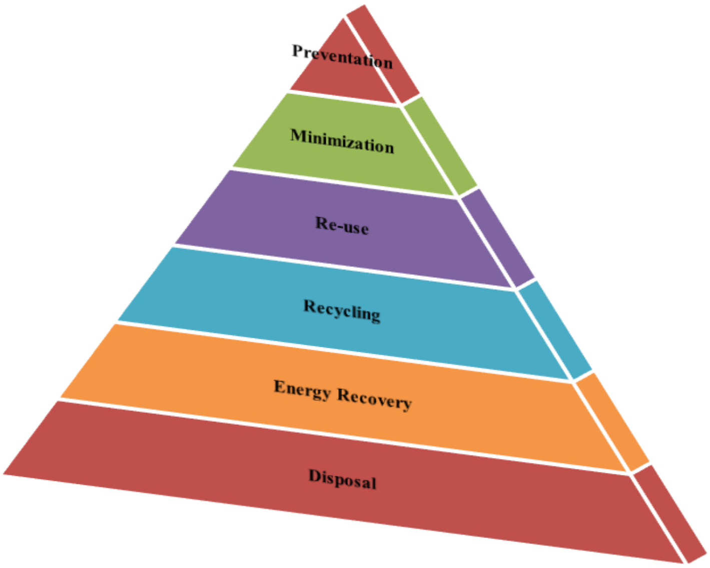


Figure 1.8. The management of DM Waste Management Pyramid (WFD, 2008)

In AYY-Appendix IV, national waste list has been identified in twenty main sections. DM is categorized as; **17** Construction and demolition wastes (including excavation removed from contaminated areas); **17 05** Soil (included “excavation” performed in contaminated location), rocks and dredging sludges; **17 05 05*** Dredging spoil containing dangerous substances (M) and **17 05 06** Dredging sludges except 17 05 05 pursuant to the “Appendix IV: Hazardous Waste List” of AYY. Wastes indicated with mark (M) in Appendix IV are the wastes that their hazardousness features must have been identified by comparing with the threshold concentration values given in AYY-Appendix III. Wastes with (A) code are described as "hazardous waste" while wastes without any code are described as "non-hazardous waste".

1.1.4.1.6 The Regulation on the Landfilling of Waste (ADDDY) (26.03.2010-O.G.27533)

The aim of ADDDY Regulation is to determine the general rules to be complied with technical and administrative matters related to;

- the prevention of environmental pollution by reducing the negative effects of leachate and landfill gas on the oil, air, groundwater and surface water to a minimum level,
- the realization of technical design of appropriate storage base depending on

the type of waste and the construction of landfill sites,

- the procedures of waste acceptance in the landfill sites,
- the operation, closure with control and maintenance duration after closure of landfill sites,
- the prevention or reduction of potential adverse effects including the greenhouse effect on the environment and risks to human health in the operation, closure and maintenance durations after closure,
- the rehabilitation, closure and maintenance duration after closure of existing landfill sites,

in the disposal period of waste.

This regulation involves the technical principles for landfill sites, the acceptance of waste to landfill sites and the methods and principles for landfilling of waste with the measures to be taken, the controls to be made and responsibilities.

Landfills are divided into three classes in Article 5 of regulation:

- Class I. Landfill Sites: Sites have the infrastructure required for the storage of hazardous waste,
- Class II. Landfill Sites: Sites have the infrastructure required for the storage of non-hazardous waste with municipal waste,
- Class III. Landfill Sites: Sites have the infrastructure required for the storage of inert waste

1.1.4.1.7 The Regulation Regarding Point Source Land Pollution and Soil Contamination Control (08.06.2010-O.G.27605)

The objective of this regulation is to prevent soil pollution, to identify potential areas and sectors where pollution is present and to determine the principles about the monitoring and cleaning of contaminated soils and sites with sustainable development objectives consistently. According to Article 6, (b) all kinds of wastes and residues are forbidden to be stored and to be given to the soil directly or indirectly, contrary to the standards and procedures specified in the relevant legislation and Environmental Law giving damage to the soil.

1.1.4.1.8 The Regulation on Use of Domestic and Urban Treatment Sludge in Soil (EKAÇTKY) (03.08.2010-O.G.27661)

The purpose of "EKAÇTKY" puts forward the principles about taking the necessary precautions related to the use of sewage sludge in soil with sustainable development goals consistently. Pursuant to relevant by law, the usage of wastewater treatment plant sludges under certain conditions after stabilization is allowed. Although this regulation is applied for the sewage sludge, the use of DM in the soil as a conditioner will be discussed as a recovery alternative under the scope of EKAÇTKY.

1.1.4.1.9 The Swimming Water Quality Regulation (09.01.2066-O.G.26048)

The aim of this regulation is to protect human health and the environment, to determine the quality of water used for swimming and recreation and to ensure the prevention of contamination of this water with all kinds of contaminants (particularly microbiological things). According to Article 5; (a) no solid waste can be disposed into the aquatic environments used for swimming and recreation.

1.1.4.1.10 The Regulation on Collection, Exploitation and Control of Sand, Gravel and Similar Substances (08.12.2007-O.G.26724)

The purpose of this regulation is to organize the principles related to the receiving, processing and control of sand, gravel and similar materials from places outside the forest areas so as not to damage the environment and human health. The scope of this regulation is;

- the area between coastline and shoreline in seas and in the sea coast lines,
- the less deep seas from 20 meters from the shoreline toward to sea direction,
- sand, gravel layers showing continuity in locations of both seaside desired to the expansion of current bed,

- in case of requested quarry place to be on the residue come next to the output of a river or creek,
- the distances identified in the protected area with other legislation and international conventions

Opening and processing of sand and gravel pit cannot be allowed for removing sand, gravel and similar materials.

The principles to be observed during the processing operations of sand, gravel and similar materials taken from the sea, lake, river and dry riverbed are described in Articles 6 and 7. The protection of ecosystem integrity and natural life are essential.

1.1.4.1.11 The Regulation on the Protection of Wetlands (04.04.2014-O.G.28962)

The purpose of this regulation is to protect and develop all wetlands whether they are important internationally or not, and to determine the principles about cooperation and coordination between official institutions and organizations in this regard. According to Article 15; garbage, debris, excavation, dredging and process sludges cannot be spilled in the areas falling within the scope of regulation. Dredging cannot be done and dredged sludge cannot be excavated without the approval of the General Directorate.

1.1.4.1.12 The Regulation on the Control of Hazardous Materials Causing Pollution in Aquatic Environment (26.11.2005-O.G.26005)

The Regulation involves the technical and administrative procedures related to the determination of hazardous substances causing pollution in the surface waters, estuary waters, regional waters; the establishment of pollution reduction programs, the prevention and monitoring of pollution, making an inventory of hazardous materials discharged into the water, the determination of discharge standards and quality criteria.

Preventing the increase in pollution by controlling the hazardous substance rate in the sediments and/or molluscs and/or crustaceans, water, air, soil and other environmental components with the application of identified limit values is stated between the principles regarding the discharge of hazardous substances into the receiving environment (Article 9).

1.1.4.1.13 Fishery Law (Law No 1380) (04.04.1971-O.G.13799)

According to Article 20 in "Fishery Law"; the substances, that harm the fisheries or the health of consumers or the material, equipment, tools and equipment used for obtaining of water products, are forbidden to dump in the inland waters and removing places in the sea or around the sea. Substances having the dumping prohibition are shown in the regulation. Also, in accordance with Article 20, those, who act contrary the prohibition, restrictions and obligations in the issued regulation, are punished with an administrative fine (Article 36 (e)).

1.1.4.1.14 Marine and Inland Waters Dredging Regulation (09.08.2016-O.G.29796)

The aim of this regulation put into force by Ministry of Transportation, Maritime Affairs and Communication is to determine the procedures and principles about the dredging activities to be carried out in the sea and inland waters. It covers dredging activities carried out in marine and inland waters, their work and operations, public institutions and organizations with real and legal persons performing dredging operation.

1.1.4.1.15 The Regulation on Collection, Exploitation and Control of Sand, Gravel and Similar Substances (08.12.2007-O.G.26724)

The purpose of this regulation is to organize the principles related to the receiving, processing and control of sand, gravel and similar materials from places outside the forest areas so as not to damage the environment and human health. The scope of this regulation;

- the area between coastline and shoreline in seas and in the sea coast lines,
- the less deep seas from 20 meters from the shoreline toward to sea direction,
- sand, gravel layers showing continuity in locations of both seaside desired to the expansion of current bed
- in case of requested quarry place to be on the residue cone next to the output of a river or creek,
- the distances identified in the protected area with other legislation and international conventions

Opening and processing of sand and gravel pit cannot be allowed for removing sand, gravel and similar materials.

The principles to be observed during the processing of the process owner taking and processing operations of sand, gravel and similar materials to be performed from the sea, lake, river and dry riverbed are described in Articles 6 and 7. According to this; the protection of ecosystem integrity and natural life are essential.

1.1.4.2 International Legislation

Our country at the regional level is a part to the Bucharest Convention for the Black Sea and the Barcelona Convention for Mediterranean, respectively. It is obliged to act in accordance with the protocols and (provisions) of interested conventions related to the management of DM. Also, Turkey is trying to be a Party to the London Convention (1972) and Protocol (1996) by the Ministry of Foreign Affairs' efforts.

In accordance with "Protocol for the Prevention of Pollution of the Mediterranean Sea by Dumping from Ships and Aircraft" and "Protocol on the Protection of the Marine Environment of the Black Sea from Dumping", which are adds to the Convention of Barcelona (1995) and Bucharest (1993), permission is required for the dumping of DM excavated from the sea. However, dumping criteria are not defined in both protocols. Regular monitoring for following the impacts in the dumping area and reviewing the dumping activities have not been taken apart (Anonymous, 1993; Anonymous, 1995).

In London Convention and Protocol; technical details are available in the characterization of DM, determination and control of contamination source, evaluation of dumping/disposal options, determination of the principles of dumping at sea and evaluation of the potential effect in these areas (IMO, 1972) (Figure 1.9).

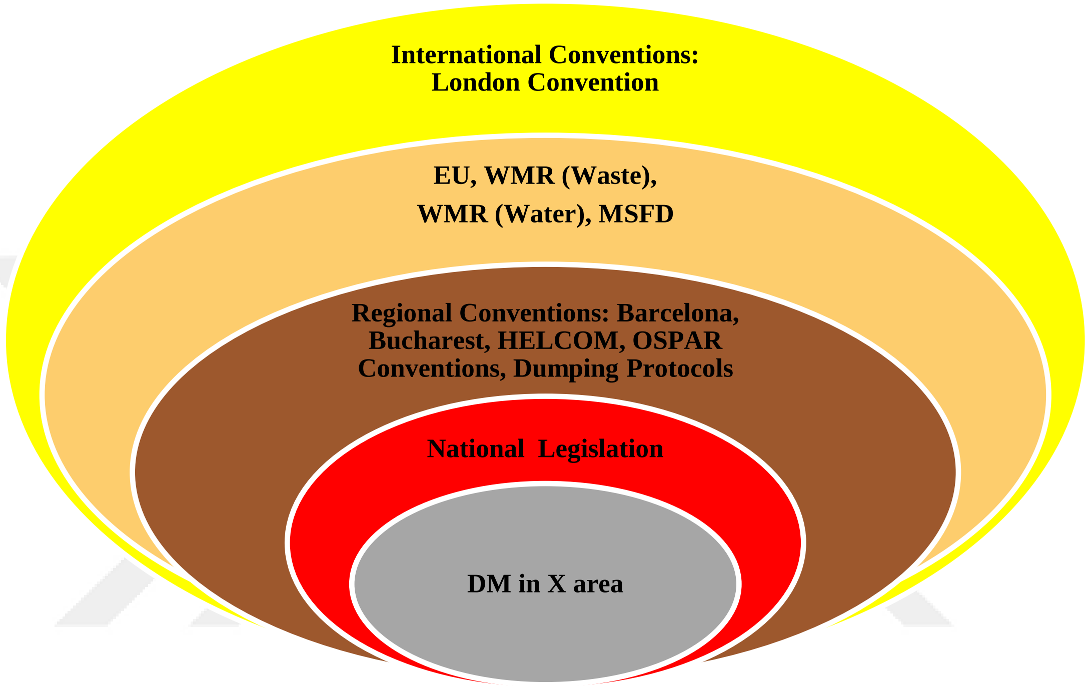


Figure 1.9. The relationship of dredging and dumping applications with national, international and regional conventions (DIPTAR, 2016)

1.1.4.2.1 International Conventions

1.1.4.2.1.1 London Convention / Protocol (1972/1996)

The **"Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter 1972"**, the "London Convention" for short, is one of the first global conventions to protect the marine environment from human activities and has been in force since 1975. Its objective is to promote the effective control of all sources of marine pollution and to take all practicable steps to prevent pollution of the sea by dumping of wastes/matters. Currently, 87 States (countries) are parties to this Convention.

The purpose of the London Convention is to control all sources of marine pollution and prevent pollution of the sea through regulation of dumping into the sea of waste materials. A so-called "black- and grey-list" approach is applied for wastes, which can be considered for disposal at sea according to the hazard they present to the environment. For the blacklist items dumping is prohibited. Dumping of the grey-listed materials requires a special permit from a designated national authority under strict control and provided certain conditions are met. All other materials/substances can be dumped after a general permit has been issued. Protocol has taken into consideration both prevention approach and “the polluter pays principle” (London Protocol Article 2).

1.1.4.2.2 Regional Conventions

1.1.4.2.2.1 Convention on the Protection of the Black Sea against Pollution (Bucharest Convention (1992))

In 1992, "Convention for the Protection of the Black Sea against Pollution (Bucharest Convention)" was adopted with the participation of the six Black Sea littoral countries (Bulgaria, Georgia, Romania, Russia, Turkey and Ukraine). It has entered into force in 1994. According to the Bucharest Convention, "The Contracting Parties are obliged to take all measures in accordance with separately or together with the provisions of this convention for the prevention of pollution of the marine environment to protect the Black Sea, reduction of the current pollution and the control of resulting from pollution. There are four protocol of the Bucharest Convention which Turkey has also party to these protocols.

1.1.4.2.2.2 The Convention for Protection of the Mediterranean Sea against Pollution (Barcelona Convention (1976))

Barcelona Convention, which all the Mediterranean countries are parties and signed in 1975, is a legal text for the protection of the Mediterranean Sea against pollution. Convention has been made for the protection of the Mediterranean marine and coastal area by revising in 1995. This text with 6 protocol forms in the legal framework of Mediterranean Action Plan. The main objective is to ensure having more healthy environmental structure of Mediterranean based on the principles of sustainable development.

1.1.4.2.2.3 Convention on the Protection of the Marine Environment of the Baltic Sea Area (Helsinki Convention (1992))

According to Helsinki Convention (1992), "dumping" means any deliberate disposal at sea or into the seabed of wastes or other matter from ships, other man-made structures at sea or aircraft; any deliberate disposal at sea of ships, other man-made structures at sea or aircraft; Dumping" does not include the disposal at sea of wastes or other matter incidental to, or derived from the normal operations of ships, other man-made structures at sea or aircraft and their equipment, other than wastes or other matter transported by or to ships, other man-made structures at sea or aircraft, operating for the purpose of disposal of such matter or derived from the treatment of such wastes or other matter on such ships, structures or aircraft; placement of matter for a purpose other than the mere disposal thereof, provided that such placement is not contrary to the aims of the present Convention (Article 2).

Current parties to HELCOM are Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden. Also, the European Union has been a party to the convention. Parties are required to do the necessary technical assessments for dumping of DM at sea by utilizing a technical guideline (HELCOM Guidelines for the Disposal of Dredged Material at Sea, 2007) prepared under convention. Article 5 of mentioned guideline relates to the characterization of materials to be dumped. Criteria / parameters are specified in the Article 1 List 8.

1.1.4.2.2.4 The Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR) (1998))

The OSPAR Convention has entered into force in 1998. Convention was formed from the combination of Oslo Convention (1972, The Convention for the Prevention of Marine Pollution by Dumping from Ships and Aircraft) and Paris Convention (1974, The Convention for the Prevention of Marine Pollution from Land-Based Sources). Convention is aimed at the protection of the marine environment by means of control and monitoring of impacts caused by human activities. In particular, it aims to prevent pollution caused by land-based pollution sources, the realization of oil and gas activities in the open sea and dumping of DM at sea. Convention based on “the polluter pays principle” with the aim of the prevention pollution at source has been supported as far as possible applications including the development of clean production technology.

1.1.4.2.3 EU Directives

1.1.4.2.3.1 Waste Framework Directive (75/442/EEC, 91/156/EEC, 2006/12/EEC, 2008/98/EC) and Commission Decision Establishing a List of Wastes (2000/532/EC)

Waste is a substance or material thrown or released to the environment by manufacturer or actually containing in the hand of ordinary or legal person. The steps outlined "waste management hierarchy" should be followed in the waste management. Hierarchy is a/an (inter)national guide used to determine the preferred order of priority to ensure optimum environmental objectives and sustainable resource use in the waste management practices. The Hierarchy was first introduced with “1975-Waste Framework Directive (WFD)" (WFD, 1975) and revised by “2008/98/EC-WFD” (WFD, 2008). The order of priority of waste management including the steps is illustrated in Figure 1.10.

Figure 1.10. Waste management hierarchy (new) (JOCE, 2008; SMOCS, 2011)

According to the WFD (2008/98/EC); DM is a "waste" requiring license/permit for the purification and landfill disposal. Although DM is called as waste under WFD, it can be considered as a valuable resource by dredging industry and potentially a useful product (PIANC, 2009; Murray, 2008; Rijkswaterstaat, 2004).

European Waste Catalogue (EWC 2000/532 / EC) has listed DM as follows:

- 17 05 05 (M)- dredging spoil containing dangerous substances
- 17 05 06 - dredged material (other)

1.1.4.2.3.2 Landfill of Waste Directive (1999/31/EC) and Council Decision Establishing Criteria and Procedures for the Acceptance of Waste at Landfills (2003/33/EC)

The aim of this Directive is to provide measures, procedures and guidance to prevent or reduce as far as possible negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air, and on the global environment, including the greenhouse effect, as well as any resulting risk to human health, from landfilling of waste, during the whole life-cycle of the landfill. Landfills can be classified as follows: Landfill for hazardous waste, non-hazardous waste, and inert waste, respectively.

1.1.4.2.3.3 Hazardous Waste Directive (91/689/EEC)

The objective of the Directive is to provide the management of hazardous waste, recovered and correct disposal of waste. In summary, Member States guarantee that hazardous waste is recorded and identified; hazardous wastes in different categories are not mixed with each other and with non-hazardous waste, proper storage and disposal of hazardous waste in order to protect human health and the environment. Member countries are responsible packaging and labelling of waste properly according to the standards of international and union members during the collection of hazardous waste, transporting and storing temporarily.

1.1.4.2.3.4 The Directive of Sewage Sludge Used in Agriculture (86/278/EEC)

This directive regulates the limit values about the laying of sludge in the farmland. Primarily, it is directed to the sewage sludges. But, it can also be taken into account in the application of DM into the soil.

1.1.4.2.3.5 Water Framework Directive (2000/60/EC)

Water Framework Directive is intended to reach "good status" of surface waters (rivers, lakes, transitional and coastal waters) of all member countries in terms of chemical and ecological quality until 2015. The amount of specific (private) pollutants in the matrix of water, sediment or biota for each country must meet their environmental quality standards (national) while determining the ecological quality status. Established quality standards at EU level should not be exceeded for priority pollutants in Water Framework and Subsidiary Directive for the chemical quality status. Also, the results of sediment and biota in the relevant guidelines need to be monitored in terms of quality status.

1.1.4.2.3.6 Marine Strategy Framework Directive (2008/56/EC)

Directive has been identified to reach "Good Environmental Status" in the marine environment or a framework to take the necessary measures to ensure the sustainability of this status (MSFD, 2008). The concept of environmental conditions takes into account the natural physiographic, the structure and function of the marine ecosystem with geographic and climatic factors. Also, the physical and chemical conditions caused by human activities in the studied areas are assessed (Borja and Rodriguez, 2010). In order to apply the ecosystem-based approach, the proposed identifiers, which are closely associated with marine dredging and drainage issues, are: Seabed Integrity (T6) and Contaminants (T8). The criteria of seabed integrity are defined as "physical damage about substrate properties and the state of benthic community". "Contaminants (T8)" are defined as toxic, persistent and likely to make bio-accumulative substances (chemicals) or group of substances and equally important other substances. According to Directive, "concentration of the contaminants should not be at a level to increase the pollutant effects". Concentrations in water, sediment and biota for good environmental status must be less than thresholds determined with toxicological data and should not tend to increase.

1.1.4.2.3.7 The Habitats Directive (92/43/ECC) and the Birds Directive (79/409/EEC)

The Habitat Directive aims to promote the maintenance of biodiversity, taking account of economic, social, cultural and regional requirements while The Birds Directive protects wild bird species and ensures the continuity of the important wild bird species.

1.1.4.2.4 Other International Legislation

1.1.4.2.4.1 Resource Conservation and Recovery Act (RCRA-1986)

It is the public law that creates the framework for the proper management of hazardous and non-hazardous solid waste. The law describes the waste management program mandated by congress that gave EPA authority to develop the RCRA program. The term RCRA is often used interchangeably to refer to the law, regulations and EPA policy and guidance.

1.1.5 The Characterization of DM

The physical, chemical and biological analysis are applied in the characterization of DM. Physical analysis is important in order to show the behaviour of DM during dredging and dumping at sea with the evaluation of additional chemical and/or biological analysis requirement. Particle size distribution (%), solid content (%), specific gravity and organic matter content (%) are recommended physical analysis to be performed in the sediment. If the evaluation of beneficial use alternatives of DM is considered, engineering properties such as permeability, compressing characteristic, plasticity, mineralogy, etc. are also necessary to be realized (OSPAR, 2004). If DM does not meet at least one of the following criteria; the chemical and biological characterization is required to assess the potential impacts (NOAA, 2011).

- DM is excavated from a site away from existing and historical sources of appreciable pollution, so as to provide reasonable assurance that the DM has not been contaminated, or
- DM is composed predominantly of sand, gravel and/or rock, or
- DM is composed of previously undisturbed geological materials (NOAA, 2011).

Chemical analysis to be applied to the DM is classified as primary and secondary analyses. The primary analyses; are a) heavy metals (Cd, Cr, Cu, Pb, Hg, Ni, Zn, As) and b) organic/organometallic compounds: Polychlorinated biphenyls

(PCBs), Polyaromatic hydrocarbons (PAHs) and Tributyltin (TBT) compounds, respectively. Secondary analyses are other chlorinated biphenyls, organophosphorus pesticides, petroleum hydrocarbons, organochlorine pesticides, other organotin compounds and Dioxins/Furans (PCDD/Fs), respectively (OSPAR, 2004).

The potential impacts of the DM to be dumped at sea cannot be assessed on the basis of the chemical and physical characterization where available biological information and biological testing should also be conducted. It is important to ascertain whether an adequate scientific basis exists on the characteristics and composition of the material to be dumped and on the potential impacts on marine life and human health or not. In this context, it is crucial to consider information about species known to occur in the area of the dumping site and the effects of the material to be dumped and of its constituents on organisms. The investigative methods include a battery of tests revealing various aspects of toxicity such as, acute or chronic impacts, solid or liquid phase organisms, transmissible or single generation effects, etc (Khosrovyan et al., 2015; Rodríguez-Romero et al., 2016). Biological tests should incorporate species that are considered appropriately sensitive and representative and exposures should be undertaken to representative materials so as to determine the potential for: a) acute toxicity; b) chronic toxicity such as long-term sub-lethal effects, covering an entire life cycle; c) the potential for bioaccumulation; and d) the potential for tainting at and in the vicinity of the disposal site, respectively. If DM is so poorly characterized that proper assessment cannot be made of its potential impacts on human health and the environment, it shall not be dumped (NOAA, 2011).

1.1.6 The Management Options of DM

Several hundred million cubic yards of sediment must be dredged from waterways and ports each year to improve and maintain the nation's navigation system and to maintain coastal national defense readiness. Alternatives for the management of DM must be carefully evaluated from the standpoint of environmental acceptability, technical feasibility, and economics (EPA, 2004).

Selection of proper dredging and transport equipment and techniques must be compatible with disposal site and management requirements. Three major alternatives for DM management (Figure 1.11) are generally available:

Figure 1.11. The management of DM (DIPTAR, 2016)

The management of DMs has become a global problem. Conventional solutions such as dumping the dredged sediments at sea are causing potentially negative impacts on the aquatic/fisheries environment (Sheehan and Harrington, 2012). Alternative solutions, such as landfill disposal, are high priced and needed large areas and also it needs to long-term monitoring (LIFE, 2002; Grégoire, 2004, Cappuyns, 2015). Therefore, the development of beneficial use alternatives for DM is required. A beneficial use is a process that uses DM as a resource and potentially useful product instead of solely dumping/disposal; this recycling approach is not a new concept (Sheehan, 2013). Because of natural resources are close to extinction and the sustainable development policy pursued in many countries, the usage of DM in beneficial use areas gathers more interest compared to the dumping at sea and landfill disposal (Dubois et al., 2009).

Each of the major alternatives for DM management involves its own set of unique considerations, and selection of a management alternative should be conducted considering environmental, technical, and economic aspects (EPA, 2004). In its current state, dumping of DM at sea is one of the most substantial human activities to be considered in coastal zone management (Marmin et al., 2014).

In summary, different management options are available depending on the nature and quantity of DM. These options are discussed below individually under five classes, including a) minimization, b) beneficial use, c) sustainable relocation, d) treatment, and e) landfill disposal/dumping at sea, respectively (Cohen, 2005; Sheehan and Harrington, 2012). Figure 1.12 presents the hierarchy within the context of DM.

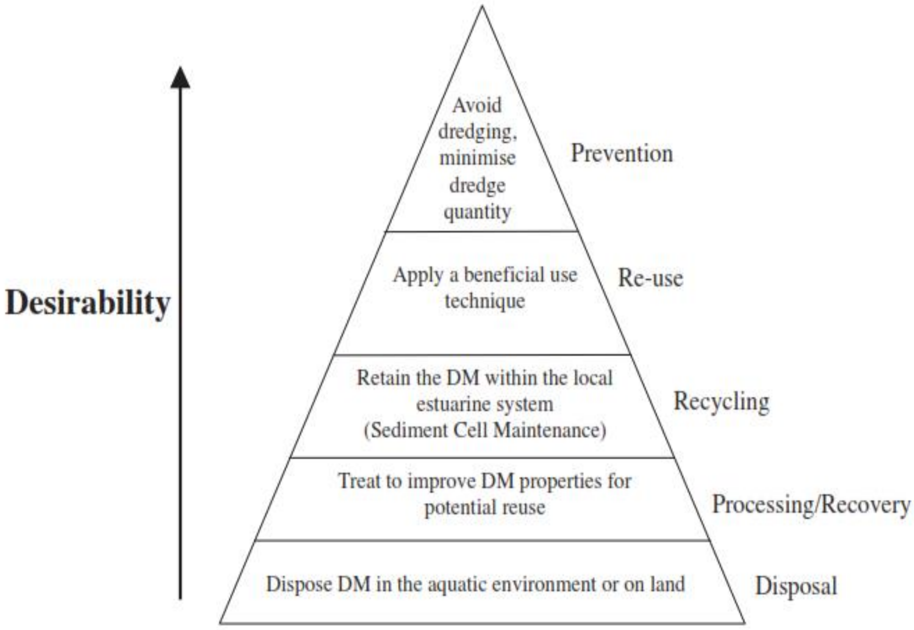


Figure 1.12. Hierarchy for prioritizing DM management (Sheehan and Harrington, 2012)

Minimization of generated DM as prevention is inapplicable; thus, appropriate beneficial use techniques should be assessed and applied in order to reduce dumping and/or disposal of DM. Nowadays, DMs have been retained and relocated in the local environment in a sustainable way within the estuarine system in order to reduce potential local erosion. For example, the UK Humber Estuary in England deposits 7 million m^3 DM per year within the estuary system (CEDA, 2010). Hence, DM can be beneficially evaluated in the environmental fields instead of being waste.

If the chemical properties of DM exceed the limit values set out in regulations, it may have a negative effect on the environment; therefore, it is necessary to perform the treatment process. The final choice in the management of DM must be dumping at sea or landfill disposal (Sheehan and Harrington, 2012).

1.1.6.1 Dumping of DM at Sea

Dumping at sea is the placement of DMs in rivers, lakes, estuaries, or oceans via pipeline or release from hopper dredges or barges. Such disposal may also involve appropriate management actions or controls such as capping (Cohen, 2005). The potential for environmental impacts is affected by the physical behaviour of the dumping at sea. Physical behaviour is dependent on the type of dredging and disposal operation used the physical nature of the material, and the hydrodynamics of the disposal site (EPA, 2004).

DMs can be placed in open-water sites using direct pipeline discharge, direct mechanical placement, or released from hopper dredges or scows. A conceptual illustration of open-water disposal using the most common placement techniques (EPA, 2004) is shown in Figure 1.13.

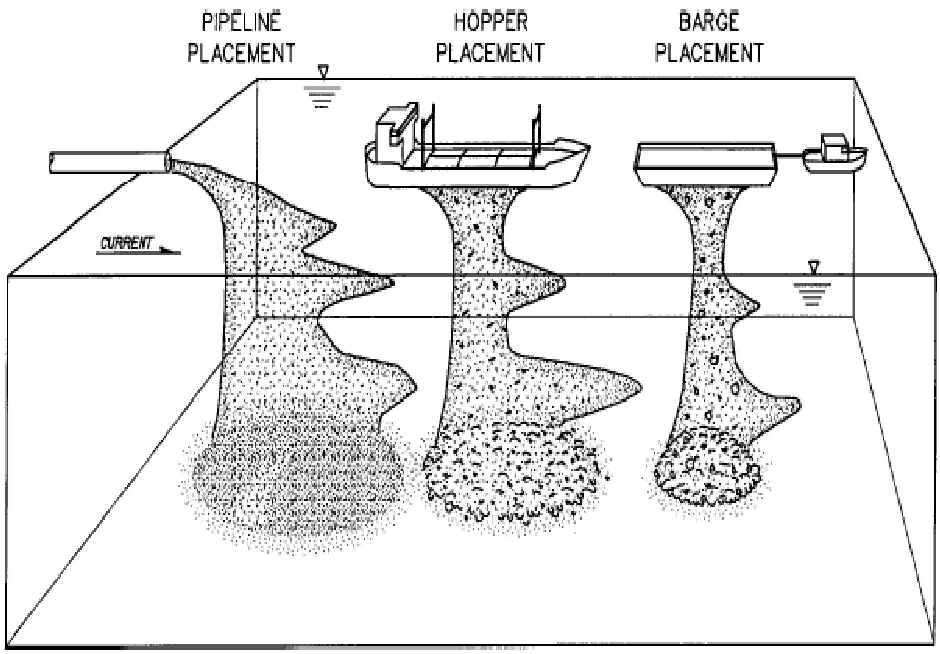


Figure 1.13. Dumping at sea operations (EPA, 2004)

Dumping of DM at sea is widely used management practice nowadays as in the past. It has been relatively easier practice compared to beneficial use options. Between 1999-2008, the amount of DM dumping at Baltic Sea from Russia, Denmark, Estonia, Sweden, Poland, Lithuania, Latvia, Germany and Finland was recorded as 2-13 million tons (Kubiliut and Durkin, 2011). In the same years, the amount of DM dumping at sea in Ireland was determined between 400.000-1.600.000 tons (OSPAR Commission, 1999-2008).

The positive environmental impacts of dredging activities can be evaluated in some beneficial use areas such as beach nourishment, wetland creation, production of building materials (clay bricks, aggregates) and erosion control, respectively (Bray, 2008, Berkowitz et al., 2016).

The impact of dredging and dumping activity is special to the area (Ware et al., 2010) and it is necessary to know well the properties of the area to assess the potential environmental impact of these activities. The physical and chemical properties, dumping period, the volume to be evacuated and the possible frequency of dumping operations are important components that should be considered when evaluating the potential environmental impacts of DM dumping to be performed (Bolam et al., 2006). It is essential to set out precautions for the determination and elimination of adverse effects of dredging and dumping activities on the marine environment, water quality and human health (Anonymous, 2013).

The literature demonstrates that dumping at sea can have the physical, chemical and biological effects on the aquatic environment through bottom smothering, increased localized sedimentation/turbidity, contamination and bioaccumulation, respectively (OSPAR Commission, 2009). Environmental impacts of dredging and dumping at sea applications are summarized below:

a) The benthic community can be adversely affected by direct burial and through alteration of the sediment structure within the habitat (Zimmerman et al., 2003).

b) Dredging and dumping at sea applications increase the concentration of total suspended solid (TSS) for a short time, and; therefore, the level of turbidity. This has a direct effect on marine flora and fauna species. The turbidity created by the dispersion of DM within the water column can both reduce the levels of transmitted light reducing phytoplankton production and increase the levels of TSS clogging the gills of fish and interfering with the food intake of filter feeding benthos (Essink, 1999).

c) The deposition of TSS can be resulted on the covering of the bottom fauna (benthic organisms) and the degradation of their activities. Covering the seabed can cause stresses or the reduction of life sliding, growth and reproduction rates in aquatic benthic organisms (Bray et al., 1997).

d) Blue mussels use TSS as the primary food source. When dredging sediments of the seabed, who served as an additional food source for blue mussels, is dumped at a different environment of sea, it causes the release of these nutrients into the water and damage to the food chain (Kiorbe et al., 1981).

1.1.6.2 Landfill Disposal of DM

The dumping of DM having hazardous waste property at sea is prohibited. If DM taken from seabed is a hazardous waste, it is evaluated within the scope of "AYY Regulation" (02/07/2015 dated and Official Gazette No: 29314). DM is categorized as 17 05 05 (dredged sludge containing dangerous substances) according to the "Appendix IV: Hazardous Waste List" of AYY Regulation and is indicated with mark (M) and (*). The assessments related to the H3-H8 H10 and H11 from the listed properties in AYY Appendix-IIIA and the threshold concentration values in AYY Appendix-IIIB are considered in order to determine the hazardousness characteristics of waste marked with (M) in the related hazardous waste list (Anonymous, 2015).

Landfill is defined as the storage of waste gradually with a certain slope not as large blocks in the sealed and made gas control areas. If measures taken to prevent negative effects on the environment are sufficient during the storage process, waste can be stored or for this purpose, the establishment of storage sites can be allowed (Babacan, 2008). It is obvious that landfill disposal is not a usable option for the management of DM (GLC, 2004). Nevertheless, DM must be analyzed in accordance with "ADDDY-Appendix 2: The acceptance criteria of the landfilling of waste" and it is necessary to decide its appropriate landfill sites' class to be stored in case of landfill disposal (Anonymous, 2010).

1.1.6.3 Beneficial Use of DM

Beneficial use is the utilization of DM as a resource instead of disposing of it as a waste. This involves placing or using DM for some productive purpose, such as beach/nearshore nourishment, habitat creation or restoration, landscaping, topsoil creation or enhancement, road construction, land creation or reclamation (e.g., strip mines, brownfields), and in the manufacture of aggregates for marketable products such as ceramics or asphalt, respectively (GLC, 2001). In other words, beneficial use may be defined as "any use which does not regard the material as a waste" (Cohen, 2005). It can be expressed as a process evaluating a potential product of DM through ensuring some environmental, economic and social benefits (Lukens, 2000). Beneficial use, in general, is all kinds of applications in order to evaluate DM as a source of raw material instead of landfill disposal/dumping at sea (Sheehan, 2013). The benefits may be derived from the DM itself or the design and location of a placement site (GLC, 2001). Beneficial use options should be evaluated in the previous stages of the dredging project in order to assess the logistical and economic constraints that may affect the feasibility of the project (GLC, 2004). The following factors should be considered to determine the beneficial use alternatives of DM:

a) **The Composition and Particle Size Distribution:** DM is characterized as one of five sediment types: a) rock; b) gravel and sand; c) consolidated clay; d) silt/soft clay; and e) mixture (rock/sand/silt/soft clay), respectively (Table 1.2 and Table 1.3) (URL-2).

b) **Contamination Status:** In general, highly contaminated sediments will not normally be suitable for most proposed beneficial use applications and particularly for proposed wildlife habitat development projects. However, after appropriate examination, testing, and treatment, the material may be classified as suitable. DM from ongoing activities (maintenance dredging) should be re-evaluated periodically in order to ensure that the sediment contamination level has not worsened since the last dredging cycle. Guidance for evaluating the contaminant status of DM can be obtained from local, regional, or national regulatory agencies (URL-2).

Table 1.2. Beneficial use options of material excavated from bottom of sea (DIPTAR, 2016)

Type of Material	Priority Order of Beneficial Use Options
Stone	1. Wetlands/terrestrial habitat creation/restoration and improvement of field in the area removed material (Example: the construction of artificial island on the coast) 2. Coast (expansion) feeding and underwater trench filling 3. Land creation and improvement 4. Use in filling of active/abandoned mineries and rehabilitation (Salinity removal must be documented*) 5. Use in road filling 6. Use as a building material in the construction industry (Example: structural fillers) (Salinity removal must be documented*) 7. Flood and coastal protection
Sand and Gravel	1. In-situ wetlands/terrestrial habitat creation/restoration (Example: the construction of artificial island on the coast) 2. Coast (expansion) feeding and underwater trench filling 3. Land creation and improvement 4. Use in filling of active/abandoned mineries and rehabilitation (Salinity removal must be documented*) 5. Use in road filling 6. Use as daily cover in the solid waste landfill sites 7. Use as a building material in the construction industry (Example: structural fillers) (Salinity removal must be documented*) 8. Use in the parks and recreational areas by the nearest municipality 9. Use in agriculture, forest areas and horticulture 10. Flood and coastal protection 11. In-situ sustainable substitution
Consolidated Clay	1. In-situ wetlands/terrestrial habitat creation/restoration (Example: the construction of artificial island on the coast) 2. Land creation and improvement 3. Use in filling of active/abandoned mineries and rehabilitation (Salinity removal must be documented*) 4. Use in road filling 5. Use as impermeable layer at the top cover or the base of solid waste landfill sites 6. Use as a building material in the construction industry (Example: structural fillers) (Salinity removal must be documented*) 7. Flood and coastal protection 8. Aquacultural work facilities 9. In-situ sustainable substitution

Table 1.3. Beneficial use options of material excavated from bottom of sea (DIPTAR, 2016) (Table 1.2 continued)

Type of Material	Priority Order of Beneficial Use Options
Sand and Silt	1. In-situ wetlands/terrestrial habitat creation/restoration (Example: the construction of artificial island on the coast) 2. Land creation and improvement 3. Use in filling of active/abandoned mineries and rehabilitation (Salinity removal must be documented*) 4. Use in road filling 5. Use as daily cover in the solid waste landfill sites 6. Use as impermeable layer in the top cover of solid waste landfill sites 7. Use in the parks and recreational areas by the nearest municipality 8. Use in agriculture, forest areas and horticulture 9. Use as building material in the construction industry (Example: Brick/ceramic production, structural fillings, concrete and aggregate production) (Salinity removal must be documented*) 10. Flood and coastal protection 11. Aquacultural work facilities 12. In-situ sustainable substitution
Clay (Silty, Soft)	1. In-situ wetlands/terrestrial habitat creation/restoration (Example: the construction of artificial island on the coast) 2. Land creation and improvement 3. Use in filling of active/abandoned mineries and rehabilitation (Salinity removal must be documented*) 4. Use as impermeable layer at the top cover or the base of solid waste landfill sites 5. Floor improvement by doing stabilization (Water, electricity, gas and so on. in the excavations) 6. Aquacultural work facilities 7. Use as building material in the construction industry (Example: Brick/ceramic production, structural fillings, concrete and aggregate production) (Salinity removal must be documented*) 8. Flood and coastal protection 9. In-situ sustainable substitution
Mix (Stone, Sand, Gravel, Silt and Clay)	1. In-situ wetlands/terrestrial habitat creation/restoration (Example: the construction of artificial island on the coast) 2. Coast (expansion) feeding and underwater trench filling 3. Land creation and improvement 4. Use in filling of active/abandoned mineries and rehabilitation (Salinity removal must be documented*) 5. Use in asphalt production by nearest municipality 6. Use in road filling 7. Use as daily cover in the solid waste landfill sites 8. Use as building material in the construction industry (Example: Structural fillings concrete production) (Salinity removal must be documented*) 9. Use in the parks and recreational areas by the nearest municipality 10. Use in agriculture, forest areas and horticulture 11. Aquacultural work facilities 12. Use in floor filler after solidification and stabilization 13. Flood and coastal protection 14. In-situ sustainable substitution

* The technical details of the DM pre-treatment plant to be established for desalination and the discharge of formed wastewater are determined by the Ministry.

c) Site Selection: There are a number of tools and exercises that can be used to find a placement site. Knowledge of the area is a valuable asset. The siting process must take into consideration both the physical features of a location and the social and political influences imposed by people and businesses around the location, respectively. Transportation costs will be a major factor in selecting a site. These costs are affected by the distance from the DM source and available transportation alternatives. Project location is another important cost consideration. Location in an urban area is more likely to be successful if the municipality has plans for remediation or renovation of lands that have fallen into disuse. On the other hand, rural areas with large parcels of open or unoccupied land with fewer restrictions due to past use may be more likely locations for clean fill or landscaping amendment. Suburban lands offer a mix of the advantages and disadvantages of each. Because most dredging operations take place in urbanized waterways or harbors, use of rural or suburban locations may pose higher transportation costs (GLC, 2004).

d) Transportation Costs: Transportation options often determine the feasibility of a beneficial use option. Travel distance and travel time between the point of generation of DM and reuse locations has a significant effect on project costs, particularly for large projects. Options for transporting DM to its site of use include rail, barge, and trucking, respectively. In addition, hydraulic dredges can pump available materials up to approximately one mile and can serve as a means of material transport for projects close to the dredging site. Rail and barge transport typically cost the least per mile and their costs are less sensitive to the cost of fuel than trucking. However, rail and barge are less available than trucking. Transportation costs are typically a function of volume or weight and distance. Wet DM is heavier and bulky, and; therefore, more expensive to move. Processing DM at the site of dredging by dewatering, stabilization or decontamination may facilitate transport by decreasing the volume and weight of DM, and in some cases, rendering DM less contaminated. Some states impose rules on transport of solid wastes, issuing permits or requiring special controls. The need to comply with such rules should be considered in evaluating the beneficial use options (GLC, 2004). The transportation distance for other materials needed at the site, such as fill soil, clay, sand, or gravel must also be considered. In some cases, such as production of bagged or bulk products, the access and transport to markets should be thought as well (GLC, 2004).

e) Environmental Acceptability: Before any substantial work can be undertaken for the determination of the beneficial use of DM, the environmental impact before, during and after the construction of the application must be investigated (URL-2).

f) Cost/Benefit: After one or more potential beneficial use options have been identified and the engineering methods have been specified, estimated costs and benefits should be analyzed (URL-2).

g) Legal Constraints: Early and concentrated coordination between permitting agencies, local interests, and environmental protection agencies is mandatory. Some beneficial use options or sites selected may be prohibited or rendered inappropriate by law or regulation. However, some beneficial uses may actually be encouraged through grants or subsidies by governmental or private organizations. Guidance for legal policy and regulations can be obtained from local, state, or national regulatory agencies (URL-2).

h) Market Analysis: Many DM beneficial use projects occur at a single time and place. However, some beneficial uses may involve ongoing manufacture and distribution of DM as a product, such as aggregate or grading fill, or component of a product, such as MT. The feasibility of such beneficial uses depends on whether a market exists for such products (GLC, 2004).

A wide range of beneficial uses of DM have been practiced; these may generally be categorized as: a) Agricultural/Product use, b) Engineering use and c) Environmental enhancement, respectively (Dubois et al., 2009; Limeira et al., 2010; Limeira et al., 2011; Limeira et al., 2012; Reine et al., 2013; Sheehan, 2013; Cappuyns, 2015; Said et al., 2015; Ozer-Erdogan, 2016; Park et al., 2016). The beneficial use alternatives of DM are given in Table 1.4.

Table 1.4. Beneficial use alternatives of DM (Sheehan and Harrington, 2012)

Agricultural/Product Use	Engineering Use	Environmental Enhancement
- The Aquaculture	- Beach Nourishment	- Wetland Habitat Creation /Enhancement
- The Construction Materials	- Land Creation	- Habitat Restoration/Creation
• Road Application	- Land Remediation/Reclamation	- Sustainable Relocation
• Bricks, Tiles and Ceramics	- Build-up Artificial Islands	- Improve Fisheries Habitat
• Concrete, Mortar	- Flood and Coastal Protection	
• Aggregate	- Building Offshore Breakwaters	
• Filler Material	- Landfill Liner/Daily Cover	
• Manufactured Soil	- Fill for Quarries/Mines	

Agricultural/Product Use: It involves the conversion of DM to a suitable form in accordance with the appropriate industry standards such as MT, landfill cover/liner or production of ceramics/bricks/concrete/lightweight aggregate/filler material in order to use in the agricultural, construction and other sectors (Sheehan and Harrington, 2012; Ozer-Erdogan, 2016).

Engineering Use: It includes the beneficial use of suitable DM to land-based resources (e.g. quarry aggregate) as an alternative material especially in engineering projects, e.g. land reclamation, beach nourishment, coastal protection works and so on (Sheehan and Harrington, 2012).

Environmental Enhancement: It contains the usage of DM beneficially as a potential resource for environmental works in a sustainable manner, e.g. habitat creation or sediment cell maintenance (Sheehan and Harrington, 2012)

International rates for the beneficial use of DMs are pointed out in Table 1.5.

Table 1.5. International rates for the beneficial use of DM (Sheehan and Harrington, 2012)

Country	Reused (%)	Comments
Ireland	20	Fill material, beach nourishment, land improvement/reclamation, construction
United States	20-30	Parks, agricultural/forestry, construction, mine reclamation, beach nourishment
Netherlands	23	4% is treated before reuse, 4% has a direct reuse, 15% is spread on land
Spain	76	Land reclamation, beach nourishment
Japan	90	Airport construction with DM stabilized-cement, environmental enhancement

1.1.7 National/International Industrial Applications Related to the Beneficial Use of DM

1.1.7.1 Large Scale National Applications for the Beneficial Use of DM

1.1.7.1.1 Haliç Environmental Protection and Cleaning Project

In the scope of Haliç cleaning project, at first, 5 million m^3 of dredged sludge was excavated from the bottom of Haliç between the years of 1997-1999 and transported by laying the giant pipe to the abandoned quarry in Alibeyköy/İstanbul. Then, concerned quarry was transformed into the sludge dam. While solid materials in the sludge pumped from Haliç were retained in the dam, the treated water was returned back to Haliç by pipes (URL-3, URL-4). In the second stage of cleaning, industrial facilities in the shore of Haliç were removed; domestic and industrial wastes polluting Haliç were handled to the collectors on both sides of Halic. Aborted maritime transportation in Haliç due to pollution was restarted (URL-5, URL-6). The excavation of 50,000 m^3 sludge per year from Haliç has been continued since 2005. In October 2012, in the scope of "Quenching Haliç from The Bosphorus" project in order to regenerate Haliç's water and increase biodiversity, 260,000 m^3/day of seawater taking from Sarıyer Çayırbaşı was began to transport to Halic (at first, with 2.2 m ID and length of 5 km giant pipes (tunnel) to Ayazağa, then, to Kağıthane creek by promoting 23 m and finally, 9 km long river ride (URL-5). Finally, Vialand Theme Park covered an area of 600 acres in size was established between September 2011 and May 2013 above the dredged sludge dam area in Alibeyköy (URL-3).

1.1.7.1.2 Application Project about the Cleaning of Mogan Lake Deep Sludge

The protocol was signed on July 2016 between the Ministry of Environment and Urbanization, and the Ministry of Transport, Maritime Affairs and Communications for the cleaning of deep sludge located in Mogan Lake where existed in "Special Environmental Protection Area" in Gölbası district of Ankara. The aim of the project is dredging of the polluted sludge layer accumulated at the bottom of Mogan Lake; thus, minimizing the level of pollution by eliminating the internal pollution sources located in the lake bottom and returning the current aquatic ecosystem to its former natural state. Approximately **2.7 million m^3** of sludge from the bottom of the lake will be removed within 480 days; dewatering process will be performed by geotextile tubes installed in the south of the lake. Then, sludge having 50% dry weight will be moved to the allocated area of the Ministry of Environment and Urbanization for establishing arboretum and botanical garden. The project of interest is the first study in Turkey to be carried out by using the latest technologies in the protected area (URL-7).

1.1.7.1.3 İzmir Gulf and Harbour Rehabilitation Project

The preparatory work was begun after the adoption of EIA application in 2016 concerning "İzmir Gulf and Port Rehabilitation Project" in collaboration with İzmir Water and Sewerage Administration and Turkish State Railways in order to make İzmir Gulf appropriate for swimming again and to increase the acceptance capacity of cargo and the ship of İzmir Port. Pursuant to the "İzmir Gulf Dredging Action Plan", a total of **46,990,000 m^3** of dredging sludge will be removed and the Project will be conducted in two stages (OSIB, 2015).

Step 1: A total of 14.660.000 m^3 of DM was planned to be removed from a) II. Part Container Terminal Course, b) The Port Basin and Maneuver Region in order to improve the efficiency and capacity of İzmir Port. 9,310,500 m^3 of DM will be used as harbour filler material while 5,349,500 m^3 of DM will be utilized in the construction of artificial island (OSIB, 2015).

Step 2: A total of 32,330,000 m^3 of DM was planned to be removed from the "Flow Improvement (Circulation) Channel" (13 km in length, 250 m wide) and "Port Approach (Navigation) Channel" (12 km in length, 250 m wide) with the aim of increasing the flow rate in İzmir Gulf, the improvement of the water cycle, the control of pollution transport and the revitalization of the ecological life, respectively. The dredged sludge will be used for the construction of another artificial island. The relevant two artificial islands are thought to be established in the opening of Bird Sanctuary for being two natural habitats for birds and endemic species (URL-8).

1.1.7.2 Large Scale International Applications for the Beneficial Use of DM

In a project jointly performed by Poland and Germany, the set and dike construction applications of DM taken from the different regions of South Baltic Sea were investigated. Two large-scale experimental sets were made. One of these sets was built in Germany whereas the other one was built in Poland (Cantre and Saathoff, 2013).

In Spain, Limeira et al. (2010) was conducted a study on the usability of marine DM as fine aggregate in the harbour pavement. 350,000 m^3 of DM removed from Sant Carles de la Ràpita in the harbour dredging operation was firstly stored during 3 months in the open air. Three different harbour way applications having 15 m long, 5 m wide and 24 cm thickness were performed with five different samples of 1 m^3 volume taken from different parts of the stored DM (Limeira et al., 2010). In another study made by Limeira et al. (2011), the usage of marine DM dredged from Barcelona Port as fine aggregate in the harbour pavement was undertaken. Aggregate tests for the detection of mineralogical, organic matter, heavy metals, chlorine and sulfate contents were performed.

On the other hand, in the patented study examined by Cheol et al. (2010) in Korea, the utilization of DM as partial replacement (50-60%) of cement and aggregate in concrete production. In another patent study performed by the same group, 10-15% cement and 50-60% DM were used in concrete production.

Several studies were also conducted for the beneficial use of DM as a resource material in road construction. Siham et al. (2008) investigated the technical feasibility of the usage of DM removed from the port of Dunkirk as a new source material for road construction. In this context, some environmental and mechanical tests (compression, carrying capacity, pressure and tensile tests) were applied to DM. In another study, Zentar et al. (2008) have built a full-scale test route with DM taken from the port of Dunkirk located in northern France in order to assess the availability of DM in road built and to evaluate the effects of mechanical testing and contaminant concentrations (trace metals, chloride, etc.) from the leachate. Miraou et al. (2012) also tried to develop a road material formulation by combining steel slag, a by-product of the steel industry, with marine sediments through applying some physico-chemical and mechanical tests.

In a patented study undertaken by Cassat et al. (2010) in France, the production of concrete from DM having a solid content of 40-80% taken from the sea and rivers was suggested. They were mixed with lithium salt to act as a catalyst, sulfoaluminate binder and sulfate source component such as calcium sulfate. In another study conducted in France, Aouad et al. (2012) tried to use the dredged sediments (via adding 39% by weight) as a raw material source to obtain Portland cement clinker.

Classification was done in compliance with the particle size distribution of DM in order to determine the management options for DM in Lithuania; thus, sediments were divided into 5 groups in accordance with the levels of pollutant (Table 1.6 and Table 1.7) (SMOCS, 2011).

Table 1.6. Classification of sediments in Lithuania according to the particle size distribution (SMOCS, 2011)

Type of Soil	Type of Sediments	Amounts of fractions
Sand	Very coarse sand	2-1 mm >50%
	Coarse sand grain	1-0.5 mm >50%
	Medium grain sand	0.5-0.25 mm >50%
	Fine grain sand	0.25-0.1 mm >50%
	Very fine sand	0.1-0.063 mm >50%
	Silty sand	<0.063 mm 10-30%
	Silty sand	<0.063 mm 30-50%
	Clayey sand	<0.002 mm 10-30%
Mud	Sandy mud	2-0.063 mm 30-50% 0.063-0.002 mm 50-70%
	Silty mud	<0.063 mm >70%
	Clayey mud	0.063-0.002 mm 30-50% <0.002 mm 30-50%

Table 1.7. Classification of sediments in Lithuania in accordance with the levels of pollutant (SMOCS, 2011)

Level of contaminant	Type of soil	Amounts of fractions										
		OP	Cu	Pb	Zn	Ni	Cd	Cr	Hg	As	PCB	PAH
I	Sand	<20	<10	<20	<60	<10	<0.5	<30	<0.1	-	-	-
II	Sand	20-200	10-40	20-50	10-40	10-20	0.5-1	30-50	0.1-0.2	-	-	-
	Mud	<500	<100	<100	<300	<50	<2	<100	<0.5	-	-	-
III	Sand	200-1500	40-200	50-200	100-400	20-100	1-5	50-200	0.2-1.2	-	-	-
	Mud	500-1500	100-200	100-200	300-400	50-100	2-5	100-200	0.5-1.2	-	-	-
IV	Sand/Mud	>1500	>200	>200	>400	>100	>5	>200	>1.2	>29	>0.03	>0.1

OP: Petroleum Products

According to the Lithuanian legislation, priority is given to the beneficial use of DM; particularly beach nourishment, agricultural practices and engineering applications have came to the fore. Other options have been discussed as dumping at sea and landfill disposal (Table 1.8).

Table 1.8. Determination of management options of DM in Lithuania (SMOCS, 2011)

Level of contamination	Type of soil	Possible use of dredged sediments	Specification
I	Sand	Restoration of beaches	Should satisfy health requirement*
I	Sand	Disposal at sea	Disposal in the nearshore zone (<30 m of depth)
II	Sand/Mud	Disposal at sea	Disposal away from nearshore zone (>30 m of depth)
III	Sand/Mud	Disposal at sea	Concentrations of harmful substances from the secondary list substances do not exceed
IV	Sand/Mud	Disposal on land	Disposal in special landfills or utilization

* Health requirements for the soil, which can be used for the beach restoration

Parameters of soil quality	Allowed limit
General amount of coliform bacteria in 1g of dry weight	1000
Salmonella bacteria in 50 g of dry weight	0
Eggs and larvas of parasitic worms (helminths)	0

In Russia, sediments were divided into five classes according to the pollution levels: 0: Clean sediments, 1: Low contamination, 2: Intermediate contamination, 3: High contamination and 4: Dangerous degree of contamination.

The levels of target, limits, approval and intervention were set in order to assess the sediment contamination in accordance with the pollutant concentrations. The beneficial use of DM was based upon the levels of contamination in Russia (Table 1.9) (SMOCS, 2011).

Table 1.9. The management options of DM in Russia (SMOCS, 2011)

DM class	Possible use of dredged sediments	Specification
0	Engineering use (land creation, beach nourishment, etc.) Disposal at sea Other uses	No restrictions for further use
I	Engineering use (after treatment) Disposal at sea	Allowable limits of pollutants should not exceed
II	Engineering use (after treatment)	After the results of chemical analysis by **full complex** of pollutants
III and IV	Disposal on land	Environmental impact assessment Mandatory long-term environmental monitoring programme of dredged areas and landfills
	Further treatment	Project of landfill construction, technologies and transportation routes

Duluth (Minnesota)-Superior (Wisconsin) Port (USA): Duluth (MI)-Superior is (WI) Port consists of twin ports established in the St. Louis River mouth in USA where 40 million tons of cargo (iron ore, coal, limestone, grain, etc.) from this port are annually carried. 115,000 m^3 of DM per year was dredged from the port navigational channel. The majority of the material removed in the last 30 years was stored in Erie Pier landfill having 1 million m^3 capacity and 36 ha area in Duluth. Plant capacity was increased to 2.1 million m^3 with expansion work and it was converted to a DM recovery plant in order to enhance the storage life of the plant. DM including coarse and fine grained material was evaluated in beneficial use areas by dividing into two classes with "sand washing" method. Since the end of 1980s, coarse particles containing basically sand was used as component in the construction of asphalt road and as a filler material in the construction field. The thin material was used for repairing the golf course near the harbour and in the construction of dyke against flooding (GLC, 2013).

Hanseaten-Stein Ziegelei GmbH Brick Plant (Hamburg-Germany): The usage of DM instead of clay was conducted in high-quality brick production in Hanseaten-Stein Ziegelei GmbH since 1996 in Hamburg-Germany. At present, DM taken from the navigation channel in the port of Hamburg and Bremen are classified according to the particle size in a treatment plant, dewatered, and then delivered to the brick plant. The annual production capacity of brick plant is about 5 million pieces of brick. Process for the production of bricks allows the substitution of natural clay with 70% by weight of DM (silt) (50% dry substance). Bricks produced using DM are mostly used in the industrial, commercial and government buildings (Netzband et al., 2002).

Fasiver (Ghent-Belgium): Contaminated soils by covering the dewatered DM can be made available for industrial activities in the abandoned industrial areas. The best example is Fasiver field near Ghent in Belgium. Fasiver has provided a solution to three problems: 1) delaying the screening process for the maintenance of the channels in Ghent due to lack of disposal/treatment plants, 2) realizing the industrial development of abandoned industrial areas, 3) lack of industrial development areas in Ghent area. 1.3 million tons of purified DM (dry matter) were laid out to the contaminated sites (42 ha) as having 5 m thickness in order to convert the mentioned field into the industrial area (Murray, 2008).

Wallasea Island (England): Wetland was created in 2006 by using 1 million tons of DM per year taken from the navigation channel in Harwich Port located in the north coast of Wallasea Island in Crouch coast of England. DM excavated from the port of Harwich was pumped with the pipeline from dredger to the controlled embankment in the sea side of newly constructed water wall. Habitat was formed for fish species such as perch, mullet in addition to bird life in the wetland. The changes in the morphology of the area was continued to be monitored until the year 2011 (Murray, 2008).

Illinois and Michigan City (Indiana) (USA): 46,000 m^3 of clean DM in Waukegan harbour in Illinois from the harbour entrance channel was dredged by mechanical equipments and located by moving trucks to Illinois beach. 78,000 m^3 of clean DM removed with hydraulic paths from the outer of Michigan City port and pumped into the target region via pipeline to be used as beach nourishment material in the western part of the harbour (GLC, 2001).

Bremen and Hamburg (Germany): Dewatered silty DM having permeability coefficient of $1*10^{-9}$ m/s was used as impermeable curtain in closed disposal plant in Hamburg and Bremen and in hazardous waste landfill site in Bremen. The same material in the industrial landfill site in Bremen was laid as the upper cover without the addition of any additives. More than 100,000 m^3 of DM was used in entire applications mentioned (Netzband et al., 2002).

Poole Harbour and Swash Channel (England): 1,240,000 m^3 of DM dredged from Swash Channel located at the main entrance of Poole harbour on England's south in 1989 was used for the feeding of Bournemouth beach right near the harbour to the purpose of the treatment and protection of the coast (Appleton, 1991).

Other international applications relating to the beneficial use of DM are given in Table 1.10.

Table 1.10. Other international applications relating to the beneficial use of DM (Murray, 2008)

No.	Name of Case Studies	Country	Construction Materials	Isolation	Flood and Coastal Protection	Placement on River Banks	Habitat Creation	Habitat Improvement	Aquaculture	Recreation	Sustainable Relocation
1	Controlled flood area	Belgium			x						
2	Mikawa Bay Project	Japan					x		x	x	
3	Fasiver	Belgium		x							
4	The Port of Oakland 50 ft Harbour Deepening Project	USA					x				
5	Galveston Bay, Texas	USA					x				
6	Backfill project at Chiba Port	Japan	x					x			
7	New docks in the Port of Aviles	Spain	x								
8	La Victoria Beach (Cadiz)	Spain			x			x			
9	Hamilton	USA			x		x				x
10	Bird Island	USA					x				
11	Wallasea Wetland Creation Project	England			x		x				
12	Nagoya International Airport Reclamation	Japan	x								
13	New Kitakyushu Airport Reclamation	Japan	x								
14	Onomichi-Itosaki Port	Japan					x		x		
15	Bricks	Germany	x								
16	Capping Project: Haringvillet	Netherlands		x							
17	Nature development Ijssel delta	Netherlands					x				
18	Scheldt Estuary/Walsoorden	Belgium					x				
19	Mounds of dredged material	Netherlands	x		x		x				
20	Self cleaning road	Netherlands	x								
21	Ca di Mezzo	Italy				x	x				
22	Large Scale Pilot Treatment	Netherlands	x								
23	Humber	England									x
24	Mudcrete	New Zealand	x								

1.1.8 The Legal Framework for the Management of DM

Dredging and dumping of marine sediments (or DM) whether clean or contaminated are managed by various local, regional and national frameworks interconnected with international agreements, conventions and directives (Apitz, 2010).

The sustainable sediment management including also beneficial use is desired in London Convention (dumping at sea) (IMO, 1972) and WFD (2008/98/EC). Contaminated DM (improper dumping at sea) carried on land are expressed as waste in many countries; it is subjected to Waste Management Hierarchy. Even though dredging operation has been undertaken for different purposes (remediation, the navigation channel deepening, construction, etc.), waste hierarchy should be considered from the initial planning stage to the end of the selection process of DM management alternatives. EU waste management hierarchy and DM management hierarchy are given together in Table 1.11.

Table 1.11. EU waste hierarchy and DM hierarchy (IMO, 1972)

EU Waste Hierarchy	DM Hierarchy
Prevention	Prevention
Reuse	Beneficial Use
	(at sea) Sediment Transportation/Placement
Recovery	Treatment/Processing
Recycling	-
Disposal	Disposal/Dumping

Prevention: The renunciation of dredging operation or the reduction of sediment and pollutant sources can be considered as a prevention strategy in terms of DM management. The organization of dumping/ocean at sea operations including sea beds performed by the London Convention are expressed in WFD (2008/98/EC). Interrogation of dredging operation, whether there is really a need or not, is emphasized in mentioned convention (IMO, 2007).

Preparing Re-use: The necessity of waste to be converted to the original form of product is situated on the basis of this management option. Therefore, "end-of-waste" status must be shown in this kind of re-use (Lee and Nash, 2009). Sampling and analysis of sediments are the use of appropriate dredging, dewatering and sieving methods to increase re-use.

Beneficial Use: As technical, in the beneficial use of DM on land or at sea by purifying/without purifying, although options are limited in accordance with the contaminant status of DM and a variety of local, regional, national or international regulations, it is possible. The treated sediments may have been classified according to particle size and state of being clean; however, they should be the same form as the original state for reuses. If they are converted into a different product, it is expressed as recycling. The relocation of DM to the selected location or placement in the appropriate disposal site can be considered as reuse in terms of ensuring sediment balance (Mink et al., 2006; Apitz, 2010).

Recycling: If the material will be recycled, it is waste and it is subjected to "end-of-waste" procedure for the permission to use in Europe (JRC, 2008). If DM was converted to a different form of the original case by treating, this process is not re-use, it is recycling; therefore, the bricks, aggregates and other materials obtained from processed DM can be classified as recycling materials (Apitz, 2010).

Recovery: Example relating to energy and biomass recovery is quite small during the administration of contaminated DM (Apitz, 2010).

Dumping/Disposal: According to the waste hierarchy, disposal is the last option. Landfill disposal and dumping at sea are subjected to many national/international laws. The purpose of the management of contaminated DM is to control the potential pollutant emission caused contaminated sediments or the exposure to the pollutants. Although landfill disposal and dumping at sea of DM are general applications, space requirement is limited and monitoring of pollutants and/or obligations involves additional costs (Apitz and Black, 2010).

Sediments can be processed for re-use, recycling or disposal. Materials prepared for re-use should not be considered as waste. However, materials prepared for recycling are waste.

The key question in the management and beneficial use of DM is "Does these materials define as raw material or waste?”. In case of DM is identified as waste, there are some waste license/permit requirements for beneficial use applications (Harrington and Smith, 2013).

Ensuring the demand-supply coordination before dredging operation will be incentive for the beneficial use of dredged sediment at a point near place performed dredging operation. Some critical issues in the selection of alternative potential use of DM should be considered:

- The quality and sufficient quantity of DM is important. Is the material appropriate in terms of physical, chemical and environmental properties? Is there a sufficient amount of material?
- Coordination is required in terms of time between dredging project and beneficial use. If they are not simultaneous, are temporary storage areas

available for the storage of the material? Or is it postponed for the time of dredging project?

- The distance between place performed dredging project and beneficial use area is also very important. Is the material available to transport to the long distance? What kind of equipment will be used for transportation?
- Flexibility is required. Can beneficial use project be modified according to the current supply properties of DM? Cost-benefit analysis should be considered very carefully (IADC, 2009).

If DM will be disposed on land, “The Landfill Directive (1999/31/EC)" or "The Regulation on the Landfilling of Waste (ADDDY); (26.03.2010-O.G: 27533)” should be applied.

The management of DM has been considered quite detailed in the OSPAR Convention revised in 2014. Despite the use of different terminology in the mentioned convention, WFD (2008/98/EC) and OSPAR Convention were highlighted as having the same purpose; these are the protection of the marine environment and human health (OSPAR, 2014). According to the convention; regardless of the quality of DM, it is defined as "waste" and is subjected to national regulations. However;

- If dredged sediments are proven to be **non-dangerous** according to the water regulations (in terms of dumping at sea) by the Member States, in this case, they are outside in the scope of WFD (2008/98/EC) by "end-of-waste" (exempt from WFD Article 2.3), they are only subjected to the national regulations regarding water and/or European directives. Also, they are the natural source for aquatic systems, quality is determined and if they meet the criteria, national water regulations are applied for the beneficial use at sea (OSPAR, 2014). If DM is not managed on land, they are not covered in the scope WFD (2008/98/EC). Thus, 90% of DM in Europe broke out from the waste category. Only DMs containing hazardous substance remain in the category of waste under WFD (IADC, 2012). If WFD is directly implemented for the management of DM, it is permitted to the re-use and recovery of waste as defined in WFD Annex-II. Member States for these activities may exempt from permit requirements to the DM (WFD Article 24) and Member States can be put general rules specifying the conditions and methods in accordance with WFD Article 25. The departure point of this perspective is an important resource for the aquatic system of DM (sediments) (OSPAR, 2014).

- If dredged sediments shows up to be **dangerous** according to the water regulations (in terms of dumping at sea), it is usually defined as waste and it is subjected to WFD (2008/98/EC); therefore, dangerousness situation should also be introduced in accordance with WFD (2008/98/EC). If DM is a waste and is transported on land, it must be managed to waste management in conformity with WFD (2008/98/EC) and in accordance with the content of hazardous substances (OSPAR, 2014; Mouvet, 2011). The recovery and evaluation of the material should be one of the management options (Mouvet, 2011).

1.1.8.1 End-of-Waste: (2008/98/EC WFD Article 6)

"End-of-waste" status must be applied not for all wastes, only for accepted and adopted certain wastes by the regulations. The purpose is to define the technical criteria to determine whether a waste when it ceased to be waste without harming the environment. End-of-waste criteria is a tool that helps development recovery independently from waste management options by specifying whether a waste when it ceased to be waste. Materials not providing the necessary conditions under the waste management can be recovered and re-used. "End-of-waste" status should be noted that it has not been listed as a concept yet in national legislation (JOCE, 2008).

According to WFD (2008/98/EC) Article 6, if it is proved that DM is not a waste, it is a product; it does not subject to WFD. Its compliance to the "end-of-waste" criteria in accordance with WFD (2008/98/EC) Article 6 should be demonstrated for beneficial use alternatives such as land reclamation, use as intermediate cover in the landfill sites, wetland habitat, stone/quarry reclamation, use as an impermeable layer in landfill sites, MT, concrete, brick/ceramic production, road applications. Beneficial use alternatives such as beach nourishment, coastal protection, seaside banquet formation are not subject to WFD Article 6 (Harrington and Smith, 2013).

"End-of-waste" status defined in WFD (2008/98/EC) Article 6 can also be applied to the dredged sediments; therefore, it is associated with "Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (2006/1907/EC)", in other words, H7 (carcinogenic), H10 (teratogenuous), H11 (mutogen), H14 (ecotoxic) criteria should be ensured (Mouvet, 2011).

1.1.8.2 By-Product: (AYY Article 19; 2008/98/EC WFD Article 5)

Substances or materials emerged during the production process, however, the main purpose is not the production of this material,

- If it is manufactured as an integral part of the production process and is found as product/by-product in the capacity report,
- If demand is continuous for future use,
- If it can be used directly in a process and does not go through another process except for the physical process in its produced place,
- Compliance with the standard of the material to be substituted or in case of it is used as raw material, it is documented that product standard of the final material does not change,
- If measures are taken to be not harmful to the environment and human health in use,

It cannot be accepted as waste, it may apply to the ministry to be regarded as "by-product" and to be compliance (JOCE, 2008; Anonymous, 2015).

In accordance with WFD (2008/98/EC) Article 5, if it is proved that DM is not a "waste", is a by-product where it does not depend on WFD (Harrington and Smith, 2013). For example, excavated soil (topsoil, subsoil) and bottom sediments are considered to be "by-product" in Italy (Peres et al., 2013).

In case of DM is used as "waste" on land, the recovery and disposal processes of DM are subject to authorization. Proper disposal methods and recycling procedures for DM are given in Table 1.12.

Table 1.12. Proper disposal methods and recycling procedures for DM (Anonymous, 2015)

Disposal Methods (AYY-Appendix 2A)	
D2	Land reclamation (for instance, biodegradation of liquid or sludge wastes in the soil, etc.)
D4	Surface filling (for example, filling of liquid or sludge wastes to the holes, pools and lagoons and so on) (2)
D6	Discharge a water body except sea/ocean
Recovery Processes (AYY-Appendix 2B)	
R10	Ecological improvement or land reclamation to be resulted in the benefit of agriculture

The use of DM [17 05 06 (dredging sludge except 17 05 05) waste codes] as an "**alternative raw material**" in cement factories are also expressed in the "Fuel Derived from Waste, Additional Fuel and Alternative Raw Material Notification-Annex 4" numbered O.G. 29036 and dated 20.06.2014.

1.2 CHAPTER II : SOIL CHEMISTRY

1.2.1 Definition of "Soil''

Soil is defined as the thin layer of unconsolidated material on the Earth's surface. It is essentially a substance formed from the decomposition and degradation products of the rocks and organic materials in various diameters, containing large creatures in the world and station and serve as the supply of nutrients for plant. It is formed with the effects of physical, chemical and biological factors throughout the various geological periods of the bedrock occurring the basis of the earth formed on the earth's crust with vegetable sourced organic waste after the cooling of the earth's crust. It especially consists of water and essential nutrients for the growth of plants for food, fiber for clothing, and forests and also construction materials. Soil productivity requirements and environmental demands such as landscaping have been reached increasingly to important levels because of land development and population growth. Thus, new sources to be used as soil should be discovered and the management of current land resources should be carried out correctly (Essington, 2005).

Soil chemistry is described as the understanding of consequence and behaviour of substances in related environment whether containing the controlled movement of plant nutrients necessary for sustainable crop farming or the strong binding and immobilization of potentially toxic elements so to provide the protection of water quality, human health, and the environment. The purpose of soil chemistry is to explain the main processes which consist of the regulation of material transfer between solid, aqueous, and gaseous phases in soil (Essington, 2005).

1.2.1.1 Soil Profile (Layers of Soil)

In general, a soil profile is a vertical cross-section of material from the earth's surface so far. Soils are named and classified based on their horizons. The soil profile has four distinct layers (Figure 1.14):

- The **O horizon**, or **topsoil**, is made of decaying organisms and plant life; it is responsible for plant production.
- The **A horizon** is of a mixture of organic material and inorganic products of weathering; it is the beginning of true mineral soil.
- The **B horizon**, or **subsoil**, is a dense layer of mostly fine material that has been pushed down from the topsoil.
- The **C horizon**, or soil base, is located just above bedrock and is made of parent, organic, and inorganic material (Boundless, 2016).

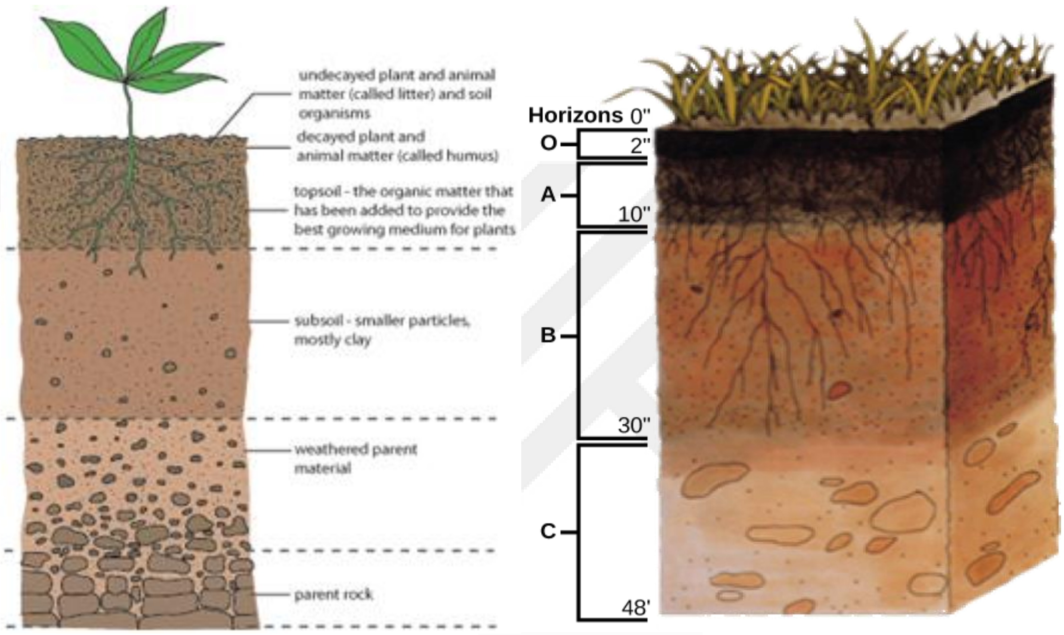


Figure 1.14. Soil layers and horizons (Boundless, 2016)

The O horizon possesses freshly-decomposing organic matter, humus, at its surface, with decomposed vegetation at its base. Humus enriches the soil with nutrients, enhancing soil moisture retention. Topsoil, the top layer of soil, is usually 5.0 cm to 7.60 cm deep, but this depth can vary considerably. It is rich in organic material and microbial processes occur there; it is responsible for plant production. The A horizon consists of a mixture of organic material with inorganic products of weathering; it is the beginning of true mineral soil. This horizon is typically darkly colored because of the presence of organic matter. In this area, rainwater percolates through the soil and carries materials from the surface. The B horizon, or subsoil, is an accumulation of mostly fine material that has moved downward, resulting in a dense layer in the soil. In some soils, the B horizon contains nodules or a layer of calcium carbonate. The C horizon, or soil base, includes the parent material, plus the organic and inorganic material that is broken down to form soil. The parent material may be either created in its natural place or transported from elsewhere to its present location. Beneath the C horizon lays bedrock (Boundless, 2016).

1.2.1.2 Chemical Properties of Soils

1.2.1.2.1 Soil pH

Soil pH is a measurement of the acidity or alkalinity of a soil. On the pH scale, 7.0 are neutral. Below 7.0 is acidic while above 7.0 is basic or alkaline. A pH range of 6.6 to 7.4 is termed **near neutral**. Many of soils are alkaline with a pH of 7.0 to 8.3. Soils with a pH of 7.5 to 8.3 generally have a high calcium carbonate content (known as **free lime**). Soil pH is an important chemical property because it can affect the availability of plant nutrients as well as the soil ecology. In very acid or alkaline soils some plant nutrients can be converted to some forms that are more difficult for plants to absorb. This can result in nutrient deficiencies. Plants which have evolved under such soil conditions often have developed mechanisms to deal with this issue (Whiting et al., 2014).

Optimum pH is between **6.5** and **7.5** for the plants in many of garden and landscaping applications. Elemental sulfur, Iron sulfate, Aluminium sulfate, Acidic peat and fertilizer (Ammonium sulfate, urea) may be added to reduce the pH of the soil in alkaline soils. However, in case of $Al_2(SO_4)_3$ usage for improving the pH of soil; Al may be toxic to the plant roots. In acidic soils, pH can be raised by participating limes ($CaCO_3$). Amount of lime to be added in the soil depends on the Cation Exchange Capacity (CEC) (plant nutrient retaining capacity). CEC is based on the clay content of soil. Soils including high amount of clay has a high CEC where they need more lime to increase pH (Whiting et al., 2014).

The pH of the soil has significant influence on plant nutrients uptake by roots. In case of high soil pH (particularly pH > 8), the hydrolysis reactions for Ca and Mg perform more rapidly and the availability of these two plant nutrients for plants increases. However, the uptake of microelements (Al, Fe, Cu, Mn, Zn and B) and the availability of phosphorus (P) would be a significant reduction (Figure 1.15). The main reason for the inefficiency of soils having high pH is that high pH affects the mobility of phosphorus and trace elements (Fe, Cu, and Zn) adversely and Na can be found in large amounts in these soils. The soil having pH between 6.5 and 7 is the most suitable soil for available-phosphorus uptake by the plants (BALKAN, 2012; Tisdale and Nelson, 1975). Sheehan et al. (2010) have accepted that the optimum pH of soil is 6.75 in the study related with the production of topsoil from DM.

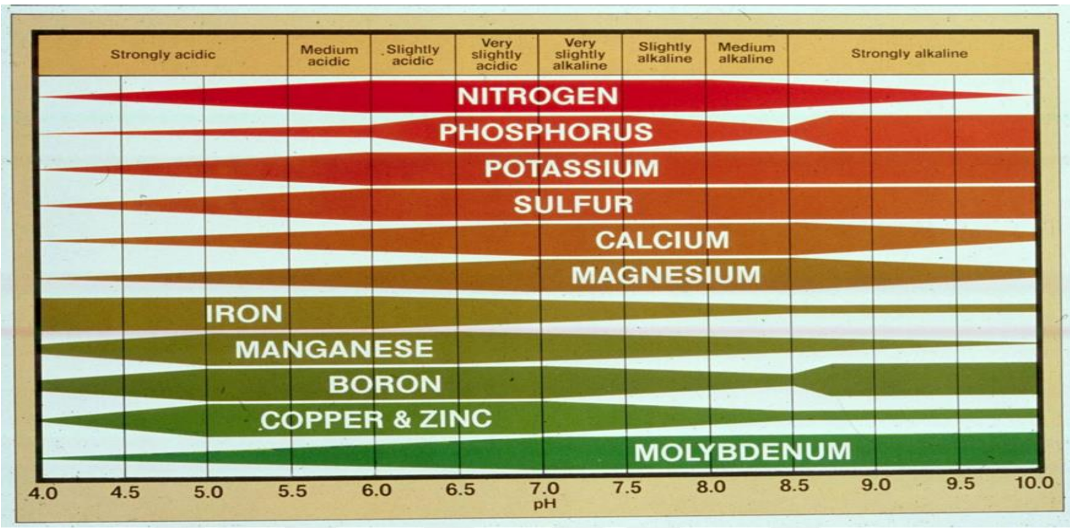


Figure 1.15. Effects of soil pH on nutrient availability (BALKAN, 2012)

1.2.1.2.2 Soil Salinity

The salt concentration in the water extracted from a saturated soil (called saturation extract) defines the salinity of soil (FAO, 1985). There is no critical point of salinity where plants' grow fails. As the salinity increases growth decreases until plants become chlorotic and die. Plants differ widely in their ability to tolerate salts in the soil. Salt tolerance ratings of plants are based on yield reduction on salt-affected soils when compared with yields on similar non-saline soils. The general soil salinity classes are pointed out in Table 1.13 (Abrol et al., 1988; Eruz, 1979).

Table 1.13. Soil salinity class and plant growth (Abrol et al., 1988; Eruz, 1979)

Soil Salinity Class	**$EC_{Satur.ext}$ (dS/m) (25°C)**	**C_{Salt} (g/l) in Saturation Extract**	**% Salt in the Soil**	**Effect on Crop Plants**
Non saline	0-2	0-1.28	0-0.14	Salinity effects negligible
Slightly saline	2-4	1.28-2.56	0.14-0.28	Yields of sensitive crops may be restricted
Moderately saline	4-8	2.56-5.12	0.28-0.56	Yields of many crops are restricted
Strongly saline	8-16	5.12-10.24	0.56-1.12	Only tolerant crops yield satisfactorily
Very Strongly saline	>16	>10.24	>1.12	Only a few very tolerant crops yield satisfactorily

1.2.1.2.3 Salt Content of Soil

The salt content of soil is calculated by using the conductivity of saturation extract at 25°C. For this purpose, the following empirical formulas are used to learn the salt content (%) of soil (Abrol et al., 1988; Eruz, 1979; Richards, 1954):

$$\% \text{ Salt (ppm/10.000) in solution} = 0.64 * EC * 10^3 \text{ (EC; mS/cm)} \quad (1)$$

$$\% \text{ Salt in the soil} = (\% \text{ salt in solution} * \text{water content (\%) in the soil})/100 \quad (2)$$

For waters and soil extracts having conductivity up to 5 mS/cm.

Conductivity to osmotic pressure (OP) in bars:

$$OP = 0.36 * EC \text{ (EC in mS/cm)} \quad (3)$$

For soil extracts in the range of 3-30 mS/cm

For example, if the EC in saturation extract is 2.35 mS/cm, the salt content in the extract will be 1.504 mg/L (0.1504 %).

% Salt in the soil and osmotic pressure values together with EC values are shown in Figure 1.16.

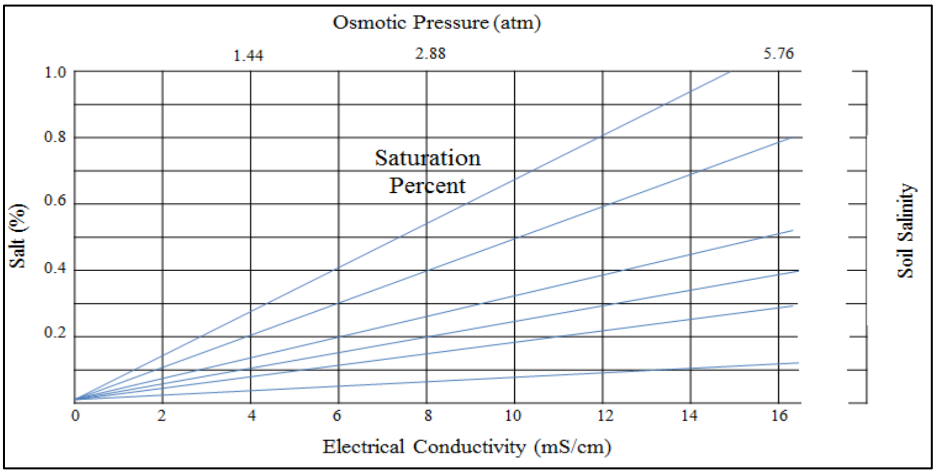


Figure 1.16. The relationship between the electrical conductivity of saturation extracts, % salt in the soil and osmotic pressure values about soils having different texture (Abrol et al., 1988; Eruz, 1979; Richards, 1954)

1.2.1.2.4 C/N Ratio

C:N ratios indicate the potential for a soil to release nitrogen for plant growth. The potential to release (or immobilize) nitrogen also depends on the bioavailability of the carbon and of the nitrogen. Excluding very acidic soil (pH < 5) and poorly drained soils, the carbon: nitrogen (C:N) ratios of topsoils fall within the range of 10 to 14 (British Standard, 2015).

1.2.1.2.5 Soil Organic Matter (SOM)

Soil organic matter (SOM) expresses directly the soil organic matter content. It contains the plant and animal residues resulting from the decomposition process, organisms in soil and substances produced by these organisms, respectively. It has the positive impacts on the soil functioning. It ensures soil biodiversity, the storage of plant nutrients, water retention, and buffer capacity. Therefore, the soil fertility is enhanced with SOM. It provides cation exchange sites and plays an important role as holding plant nutrients, particularly phosphorus, nitrogen and sulfur. There is a significant and direct relationship between SOM content and soil fertility. SOM also behaves as the source of soil carbon (C). Although the C content of SOM varies significantly, SOM is typically estimated to contain 58% C, and the terms “soil organic carbon (SOC)" and SOM are often used interchangeably (Périé et al., 2008).

Soil organic carbon x 1.72= Soil organic matter (BS, 2015) (4)

1.2.1.2.6 Salinity-Alkalinity Properties

Soil analysis is an important tool for managing salt-affected soils. Suggested soil salinity-alkalinity analysis for assessment of salt-affected soil problems are demonstrated in Table 1.14 (Horneck et al., 2007).

Table 1.14. Suggested soil salinity-alkalinity analysis for assessment of salt-affected soil problems (Horneck et al., 2007)

Analysis	Units	What is measured?	Interpretation of Analysis Results
pH	Scale of 0-14	Acidity or Alkalinity	Assesses whether pH is favourable for target crop. Indicates potential solubility of soil minerals and nutrients. One indicator of potential sodic soil conditions.
EC	dS/m or mmhos/cm	Ability of soil solution to conduct electricity.	The higher the EC, the more dissolved ions the soil contains.
Exchangeable Cations	meq/100 g	Calcium (Ca), magnesium (Mg), potassium (K), and sodium (Na). Concentration of cations that are adsorbed to negatively charged surfaces in soil.	Estimates sodium hazard by calculation of ESR. Estimates gypsum requirement for sodic soil reclamation.
Specific Elements	ppm	Boron (B), chloride (Cl), sodium (Na). Concentration of element in soil solution.	Assesses potential for toxicity of element to plants.
SAR	Unitless number	Relative concentrations of sodium, magnesium, and calcium. Calculated from cation concentrations in a saturated paste extract.	Assesses sodium hazard in soil or irrigation water.
ESP	%	Percentage of the total cation exchange sites in soil occupied by sodium.	Sodium hazard increases as ESP increases. The ESP is used to determine gypsum requirement for treatment of sodium-affected soils
CEC	meq/100 g	Capacity of soil to hold positively charged ions (cations).	The higher the CEC, the more gypsum is needed to adjust SAR and ESP.
Calcium Carbonate ($CaCO_3$) Equivalent	%	Percentage of soil by weight that is undissolved limestone.	If calcium carbonate is present, it usually is not economical to adjust pH below 8. In this case, acidifying soil amendments such as elemental sulfur or sulfuric acid can be used instead of gypsum for sodic soil reclamation.

Table 1.15 presents the relative risk (low, medium, or high) of soil and crop damage from sodium and other salts based on soil analyses. Soils having “high risk” indicate a severe salt and/or sodium problem where the severity of the problem is crop-dependent. Soils with “low risk” values generally do not have salt or sodium problems. Soils in the “medium risk” category need to be continually monitored for salt accumulation (Horneck et al., 2007).

Table 1.15. Relative risk of sodium and other salt problems as determined by soil testing (Horneck et al., 2007)

Soil Test	Risk of Problem			Problem
	Low	**Medium**	**High**	
EC (dS/m)	below 0.75	0.75-4	above 4	EC is an indicator of the quantity of dissolved salts. High salt concentrations may reduce seed germination and plant growth.
ESP	below 5 %	5-15%	above 15 %	As ESP (sodium) increases, soil structure decreases; the infiltration rate of water into soil and the rate of water movement through soil may be reduced. High concentrations of sodium can be toxic to plants.
SAR	below 5	5-13	above 13	Same as ESP above
pH	below 7.5	7.5-85	above 8.5	Soil iron, manganese, and other micronutrients are less available for plant uptake. If pH is above 8.5, careful monitoring of SAR or ESP is recommended.

1.2.1.2.6.1 Sodium Adsorption Ratio (SAR)

The SAR of a saturated paste extract or irrigation water is a relationship between the concentrations of sodium (Na^+) and calcium + magnesium (Ca^{2+} + Mg^{2+}). SAR reflects the Na^+ status of the soil cation exchange complex. It is calculated as (Horneck et al., 2007) given in Equation (5):

$$SAR = \frac{[Na^+]}{\sqrt{0.5([Ca^{2+}] + [Mg^{2+}]}} \quad (5)$$

where calcium, magnesium, and sodium concentrations are expressed in units of milliequivalent per liter (meq/L) (Horneck et al., 2007).

1.2.1.2.6.2 Cation Exchange Capacity (CEC)

CEC is a measure of the net negative charge of a soil. It is defined as the total quantity of cations that can be exchanged on a unit of soil material where expressed as milliequivalents per 100 grams of soil (meq/100 g), millimoles of charge per kilogram of soil (mmol [+ charge]/kg) or centimoles of charge per kilogram of soil (cmole [+ charge]/kg) (Horneck et al., 2007).

$$NaX = [C_{ext}Na / (10*D)]*V/A \quad (6)$$

$$KX = [C_{ext}K / (10*D)]*V/A \quad (7)$$

$$CaX = [C_{ext}Ca / (10*D)]*V/A \quad (8)$$

$$MgX = [C_{ext}Mg / (10*D)]*V/A \quad (9)$$

$$CEC = NaX + KX + CaX + MgX \quad (10)$$

In Equation (6), (7), (8), (9) and (10), NaX, KX, CaX and MgX state the exchangeable cation concentrations (milliequivalents per 100 grams of soil (meq/100 g), millimoles of charge per kilogram of soil (mmol [+ charge]/kg)), $C_{ext}Na$, $C_{ext}K$, $C_{ext}Ca$, $C_{ext}Mg$ indicate the soluble cations in the saturation extract (mg/l), D defines the density of the sample (g/ml), V reveals the cation valence (Na: +1, K: +1; Mg: +2; Ca: +2), A specifies the relative atomic weight of the cation (unitless) (Na: 22.990; K: 39.098; Mg: 24.305; Ca: 40.078), respectively (Horneck et al., 2007; BS, 2015).

1.2.1.2.6.3 Exchangeable Sodium Percentage (ESP)

Percentage of the CEC is filled by sodium. When the EC comes up above 4, the accumulation of sodium begins and ESP value goes to over 15%. When ESP value comes out to over 15% and especially pH is greater than 8, the physical properties of soil are degraded and water permeability of it decreases rapidly. ESP (%) is calculated as reported in equation (11) (BS, 2015):

$$ESP\ (\%) = \frac{Na^{+}\text{,meq}/100gsoil}{CEC,meq/100g\ soil} x100 \quad (11)$$

ESP is a measure of the exchangeable sodium ions relative to the total exchangeable ions. If the conductivity is greater than 2.8 mS/cm, the ESP shall be measured. An ESP of up to 15% is acceptable where the clay content is less than 35%. Only soils with ESP less than 15% conform to this standard. Gypsum can be applied in order to ameliorate structural instability due to excessive sodium, preventing clay dispersion by exchanging the exchangeable sodium with calcium (BS, 2015).

The relationship between SAR value of the saturation extract and ESP value of soil for many soils located in the Western America is expressed by the following Equation (12) (Richards, 1954):

$$ESP(\%) = \frac{100(0.01475 * SAR - 0.0126)}{1 + (0.01475 * SAR - 0.0126)} \qquad (12)$$

Limit values used in the assessment of soil productivity and soil salinity-alkalinity analysis results together with the relevant references are given in Table A.1, Table A.2 and Table A.3.

1.2.1.3 Classification of Salt-Affected Soils

Kinds of Salt-affected soil: Classification made for saline soils by Riverside Salinity Laboratory founded in 1937 in California; USA has been adopted as the best classification for mostly today. This classification is used to describe saline and sodic soils in our country as well. According to this classification, the management of salt-affected soils has been identified in three general soil categories (Eruz, 1979):

Three general categories of salt-affected soils have been identified for management purposes:

- Saline soils: Salt problems in general,
- Sodic soils: Sodium problems,
- Saline-sodic soils: Problems with sodium and other salts (Horneck et al., 2007).

These categories on the soil classification literature have been specified by using some quantitative criteria by Natural Resources Conservation Service (NRCS) (Table 1.16) (e.g., saline soils must have electrical conductivity (EC) above 4 dS/m) (Horneck et al., 2007).

Table 1.16. Classification of salt-affected soils used by NRCS (Horneck et al., 2007)

Salt-affected soil classification	**(EC) (dS/m)**	**pH**	**Sodium adsorption ratio (SAR)**	**Exchangeable sodium percentage (ESP)**	**Typical soil physical condition (soil structure)[a]**
None	< 4	< 8.5	< 13	< 15	Flocculated
Saline	> 4	< 8.5	< 13	< 15	Flocculated
Sodic	< 4	> 8.5	> 13	> 15	Dispersed
Saline-sodic	> 4	< 8.5 > 8.5	> 13	> 15	Flocculated

[a] Soil physical condition (dispersion or flocculation) also depends on factors not included in the NRCS classification system, including soil organic matter, soil texture, and the EC of irrigation water.

In the same way, the NRCS classification threshold for sodic soils (SAR above 13 or ESP above 15) is somewhat arbitrary. Generally, the change from flocculated (aggregated) to dispersed soil occurs step by step as sodium level increases. Thus, salinity and alkalinity should be considered as variable parameters affecting the plant and soil productivity (Horneck et al., 2007).

1.2.1.3.1 Saline Soils

Saline soils have electrical conductivity (EC) of more than 4 dS/m and less than ESP value of 15 in the saturation extract at 25°C. pH is usually lower than 8.5. Sodium cation is higher compared to other cations. They possess a very low rate of potassium and different proportions of calcium and magnesium apart from sodium. They have a high rate of chlorine and sulfate anions and include a low rate of bicarbonate and nitrate anions. They contain poorly soluble salts such as $CaSO_4$, $CaCO_3$ and $MgCO_3$ besides easily soluble salts (Eruz, 1979):

Calcium and magnesium are the dominant exchangeable cations in saline soils. They usually have visible salt accumulations on the surface and are sometimes defined as "white alkali" soils. On soil structure and water infiltration, a lot of salts in the soil solution have positive effects. Thus, the penetration of water is not a main concern in the saline soil (Horneck et al., 2007).

Disadvantages caused by salts in the soil may be considered as follows:

- Salts in the root zone which makes it difficult to take water from the soil to the roots may reduce the product yield.

- Salts increase the osmotic potential of the soil; therefore, the displacement of water carries out from the plant tissue having low salt concentration to the soil with a high salt concentration.
- High salt concentration in soil may lead to discoloration of the plant even if soil has enough moisture (Horneck et al., 2007).

Salts include positively charged ions (cations) and negatively charged ions (anions). They may be dissolved in water (soluble salts) or found as solids. The salts in the soil can be sourced from soil parent materials; the irrigation water; manure, compost or other improvers. The accumulated predominant salts in the soil are Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, SO_4^{2-}, Cl^{-}, CO_3^{2-} and HCO_3^{-}. Any salt that accumulates excessively in the soil would cause problems in plant growth. As the percentage of Na enhances, soil structure deteriorates and the dispersion of risk of soil aggregates increases (Figure 1.17) (Horneck et al., 2007).

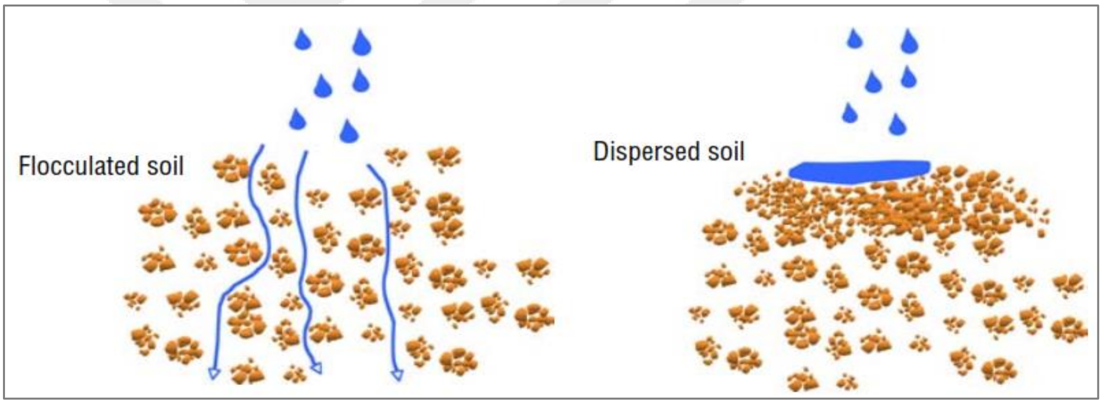


Figure 1.17. The difference between flocculated (aggregated) and dispersed soil structure (Horneck et al., 2007).

Besides other environmental conditions, plant nutrients must be presented in optimal quantities in the root environment for the demonstration of balanced nutrition and maximum development of plants. Soil salinity is not appropriate in terms of balanced nutrition due to the influence of water and nutrients uptake of plant in a negative way. Osmotic conditions in the root cells and root environment (in the soil solution) adjusts to the plant's water intake. Osmotic value of root cells must be greater than osmotic value of soil solution so as to get water continuously. However, the presence of salts in the soil leads to higher osmotic value in the root environment. In this case, a loss of water (dehydration) from the roots to the soil solution may also be in extremely salty environments (Eruz, 1979).

Flocculation is important, because water moves between the large pores and plant roots developing in pore spaces. Disperse clays clog the soil pores and slows the movement and drainage of water (Horneck et al., 2007).

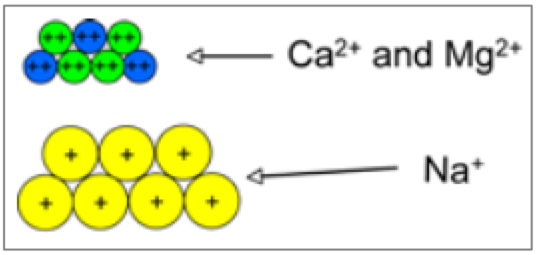


Figure 1.18. Cations as flocculators (Horneck et al., 2007)

Cations combine the negatively charged clay particles to flocculate the soil clays (making clumps or "aggregates") (Figure 1.18). Sodium is weaker flocculator than calcium and magnesium, because its charge is less than the others and ion diameter is larger in water. Mg^{2+} has 27 times, Ca^{2+} has 43 times greater flocculating power in accordance with Na^{+} (Horneck et al., 2007).

1.2.1.3.2 Sodic Soils

The amount of exchangeable sodium is greater than exchangeable calcium and magnesium in alkaline soil. EC value is less than 4 dS/m, even is lower than 2 dS/m commonly. The soil pH is typically larger than 8.5 and it can be up to 10 to 11 levels in extraordinary cases. pH>8.5 shows that there is sodium problem in the soil (Horneck et al., 2007).

- High exchangeable sodium value combining with high pH and low calcium and magnesium values leads to the dispersion of soil; in other words, soil particles can act independently.
- The dispersion of soil particles disrupts the soil structure and they prevent the movement of water by plugging the pore space into the soil and through the soil.
- Because of the dispersion of organic matter, sodic soils have black colour in most of the times and slippery-greasy-looking surface, where there is little or no plant growth.
- These soils are called as "**black alkali**" or "**slick spots**" (Horneck et al., 2007).

Calcium is necessary for reclamation of alkali soils. The replacement of sodium with calcium goes down ESP and SAR values (Figure 1.19 and Figure 1.20). As a result of the examination of Figure 1.19, soil particles will be dispersed (left) when the amount of (Ca^{2+} + Mg^{2+}) reduces according to the Na^{+} (SAR is increased). Soil particles will be flocculated (right) when (Ca^{2+} + Mg^{2+}) is enhanced in accordance with Na^{+} (SAR is decreased) (Horneck et al., 2007).

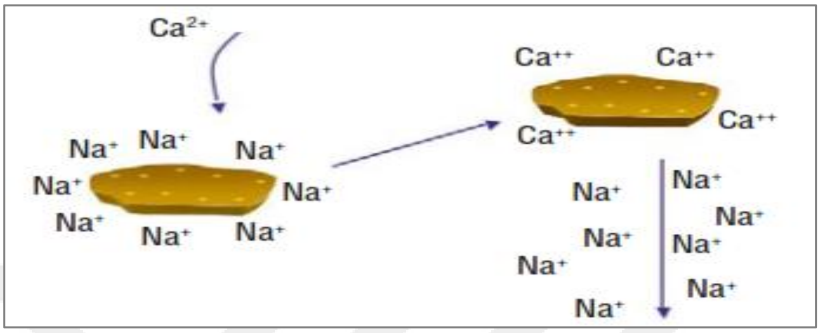


Figure 1.19. Apply a source of calcium (such as gypsum) before leaching salts out of soils susceptible to dispersion. Replacing sodium with calcium before leaching will stabilize soil structure (Horneck et al., 2007)

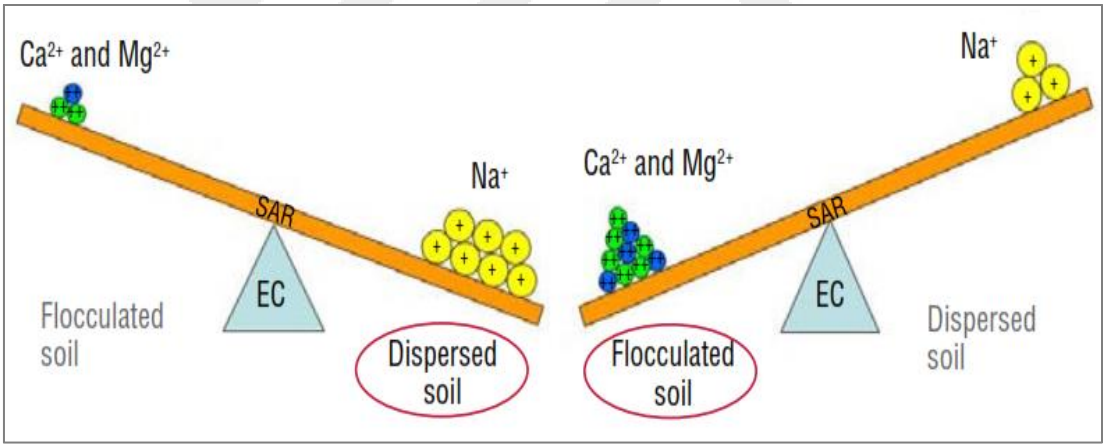


Figure 1.20. The relationship of soil structure (dispersed-flocculated) with soil SAR (Ca^{2+}, Mg^{2+} and Na^{+} balance) and soluble salts (EC) (Horneck et al., 2007)

Gypsum ($CaSO_4.2H_2O$) is the most common material used to supply calcium in the alkaline soil remediation. The reasons for the use of gypsum: It is rich in calcium, dissolution at high pH and does not contain the element/compound to be made attempt during remediation. Sulfate in gypsum is not a problem for the crops unless it is used much more than the plant requirements. Gypsum requirement is the amount of required gypsum to reclaim the soil until the desired depth (Horneck et al., 2007).

Calcium nitrate or calcium chloride minerals may be used for the reclamation of sodic soil; however, they are typically more expensive and generate negative impacts on the environment and plant growth. Nitrate is underground water pollutant and is not a good choice (Horneck et al., 2007).

Limestone containing calcium is another fairly common mineral; however, it is not used for the treatment of sodic soils. Because, it is insoluble at high pH in this type of soil. In theory, if acidifying agents are added to the soil, it can be used. This solution is both expensive and unpractical (Horneck et al., 2007).

Elemental sulfur (S) may be used for the improvement of sodic soils. If there is a free lime in the soil, elemental S should be used. The addition of sulfur does not add calcium directly; however, sulfuric acid forms by oxidizing elemental S. Sulfuric acid dissolves lime (calcium carbonate, $CaCO_3$). The dissolution of indigenous lime would have achieved necessary calcium for the reclamation of sodic soils. If there is sufficient moisture and heat, the oxidation of elemental sulfur is completed within 1-2 growing season (Horneck et al., 2007).

It is necessary to improve the chemical and physical properties of alkaline soils in order to prevent both the loss of agricultural productivity and soil erosion. Improvement for the salt-affected soils is achieved to the replacement of exchangeable Na^+ with divalent cations (usually Ca^{2+}) to the soil directly or indirectly. The exchange of Ca^{2+} for Na in the soil exchange complex results in the flocculation of soil particles and the restoration of the porous structure and high permeability of the soil (Joo et al., 2008).

1.2.1.3.3 Saline-Sodic Soils

EC of the saturation extract at 25°C is greater than 4 dS/m (mmhos/cm). In saline-sodic soils, sodium and other salts are found high quantity. SAR value is more than 13 while ESP value is greater than 15. The soil pH may be less or more than 8.5. Saline-sodic soils have generally good soil structure and sufficient water movement through the soil profile (Horneck et al., 2007).

1.2.1.4 Physical Properties of Soils

The physical properties of soil particularly define the soil horizons and soil profile features. The appearance and feel of a soil are affected soil physical properties (Brady and Weil, 2014). The main physical properties of soil can be listed as follows:

- Soil Texture (Sand, Silt and Clay (%))
- Soil Structure (Arrangement of Individual Soil Particles)
- Soil Porosity (%)
  - Particle Density (Specific Gravity) (g/cm^3)
  - Bulk Density(g/cm^3)
- Soil Consistence
- Soil Colour
- Soil Temperature
- Soil Water
- Soil Permeability (Brady and Weil, 2014).

1.2.1.4.1 Soil Texture

Soil texture refers to the proportion of the soil "separates" that make up the mineral component of the soil. These separates are called sand, silt, and clay and having the following size ranges:

Sand: <2 to 0.06 mm; Silt: 0.06 to 0.002 mm; Clay: <0.002 mm

For all mineral soils, the proportion of sand, silt, and clay always adds up to 100%. These percentages are grouped into soil texture "classes", which have been organized into a "textural triangle" (Figure 1.21) (USDA, 1987).

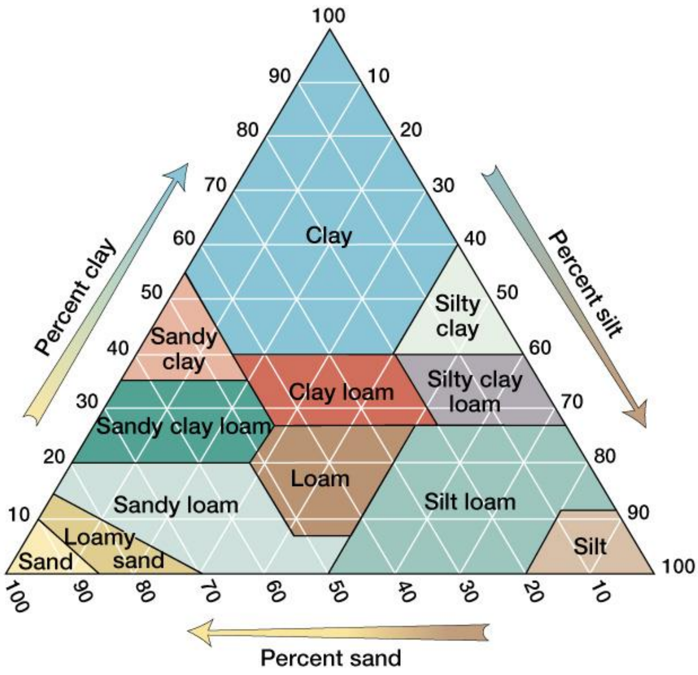


Figure 1.21. Textural triangle used for the determination of soil texture (BS, 2015)

On this basis, soils are classified into various textural classes:

Sandy Soils: They have coarse structure comprising more than 85% sand. Two specific textural classes are recognized in this group, sandy and loamy sand, respectively. Their water holding capacity is low since the clay and organic matter content of these soils are too low. They are inefficient and poor in terms of plant nutrients. A significant amount of clay and manure are mixed to improve these soils' productive. They are often very acidic (Donahue et al., 1977; Brown, 2003).

Silty Soils: The silt group includes soils with at least 80% silt and 12% or less clay. Naturally, the properties of this group are dominated by those of silt. Water holding capacity and water permeability of these soils are moderate. They are usually unproductive soils. (Brown, 2003).

Clay Soils: A soi1 must contain at least 35-40% clay in order to be designated as clay. In such soils, clay has distinctly dominant characteristics in such soils and is classified as clay, sandy clay and silty clay, respectively. Sandy clays may contain more sand than clay whereas the silt content of silty clays usually exceeds clay fraction (Brown, 2003). Water-holding capacity of clay soil is very high. These soils are slime quickly to keep the water in a very high percentage when they are irrigated excessively. This feature is not desirable in terms of plant production due to the fact that pores are filled with water instead of air in the slime type soil. Thus, plant roots can die from lack of air in such soil. When the same soil suddenly dries, soil hardens and sticks. This is also undesirable in terms of the plant production. It affects the plant development negatively. They are not usually productive despite the high capacity of storage of plant nutrient such as water retention, calcium, magnesium, phosphorus, and ammonium, respectively (Donahue et al., 1977).

Loamy Soils: The loam group containing many subdivisions, is a more complicated soil textural class. They contain approximately equal amounts of sand, clay and silt. Water holding capacity, aeration, structure, porosity and water-air balance of these soils are in the most optimum (soil type) state. They are fertile, well-drained and easily worked. They can be clay-loam or sandy loam depending on their predominant composition and cultivation characteristics. If sufficient plant nutrient comprises, production capacity is very high (Donahue et al., 1977; Brown, 2003).

1.2.1.4.2 Soil Structure

Soil structure is mainly consisted of soil aggregates. At first, primary aggregates (microaggregates) transform into the macroaggregates comprising coarse sand and silt connected with colloids such as clay particles and organic materials. Then, macro pores are formed between macroaggregates; thus, soil structure reveals. In other words, the arrangement of soil aggregates gives the soil structure (Donahue et al., 1977; Oğuz, 2008).

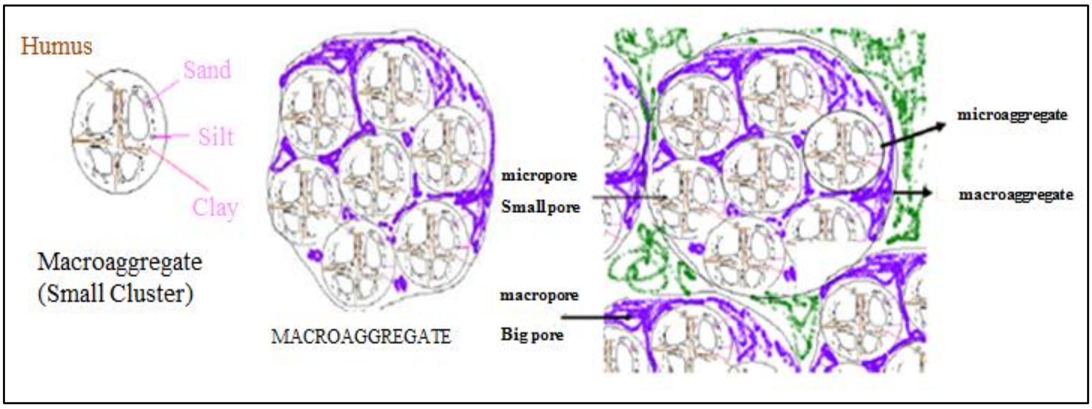


Figure 1.22. Soil structure (Oğuz, 2008)

Soil structure is divided into two parts (Figure 1.22):

- **Primary soil particles:** Primary soil particles such as sand, silt and clay are located independently in the soil without any connection to each other (Oğuz, 2008).
- **Secondary soil particles:** Aggregates (micro and macro clusters) combined with primary soil particles (sand, silt and clay) form macro and micro aggregates with the help of various binders such as, humus, clay and water cations. This aggregate is called secondary aggregate (Oğuz, 2008).

Soil structure is evaluated according to three criteria: a) Type (shape or form and arrangement pattern of peds), b) Class (size of peds) and c) Grade (degree of distinctness of peds), respectively (SSDS, 1993).

Soil structure type (Figure 1.23) is **the shape** and arrangement of peds:

- Platy: It is the type of structure that the horizontal axis are formed as longer aggregates than those of vertical axis. It is found in the upper and lower layers of raw soils.
- Prismatic and columnar: It is the type of structure that the horizontal axis is formed as less developed aggregates than those of vertical axis. Lengths are in different length according to their soils; sometimes it may be longer than 15 cm. It is characteristic for B horizons.
- Angular and subangular: The horizontal and vertical axes are created as equal aggregates approximately. Irregular aggregates are six-faced shape. It tends to form in the B-horizon where clay has accumulated and indicates poor water penetration.
- Granular and crumb: It is the type of structure that the horizontal and vertical axis is formed as equal round-shaped aggregates. Aggregates having diameters smaller than 1.5 cm are easily separable from each other as they loosely arranged. This type of structure is found in the surface layer (Horizon A) of soil richier in organic matter (SSDS, 1993).

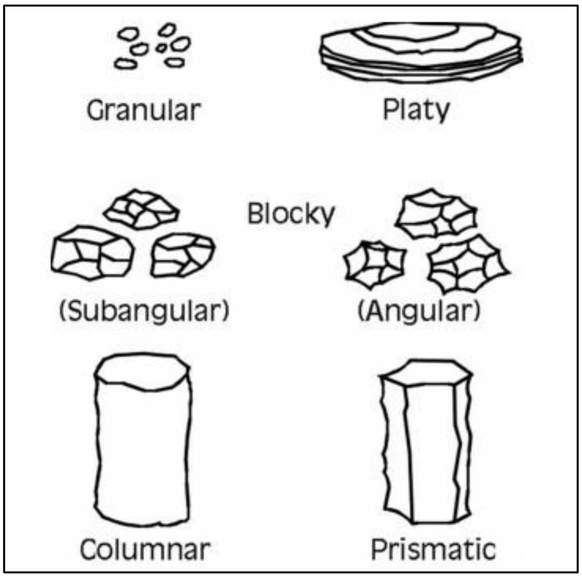


Figure 1.23. Illustration of shape and arrangement of peds (SSDS, 1993)

Size of peds whose ranges depend upon the above type:

- Very fine or very thin: <1 mm platy and spherical; <5 mm blocky; <10 mm prism like.
- Fine or thin: 1–2 mm platy, and spherical; 5–10 mm blocky; 10–20 mm prism like.
- Medium: 2–5 mm platy, granular; 10–20 mm blocky; 20-50 prism like.
- Coarse or thick: 5–10 mm platy, granular; 20–50 mm blocky; 50–100 mm prism like.
- Very coarse or very thick: >10 mm platy, granular; >50 mm blocky; >100 mm prism like (SSDS, 1993).

Soil structure grades are divided into five classes on the basis of ease of separation from each other within the continuity, durability and stability of aggregates: Weakly developed, moderately developed, well-developed and strongly developed, respectively (SSDS, 1993; Oğuz, 2008).

The importance of soil structure is explained as follows:

- Infiltration of water is enhanced; thus, reducing runoff and erosion and the amount of plant available water are increased.
- Seedling emergence, root growth and rooting depth are developed.
- Permeability is increased with large continuous pores (Donahue et al., 1977).

1.2.1.4.3 Soil Porosity

The ratio of the sum of micropores existed between microaggregates and the macropores also existed between macroaggregates by volume to the entire soil volume gives the porosity (pore volume) (Oğuz, 2008; Johnson et al., 2013) and the porosity is calculated as given in Equation (13) as follows:

$$\%porosity = 100 - \frac{Bulk\ Density\left(\frac{g}{cm^3}\right)}{Particle\ Density\left(\frac{g}{cm^3}\right)} x100 \qquad (13)$$

Bulk density is the proportion of the weight of a soil relative to its volume. It is expressed as a unit of weight per volume, and is commonly measured in units of grams per cubic centimeters (g/cm^3). **Particle density** is defined as the weight of a given soil particle per unit volume. In other words, it is the weight of a soil particle or separate, divided by the volume of that soil particle or separate (Johnson et al., 2013).

1.2.1.4.4 Soil Consistence

Consistency is described as the soil's resistance ability to keep its objects (cohesion and adhesion) together against deformation and rupture. It is generally used in the cultivation problems and the engineering of foundations. The measurement of consistency can be performed at three different conditions: air-dry, moist, and wet, respectively (FAO, 1974).

1.2.1.4.5 Soil Colour

Soil colour rises as a result of various chemical processes that occur in the soil. The biochemistry of organic matter decomposition, the chemistry of the oxidation-reduction actions of several soil minerals and the weathering of geologic material are some of these processes, respectively (USDA, 2008).

It is clear that some observations can be stated about the colour of soil; for example,:

- The more organic content, the darker colour to the soil.

- Heat is absorbed more in the dark coloured soils. Thus, these soils become warmer and possess higher soil temperatures.
- Parent material: Dark coloured soils are usually formed from the dark parent material.
- Soil drainage refers to the length of time when a soil is waterlogged (USDA, 2008).

Soil colour is described by the parameters of hue, value and chroma, respectively.

- **Hue** represents the dominant wave length or colour of the light;
- **Value**, refers to the lightness of the colour;
- **Chroma** refers to the relative purity or strength of colour (USDA, 2008).

The soil and/or sediment colour is important that reflects the composition and chemical situation. The definition of soil colour is carried out with "Munsell Soil Colour Charts" by comparing the sample with a standard set of colour chips (Figure 1.24). In these charts, the right hand top corner represents the Hue; the vertical axis, the Value; and the horizontal axis, the Chroma, respectively (Munsell Products, 1973).

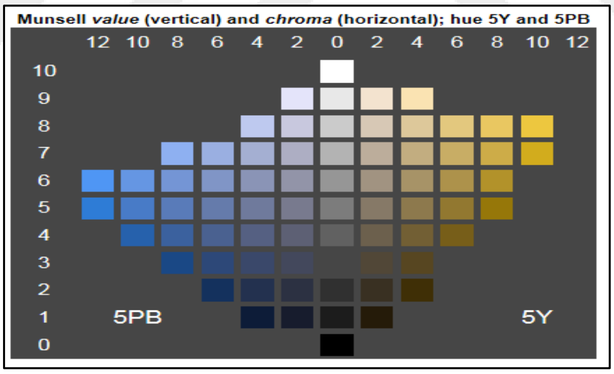


Figure 1.24. Munsell soil colour charts (Munsell Products, 1973)

1.2.1.4.6 Soil Temperature

Soil temperature must have a certain level in order to grow and get the crops in the optimum way. The ideal soil temperature is between 15°C and 25°C. However, due to environmental factors, temperatures of some soil can fall below 0°C in winter while some can rise up to 60-70°C in summer (Oğuz, 2008).

1.2.1.4.7 Soil Water

Soil water is crucial for growing plants. The plants are fed by available nutrients from the soil via their roots using water as the vehicle (Donahue et al., 1977).

Water in soil is very important for the following reasons:

1) Soil water is an important plant nutrient.

2) It is essential for photosynthesis and includes 80-95% of the plant's protoplasm.

3) Solid nutrients in the root zone of plants previously are dissolved by water; then, they are moved to the other tissues of the plant to the rhizosphere by water. Therefore, the water plays both melter and carrier roles for the plant nutrients (Donahue et al., 1977).

Soil water has been classified from a physical and biological point in Figure 1.25:

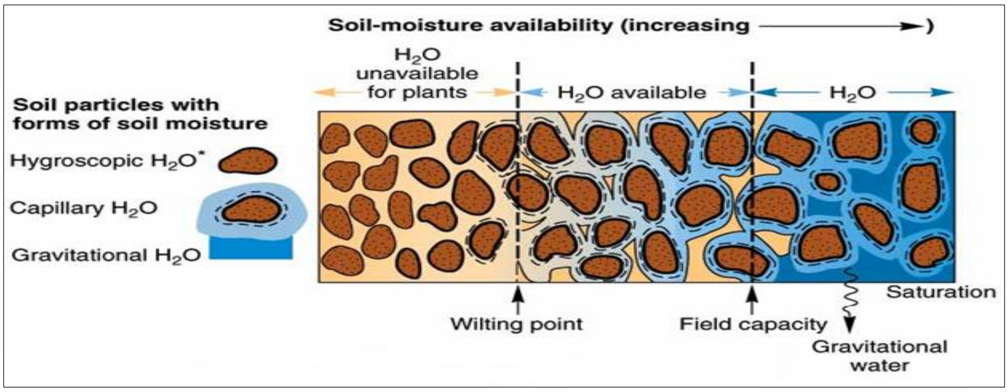


Figure 1.25. Classification of soil water (Alfred, 1957)

- **Gravitational water:** This water enters the structure of the mineral in the soil. The larger soil pores (macro pores) are occupied by gravitational water and it goes down quickly under the force of gravity. Water in excess of the **field capacity** is termed gravitational water. Plants cannot benefit the gravitational water because of the larger pores. Soil moisture tension at gravitational state is zero or less than 1/3 atmosphere (Alfred, 1957).
- **Capillary water:** It is water that is held in the capillary channels formed with overlapping especially macropores and partly micropores in the soil depending on the adhesion and cohesive strength. If there is water in the capillary, the sum of the adhesion and cohesive strength is greater than the

force of gravity. The capillary water is held between 1/3 and 31 atmosphere pressure. Capillary water is also known as **available water** (Alfred, 1957).

- **Hygroscopic water:** It is water that is connected to the soil particles with a suction force of 11 to 31 atmospheres. This water is generally retained in the soil of the small micropores. When a soil thoroughly is dried in the air, it contains a small amount of water which is called **hygroscopic water** (Alfred, 1957).

1.2.1.4.8 Soil Permeability

The permeability of soil is used as vehicle to transmit the water and air in the soil. An impermeable soil is preferred for the agricultural studies because of the high water storage capacity. The permeability is directly related to the soil layers or horizons. The permeability of a soil is determined by pore size, texture, structure and the presence of impervious layers such as clay pan, respectively. Clayey soils with platy structures have very low permeability. It is measured in terms of permeability rate or coefficient of permeability (cm per hour, cm per day, and cm per sec.) (Coche and Laughlin, 1985).

1.2.1.5 Natural Soil

The natural soil (Figure 1.26) can be viewed as a mixture of mineral and organic particles of varying size and composition in regard to plant growth and it is also defined as superficial soil layer between 5 cm and 40 cm depth from the surface. The particles occupy about 50 percent of the soil's volume. The remaining soil volume, about 50 percent, is pore space, composed of pores of varying shapes and sizes. The pore spaces contain air and water and serve as channels for the movement of air and water (Henry, 1991).

Figure 1.26. Natural soil view (Henry, 1991)

1.2.1.6 Peat

Peat is a type of organic soil that forms by falling of the water level in the lake bed, the prominence of plant operations, with the increase in water level in winter, the death of the plant and the continuous repetition of this natural event as a result of thousands of years period of the transformation of plant roots and stems (Schumann and Joosten, 2008; Oğuz, 2008).

Soils formed from the organic main material are fertile soils. This soil is found in many parts of our country (Oğuz, 2008). The process of peat accumulation continues for thousands of years so that eventually the area can be covered with meters thick layers of peat. An area of land with a soil of peat is called a peatland **(**Figure 1.27**)**. A peatland is an area (with or without vegetation) with a naturally accumulated peat layer at the surface (Schumann and Joosten, 2008).

Peat is an organic soil amendment. It provides an ideal growth environment by regulating the earth's air and moisture around the roots. It is very valuable material in the potted ornamental plants and seedlings growing. It has a fibrous structure. Its pH range is 5.5 - 6.5.

Peat occurs by the decay of grown plants (algae and reeds of the marsh usually called "sphagnum") in the marshes and similarly the land under water in regions having moist and the wettest soil where the summer heat is low in years. Approximately 11 million metric tons of sphagnum peat are used for horticultural purposes per year (Apodaca, 2013) across the world.

The characteristics of peat in the horticultural study are the homogeneity and availability of the product, its low bulk density, low microbiological activity, low nutrient contents, low pH, its large water-holding capacity (WHC) and its high air capacity at 100% WHC, respectively (Reinhofer et al., 2004; Schmilewski, 2008; Michel, 2010).

Figure 1.27. The view of peat and peatland (Hugron, 2013)

The chemical properties of peat: Although peat also varies according to the species, its pH shows acidic character. Peat in Turkey could be in 4 to 7 in pH. Microelements in the peat structure are measured as 2,195 ppm, Fe, 13 ppm Cu, 38 ppm Mn, 32 ppm Zn while the level of macroelements has been detected as 1.186% of total N, 0.215% P, 1,800 ppm K, 2,800 ppm Ca, 1,620 ppm Mg, 200 ppm Na in a study conducted in Turkey-Celtek in 1992 (Oğuz, 2008).

1.2.1.7 Manure (Fertilizer)

Manures are plant and animal wastes that are used as sources of plant nutrients. They release nutrients after their decomposition. The art of collecting and using wastes from animal, human and vegetable sources for improving crop productivity is as old as agriculture. They are the organic materials derived from animal, human and plant residues which contain plant nutrients in complex organic forms. Naturally occurring or synthetic chemicals containing plant nutrients are called **fertilizers**. Manures with low nutrient, content per unit quantity have longer residual effect besides improving soil physical properties compared to fertilizer with high nutrient content (Reddy, 2005).

Major sources of manures are:

- Cattle shed wastes-dung, urine and slurry from biogas plants
- Human habitation wastes-night soil, human urine, town refuse, sewage and sludge
- Poultry jitter, droppings of sheep and goat

- Slaughterhouse wastes-bone meal, meat meal, blood meal, horn and hoof meal, fish wastes
- By-products of agro industries-oil cakes, bagasse and press mud, fruit and vegetable processing wastes etc
- Crop wastes-sugarcane trash, stubbles and other related material
- Water hyacinth, weeds and tank silt, and
- Green manure crops and green leaf manuring material (Reddy, 2005).

Manures can also be grouped, into **bulky organic manures** and **concentrated organic manures** based on concentration of the nutrients (Reddy, 2005).

The information about the properties of sheep (or goat) manure (Figure 1.28) is given at below:

The droppings of sheep and goats contain higher nutrients than farmyard manure and compost. On an average, the manure contains 3 % N, 1 % P_2O_5 and 2 % K_2O.It is applied to the field in two ways. The sweeping of sheep or goat sheds are placed in pits for decomposition and it is applied later to the field. The nutrients present in the urine are *wasted* in this method. The second method is sheep penning, wherein sheep and goats are kept overnight in the field and urine and fecal matter added to the soil is incorporated to a shallow depth by working blade harrow or cultivator (Reddy, 2005).

Figure 1.28. The view of sheep manure (Reddy, 2005)

1.2.1.8 Plant Nutrients

Nutrients are very essential and have a vital role for the growth of all types of plants. They are taken up from the air, soil, and water by plants. Because they cannot seen by the human eyes, they are colourless gases or they can be found like powder dissolved in water or stuck onto each piece of soil. It is sometimes hard to understand how they work (Uchida, 2000).

There are three factors affecting the quantity of nutrients available to the plants. These are water quality, substrate quality and plant type, respectively.

Nutrients are taken up by the fine root hairs instead of big ones. The larger roots are used for supporting the tree and for storage of water and other plant food. The root hairs can also excrete liquids that affect the acidity of the soil (pH). When the pH changes, the amount of nutrients available may also change (Uchida, 2000).

Sixteen important elements, which are called nutrients in the plant studies, are required for the plant growth (Table 1.17). Carbon (C), hydrogen (H), and oxygen (O) are fundamental nutrients and they are attained from carbon dioxide and water in the atmospheric environment. The others are obtained from the soil by means of soil's water content and are also defined as macronutrients (primary and secondary nutrients) and micronutrients, respectively (Tucker, 1999).

Table 1.17. Plant nutrients taken from air, water and soil (Tucker, 1999)

Nutrients from air and water	**Nutrients from soil**		
Structural nutrients	**Macronutrients**		**Micronutrients**
	Primary nutrients	**Secondary nutrients**	
C, H, O	N, P, K	Ca, Mg, S	Fe, Cu, Mn, Zn, Mo, B, Cl

Each nutrient cannot be obtained from plants in its elemental form; but, instead, it is taken up in an “ionic” or charged form, with the exception of B as boric acid which is uncharged (Table 1.18). In addition, understanding nutrient functions and mobility within the plant are useful in diagnosing nutrient deficiencies (Pagani et al., 2014).

Table 1.18. Nutrient forms taken up by plants (Pagani et al., 2014)

Element	Form
Nitrogen (N)	NO_3^- (nitrate), NH_4^+ (ammonium)
Potassium (K)	K^+
Phosphorus (P)	$H_2PO_4^-$, HPO_4^{2-} (phosphate)
Calcium (Ca)	Ca^{2+}
Magnesium (Mg)	Mg^{2+}
Sulfur (S)	SO_4^{2-} (sulfate)
Iron (Fe)	Fe^{2+} (ferrous), Fe^{3+} (ferric)
Copper (Cu)	Cu^{2+}
Manganese (Mn)	Mn^{2+}
Zinc (Zn)	Zn^{2+}
Molybdenum (Mo)	MoO_4^{2-} (molybdate)
Boron (B)	H_3BO_3 (boric acid), $H_2BO_3^-$ (borate)
Chlorine (Cl)	Cl^- (chloride)

All nutrients move relatively easily from the root to the growing portion of the plant. Table 1.19 lists six mobile and eight immobile mineral nutrients. Sulfur is one element that lies between mobile and immobile elements depending on the degree of deficiency (Pagani et al., 2014).

Table 1.19. Mobile and immobile nutrients existed in plants (Pagani et al., 2014)

Mobile nutrients	Immobile nutrients
N, K, P, Cl, Mg, Mo	S, Ca, Fe, Cu, Mn, Zn, B, Cl

A plant's sufficiency range is the range of nutrient amount necessary to meet the plant's nutritional needs and maximize growth (Figure 1.29). Nutrient levels outside of a plant's sufficiency range (Table 1.20) cause overall crop growth and health to decline due to either a deficiency or toxicity. Nutrient deficiency occurs when an essential nutrient is not available in sufficient quantity to meet the requirements of a growing plant. Toxicity occurs when a nutrient is in excess of plant needs and decreases plant growth or quality (McCauley et al., 2011).

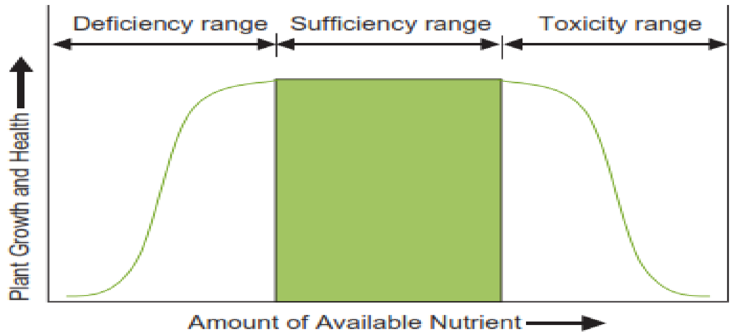


Figure 1.29. Relationship between plant growth and health and amount of nutrient available (Brady and Weil, 1999)

Table 1.20. Reference nutrient sufficiency concentration ranges for landscaping grass (Pagani et al., 2014)

Element	Sufficiency range	Role in plant	Reference
N	1-5 %	Constituent of aminoacids, proteins, chlorophyll and nucleic acids.	(Pagani et al., 2014)
P	0.1-0.5 %	Constituent of proteins, coenzymes, nucleic acids and metabolic substrates; important in energy and transfer.	
K	2-4 %	Involved with photosynthesis, carbohydrates, translocation and protein synthesis.	(Midwest, 1990)
Ca	0.4-0.8 %	Protecting the plant against heat stress, enzymatic and hormonal processes, cell elongation and regulation of the stomata.	
Mg	0.1-0.4 %	Enzyme activator; component of chlorophyll	(Pagani et al., 2014)
S	0.1-0.4 %	Component of certain amino acids and plant proteins.	
Fe	50-250 ppm	Involved with chlorophyll synthesis and in enzyme electron transfer.	(Mills and Jones, 1996)
Cu	5-20 ppm	Catalyst for respiration; component of various enzymes	(Pagani et al., 2014)
Mn	25-300 ppm	Controls several oxidation-reduction systems and photosynthesis	
Zn	25-150 ppm	Involved with enzymes that regulate various metabolism	
N:K	1.2-2.2	-	(Mills and Jones, 1996)
N:S	10-15 (>18 Sulfur Deficiency)	-	

Nitrogen is a major constituent of several of the most important substances which occur in plants. It is also returned to the soil in the form of organic materials, which are derived from former plant and animal life and animal wastes. These materials are largely insoluble in water and are reduced by biological decomposition, oxidation, reduction, and are finally mineralized to nitrate nitrogen for plant use (Figure 1.30) (Midwest, 1990).

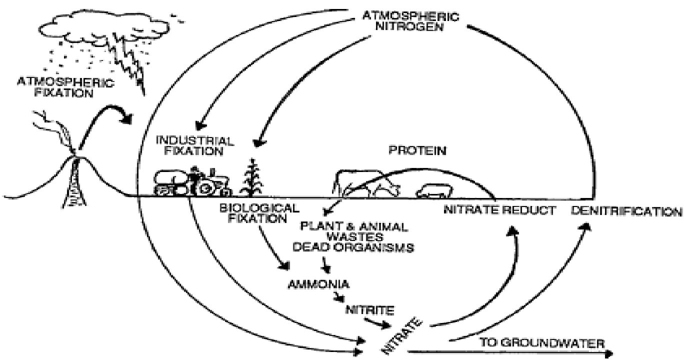


Figure 1.30. The nitrogen cycle (Midwest, 1990)

Nitrogen is the nutrients most commonly found to be low in turf grasses and is generally due to inadequate fertilization, heavy leaching rains, over-irrigation or possible root damage. N deficiency may be manifested as a light green colour, slow growth rate or excessive seed head production. N content will decrease with the age of plants; therefore, low N may indicate lately harvested grass (Planck and Kissel, 2010).

Phosphorus deficient plants are characterized by stunted growth, dark green leaves with a leathery texture, and reddish purple leaf tips and margins (Tucker, 1999). Lack of P can cause delayed maturity and poor seed and fruit development (Uchida, 2000).

Unlike N and P, K does not form any vital organic compounds in the plant. However, the presence of K is vital for plant growth, because K is known to be an enzyme activator that promotes metabolism. Potassium is very mobile in the plant (Uchida, 2000). In severe cases, the whole plant turns yellow, and the lower leaves fall off. As with other nutrients, lack of k causes stunted plants with small branches and little vigor (Tucker, 1999). Low K is generally due to low soil test K levels, inadequate K fertilization or when grass is grown on coarse-textured sandy soil that is subject to leaching. Excessive K levels may induce Mg deficiency (Planck and Kissel, 2010).

Calcium is immobile within plants and remains in the older tissue throughout the growing season (Tucker, 1999). Thus, symptoms first appear on the younger leaves and leaf tips. The growing tips of roots and leaves turn brown and die. Ca deficiency is not often observed in plants, because secondary effects of high acidity resulting from soil calcium deficiency usually limit growth, precluding expressions of Ca deficiency symptoms (Uchida, 2000). Grasses are able to take up Ca under a wide range of soil conditions, and it is rarely deficient. A high Ca level may indicate some other nutrient deficiency or disorder (Planck and Kissel, 2010).

Magnesium is a mobile element and part of the chlorophyll molecule (Uchida, 2000). Mg deficiency is most prevalent on sandy-textured soils, which are subject to leaching, particularly during seasons of excess rainfall. Depending on the stage of growth and crop, Mg deficiency can be corrected by soil application of lime or fertilizer (Tucker, 1999).

Sulfur is an essential component and is also required for production of chlorophyll and utilization of phosphorus and other essential nutrients. S ranks equal to nitrogen for optimizing crop yield and quality. Crops must have adequate sulfur to optimize nitrogen utilization. S deficiency is characterized by stunted growth, delayed maturity, and general yellowing of plants, respectively. Yellowed plants are also characteristics of nitrogen deficiency. S deficiency is the most frequently observed on very sandy soils with low organic matter content (Tucker, 1999).

Manganese (Mn) acts as an enzyme activator for nitrogen assimilation. Mn deficiency is typically characterized by interveinal chlorosis (dark green veins with yellow discoloration between the veins) (Tucker, 1999). Deficiencies are rare; but, may occur occasionally on sandy soils that are low in Mn, high in organic matter, and when the soil pH is 6.8 or higher. Excessive Mn levels can occur in some turf grasses when the soil pH is less than 5.5 (Planck and Kissel, 2010).

Iron is absorbed by an active process as Fe^{2+}. Uptake of Fe is highly dependent on the Fe form and adequate uptake depends on the ability of the root to reduce the pH nearby and reduce Fe^{3+} to Fe^{2+} for uptake. Conditions that lead to Fe deficiency are inadequate concentrations of Fe in the soil solution or basic soil conditions (pH above 7.0) (Hochmuth et al., 2012). Since Fe is an immobile element in plants, Fe deficiencies appear in the new tissue or upper portion of the plant (Planck and Kissel, 2010).

Copper (Cu) is involved as an enzyme activator (Tucker, 1999). Cu deficiency symptoms often depend on plant species or variety and the stage of deficiency. In the early stages of deficiency, symptoms are generally reduced growth. Excess Cu, especially in acidic soil may be toxic to plants (Hochmuth et al., 2012).

Zinc is not a very mobile element in plants, and deficiency symptoms occur in the newly emerging leaves (Planck and Kissel, 2010). Zn deficiency may occur in cold, wet soils or in soil with a very high pH (Hochmuth et al., 2012). High levels of Zn can lead to toxicity. This toxicity is an uncommon problem and does not generally occur until the Zn level exceeds 200 ppm (Planck and Kissel, 2010).

1.2.2 The International Studies Carried Out for the Production of MT from DMs

While green areas and parks are established, current sub-soil is normally used; topsoil is supplied from the outside. DMs can be transformed into MT mixtures and application studies of MT instead of highly demanded natural soil in urban landscaping have also gained importance despite MTs' variable characteristics (Haraldsen and Pedersen, 2003). MT mixtures are mineral based materials generally comprising high amounts of sandy particles. However, several organic waste-based products (wastepaper, yard waste, wood chips, etc.), biosolids (sewage sludge or animal manure) or peat, which takes place by the accumulation of partially decayed vegetation, are blended with the sandy DMs of concern in order to enhance the organic matter content of MT. On the other hand, different organic materials show diverse effects on the topsoil mixtures' quality in terms of soil structure, biological processes, nutrient supply-availability and erosion resistance, respectively (Jim, 1996; Boen and Haraldsen, 2011). This composting process ensures the degradation of complex organic matters and allows producing a rich soil (Davidov et al., 2007).

One of the important work on the usability of DM as MT was realized in University of Strathclyde in Glasgow/Scotland (Riddell et al., 1989; Thomas and De Silva, 1999). In 1988, the full-scale soil factory with a production capacity of 2,000 tons of topsoil per week (£ 5.20/ton topsoil selling price) was established in Clyde/Glasgow.

Topsoil manufactured from DMs has also been used in projects throughout the United States. Some notable projects are the recreational fields at Pearl Harbour, Hawaii, and landscaping throughout the city of Toledo, Ohio, respectively. In addition, topsoil prepared with DM taken from New York/New Jersey Harbor were assessed in growing wetland plants (Krause, 2000).

Young K. Joo et al. (2008) focused on the salt-tolerant turf grass re-vegetation on the reclaimed sea sand dredged from the Yellow Sea in order to utilize it at the new Incheon International Airport (The Republic of Korea).

Topsoil enhancement usually involves drying out finer DM and applying it alone or mixing it with other materials to make topsoil. DM is commonly composed of silt, clay and organic matter-all important components of topsoil (Clark and Knight, 2013). It can be incorporated as a raw material for producing MT; but, it requires significant conditioning and processing for the production of topsoil. Sieving is required to remove debris greater than 2.54 cm in diameter and in some cases smaller. Dewatering is required to minimize spillage during rail or truck transport to the processing facility. DM (preferably fine fraction) must generally be amended with additives such as organic matter (yard waste, wastepaper, wood chips, etc.) and biosolids (sewage sludge or animal manure) and composted. Composting provides for the degradation of complex organics and produces a rich soil (Jim, 1996; Davidov et al., 2007; Boen and Haraldsen, 2011; URL-9, 2013; Clark and Knight, 2013).

Grand Haven Harbour (USA): Grand Haven Harbour, located on the eastern shore of Lake Michigan, receives just under 1 million tons of water-borne coal, stone and cement per year. The harbour's outer navigation channel is dredged annually, with the DM placed in the near shore as beach nourishment. The harbour's inner channel has a dredging frequency of every two to four years with approximately 37,000 cubic yards (m^3) of sediment dredged each time. The worker group identified the most viable beneficial use solution in order to manufacture a high quality topsoil product by combining harbour sediment with composted local municipal yard waste. The city developed a temporary placement site to dry DM for mixing with the compost and the first product and successfully used in a number of landscaping and construction projects, including public recreational areas. It is now successfully marketed and sold by Grand Haven's Verplank Dock Company (Clark and Knight, 2013).

Toledo-Lucas Province Port Landfill Facility in (USA): In the scope of re-use of DM located in Toledo Port Landfill Facility, the topsoil was produced by mixing DM with lime sludge removed from drinking water treatment plant and sewage sludge. MT was only used as final herbal cover for landscaping works in Toledo landfill and in the park and along highways due to potential pathogens on municipal sewage sludge (GLC, 2013). In another application, topsoil possessing unlimited usage was obtained by mixing DM with local garden wastes (GLC, 2001).

From past to present, there are several laboratory-scale works about the production of MT from marine DM.

Study conducted by Kim and Pradhan (2015) in South Korea also assessed the mechanical and germination characteristics of dredged soil ameliorated with organic matter (humic acid) and stabilizer (slag cement). As dredged soil (or material) already consists of a high volume of organic matter useful for growth, it saves a lot of money previously spent on organic soil. High-organic-content dredged soils are known to have inferior mechanical characteristics, because they are highly compressible and have low shear strength.

MT is defined as a material that produced as a result of mixing of DM with any organic waste by Sturgis and Lee (1996). The benefit of MT is to provide long-term sustainable management solution and in this way, it reduces the amount of dumping DM at sea (Sheehan et al., 2010a).

MT production process comprises the following steps:

- Mixing of DMs with any organic waste to enhance its organic content (organic amelioration),
- pH adjustment to improve the nutrient availability,
- Dewatering and,
- Desalination process (Sheehan et al., 2010a).

The assessment of technical usability of DMs in landscaping applications should be done pursuant to the national topsoil requirements. Unfortunately, there is no Turkish Standard regarding the topsoil specifications. However, British Standard BS 3882:2015 (latest version) can also be used for this purpose. It is observed that the salinity, pH and organic matter are the most critical parameters for the production of MT due to the fact that marine DMs possess high pH value, high saline content and low organic matter content. Besides, both dewatering and desalination process should be carried out in order to estimate the time for achieving the intended salinity and handling properties. Organic content analysis should be performed in order to investigate the degree of organic improvement for rising plant's seasonal growth while pH analysis should be conducted in order to increase the availability of nutrients for the plant growth (Sheehan et al., 2010).

Sheehan et al (2010) investigated the technical feasibility of MT production by mixing Port Waterford’s harbour (one of Ireland's largest commercial port and 500,000 tons/year of DM are removed) DM together with organic household wastes. In the study, they followed dewatering and desalination period to assess the time required for the topsoil to have improved handling properties and to reach the required saline level. Organic testing is undertaken to analyze the quantities of organic amelioration to improve the seasonal growth and pH testing for pH adjustment to maximize the potential nutrients available for growth. Several mixtures of DM from the Port of Waterford were prepared for growth trials to give an indication of the optimum mix. The local market for topsoil and the public's perception of such a product is also assessed.

The removal of salinity (or desalination) should be carried out in the production of MT because high salt content shows negative impact in the plant growth. Dewatering and desalination process (Figure 1.31) are defined as monitoring of moisture and salt content and ensuring maximum production speed of the material by exposure to different climatic conditions of different mixtures. When the mixtures reached a stable moisture content and acceptable salt content (EC), trials were begun for the production of plants (Sheehan et al., 2010). The main purpose of desalination process was to decrease EC value to a suitable level for plant germination and growth of **2 mS/cm** (Kotuby-Amacher et al., 2000).

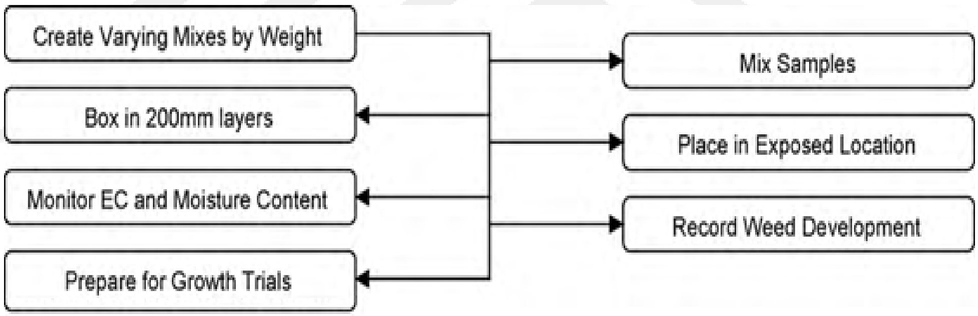


Figure 1.31. Dewatering and desalination process (Sheehan et al., 2010)

Other steps performed after the dewatering and desalination processes for the production of MT are given in Figure 1.32. Organic amelioration and pH adjustment processes for the improvement of nutrient availability after the dewatering and desalination processes are applied (Sheehan et al., 2010). In a study (Ersahin and Brohi, 2006) of 140 samples of topsoil, the results showed a minimum % organic content of 1.9%, mean of 3.8% and a maximum value of 5.8%. Wetmore (2008) recommended that a stable upper limit of 5-7% organic content. Target pH level is based on 6.75 (Gardiner and Garner, 1953). Aluminum sulfate [$Al_2(SO_4)_3$] can be used to reach the target pH and to optimize potential nutrient availability. Organic amelioration is achieved by mixing with organic wastes or compost (Sheehan et al., 2010).

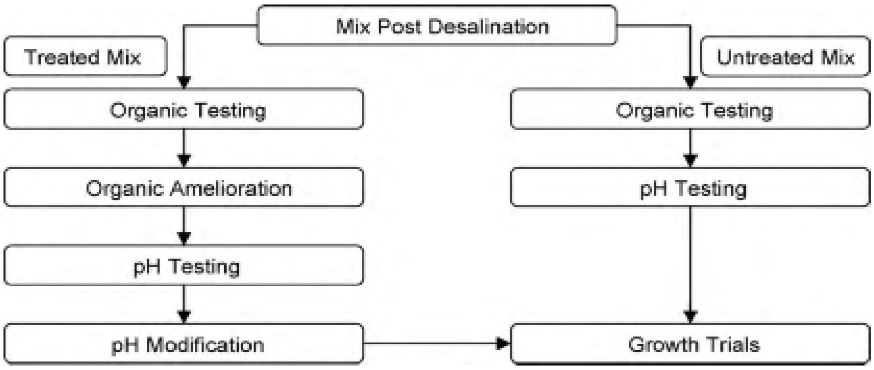


Figure 1.32. Organic amelioration and pH adjustment (Sheehan et al., 2010)

Sheehan et al. (2008) examined the point of a topsoil production by using DM excavated from the Port of Waterford. There are large deposits of silt and clay particles in Suir and Barrow rivers while further downstream the material dredged is primarily sand. DM fractions combined onshore in order to produce high quality topsoil instead of dumping at sea option. The general framework applied for the production of topsoil from DM is given as an example in Figure 1.33 (Sheehan et al., 2008).

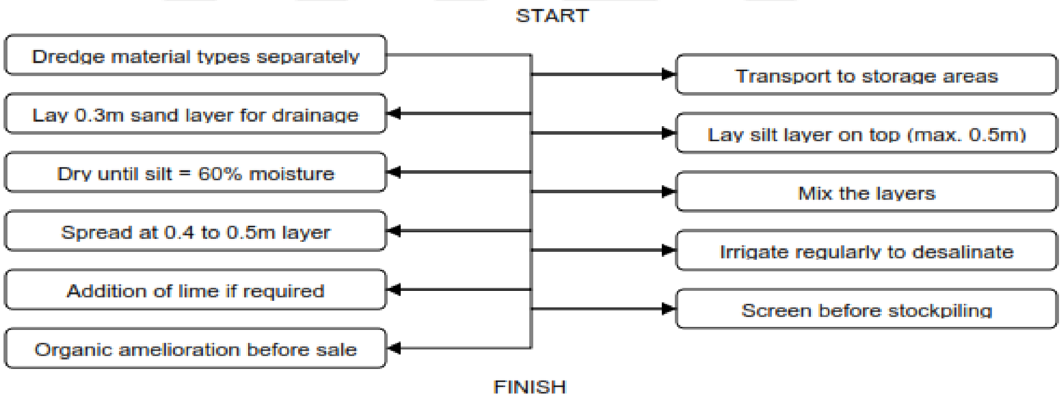


Figure 1.33. The general framework for producing MT (Sheehan et al., 2008)

In another study, Sheehan et al (2010a) have dealt with the production of MT from DM taken from the annual dredging programs in the Port of Waterford, Ireland in terms of logistical, environmental and economical aspects.

Agricultural use of DM is a method of amending poor agricultural soils. The processed DM is used in order to supply organic content and nutrients to deficient soils to increase productivity (Davidov et al., 2007; IADC, 2009). One benefit of the DM is the high concentration of nutrients necessary for plant growth. Soil tests conducted on the material showed very high levels of N, P, K, S, Mg, Ca, and such trace minerals as Zn, Fe, Cu, B and Mn. These high nutrient levels enable economical forage production once salts are reduced to acceptable levels for revegetation (TAMU, 1998). DM with the proper amount of fine material can also be beneficial in reducing the percolation rate of rainwater; thus, promoting the retention of soil moisture needed by the crops (Davidov et al., 2007; IADC, 2009).

DM can be incorporated as a land amendment in order to improve the productivity of low organic soils. DM must be conditioned prior to use as a land amendment. Sieving is required to remove debris greater than 2.54 cm in diameter. Dewatering is essential to minimize spillage during rail or truck transport to the placement site. In practice, conditioned DM is transported to the site, spread, and incorporated into the soil by rototilling or plowing. Alkalinity (generally agricultural lime) must generally be incorporated in the soil mixture to buffer acid production. However, sediment quality is critical for any land application where food crops will be grown, and public perception will likely be a big hurdle (Davidov et al., 2007).

2. AIM AND SCOPE OF THE STUDY

2.1 The Aim and Scope of Thesis

The aim of this work is to explore the usability of Turkey's marine DMs resulting from dredging activities performed in fifteen different sampling points (pilot regions) as MT in the urban landscaping works on the basis of technical, environmental and economical aspect and to provide the generalization of a limited number of beneficial use alternatives carried out in our country. This doctoral thesis was conducted in the framework of TÜBİTAK KAMAG 1007 program and under the TARAL 1007 project named **"Marine Dredging Applications and Environmental Management of DMs" [DİPTAR, Project No. 111G036]**. This project was realized on 01/10/2013-01/10/2016 in TÜBİTAK Marmara Research Center Environment and Cleaner Production Institute. Besides, the sustainable environmental management of DMs was taken into consideration with respect to dumping at sea, landfill disposal and beneficial use on the national base.

The entire studies performed in this context can be summarized as follows:

Chapter 1 contains the general information relating to the identification of dredging and DMs, dredging equipment types, national/international legislation (legal framework) on DM management, management options of DMs, national/international industrial applications related to the beneficial use of DMs, specification of soil, physical and chemical properties of soil, identification of MT components like natural soil, peat and sheep manure, specification of plant nutrients, national/international studies performed for the production of MTs from DMs, respectively.

Chapter 2 presents the aim and scope together with meaning and importance of the thesis study.

Chapter 3 summarizes the materials and methods used during the laboratory-scale studies in order to investigate the usability of DMs in urban landscaping applications as MT.

Chapter 4 includes results and discussions obtained during the laboratory-scale studies in terms of characterization of DMs, evaluation of beneficial use of DMs as MTs, preparation and soil quality assessment of MT samples, the evaluation of grass growth and (winter/summer season) seasonal outdoor ornamental plant performances of MTs, theoretical design of DM pre-treatment plant, characterization and management of DM washing-sieving wastewater, respectively.

Chapter 5 contains the cost analysis of all DM management alternatives (dumping at sea, landfill disposal, beneficial use of DM as MT). It also includes the first investment and operating cost of industrial-scale DM pre-treatment plant.

Finally, the conclusions that are drawn from this research and the recommendations for future studies are summarized in Chapter 6.

2.2 The Meaning and Importance of Thesis

The meaning and importance of the study can be briefly stated as follows:

- Converting DM into high value-added product (MT) with a variety of environmentally friendly methods,
- Contribution to the reduction of other current DM management alternatives such as dumping at sea and landfill disposal,
- Conservation of natural resources (natural soil),
- Transformation of DM into an "economical input" for our country instead of being "threat" for the environment and human health,
- Contribution to the completion of the deficiencies in national legislation on DM management,
- Being enlighten the beneficial use works of DM to be conducted on a national basis.

In our country, approximately 3 million m^3 DM per year were emerged as a result of routine dredging operations of the ports, marinas and fishery harbours; and these DMs are dumped at sea in its current situation (Özer-Erdoğan et al., 2016). However, the uncontrolled dumping of DM at sea can lead to negative effects with physical, chemical and/or biological hazards on aquatic environment (Sheehan and Harrington, 2012; European Parliament and Council, 2008). On the other hand, it is obvious that dumping at sea should be thought as last option in DM management alternatives together with upland disposal requiring high cost, large spaces and long-term monitoring (Krause, 2000; Sheehan and Harrington, 2012; Cappuyns, 2015). Because of the ongoing annual dredging operations, the minimization of DM quantities is not suitable as the most prioritized option (Sheehan and Harrington, 2012); hence, beneficial use alternative becomes the most applicable one. Beneficial use is a process using DM as a potential raw material in order to obtain productive material and provides environmental, economical and social assets (Sheehan and Harrington, 2012).

There are several examples and/or practices about the utilization of DMs in various beneficial use areas in worldwide (Riddell et al., 1989; Thomas et al., 1991; Krause, 2000; Yozzo et al., 2004; Sheehan et al., 2010; Limeira et al., 2011; Reine et al., 2013; Cappuyns et al., 2015; Said et al., 2015). However, beneficial use applications of DMs, especially as MT in landscaping applications are very insufficient in Turkey, where dumping at sea has been chosen as the most preferred option so far today, followed by upland disposal in low ratios.

Furthermore, previous studies have investigated the usage of DM together with the sewage sludge, composts of biowaste, green manure, lime, gypsum and clay minerals as geotechnical soil structure promoter and organic additive for the production of MT (Jim, 1996; Davidov et al., 2007; Boen and Haraldsen, 2011). In this study, peat and sheep manure were chosen as additives in order to improve the physical structure and organic content of DM in topsoil manufacture. As it is clearly known, finding new soil supply like DM for plant growth is required when considering the danger of extinction of natural resources at present. Furthermore, this study has a predominant emphasis in inspiring other national beneficial use attempts in Turkey.

3. MATERIALS AND METHODS

3.1 Dredging Operations and Sampling Studies

In the scope of this study, dredging operations were carried out in the sixteen sampling points in the shores (Mediterranean, Marmara, Aegean and Black Sea) of Turkey. Eleven sampling points were thought to be influenced by various anthropogenic activities. One of the sampling points, which is Mersin Erdemli METU Campus Port (DM-14), was considered to be unaffected by human activity (Clean Area). Also, there were a total of four fishing harbours identified in each sea. All sampling points of the study of concern are illustrated in Figure 3.1.

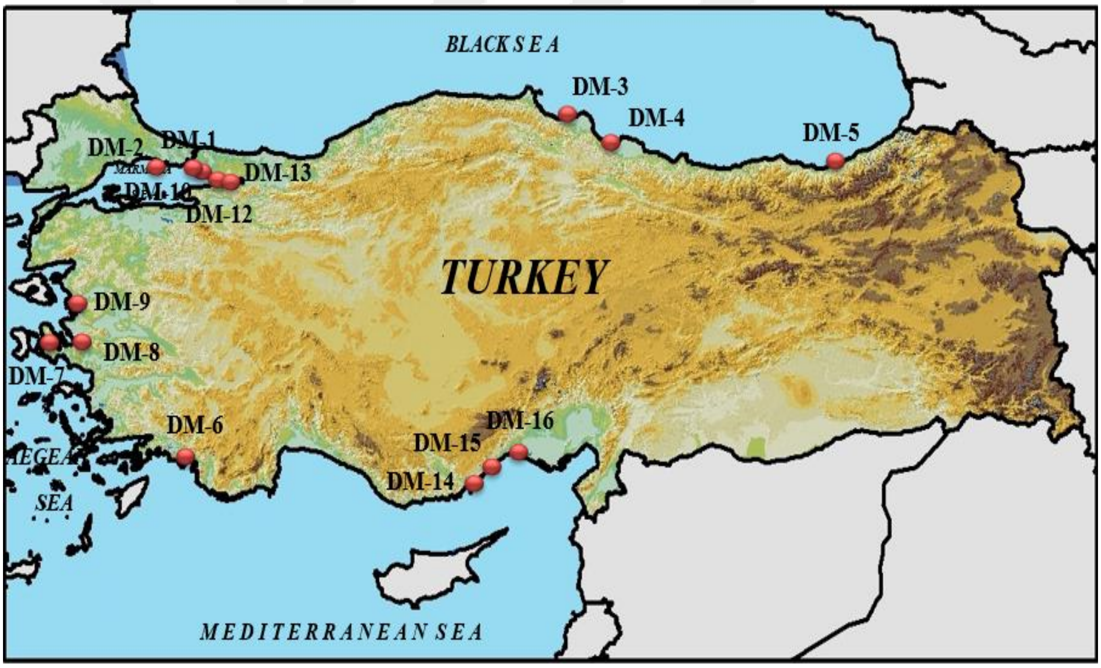


Figure 3.1. Sampling points of the study

The general information about the DM sampling points such as sampling codes, cities/seas involving the sampling point, activities in the sampling points is given in Table 3.1. DM-11 was excluded from the sampling point list because the sampling was carried out from the same port (TÜPRAŞ Yarımca Port) with different dredging equipment (cutter-suction dredger). In addition, there are industrial mining activities that can cause various pollutants in the cities where sampling points are located. These are as follows: There are copper mine beds in Rize province. Muğla, Mersin and Adana are rich in chrome mines. Mercury, lead and zinc mineral beds are located in In Izmir (Karaburun-Ödemiş). Moreover, there are refineries operating petrochemicals in Izmir.

Table 3.1. Sampling points of DMs

Sampling Points	City	Sea	Sampling Code	Activities in the Sampling Points
Tuzla Marina	Istanbul	The Sea of Marmara	DM-1	Tourism and Boats
Ambarlı Port	Istanbul	The Sea of Marmara	DM-2	Loading and Unloading
Samsun Port	Samsun	Black Sea	DM-3	Loading and Unloading
Alaçam Yakakent Fishery Harbour	Samsun	Black Sea	DM-4	Organic Contamination
Rize Port	Rize	Black Sea	DM-5	Loading and Unloading
Göcek Marina	Muğla	Aegean Sea	DM-6	Tourism and Ship Transportation
Karaburun Tepeboz Village Fishery Harbour	Izmir	Aegean Sea	DM-7	Organic Contamination
Nemrut Gulf Batıçim Harbour	Izmir	Aegean Sea	DM-8	Loading and Unloading
PETKİM Container Port	Izmir	Aegean Sea	DM-9	Petrochemical Industry
Tuzla Shipyards Area	Istanbul	The Sea of Marmara	DM-10	Boat and Ship Construction
Eskihisar Fishery Harbour	Kocaeli	The Sea of Marmara	DM-12	Organic Contamination
TÜPRAŞ Yarımca Port	Kocaeli	The Sea of Marmara	DM-13	Petrochemical Industry
Erdemli METU Campus Port	Mersin	Mediterranean Sea	DM-14	Clean Area
Erdemli Fishery Harbour	Mersin	Mediterranean Sea	DM-15	Organic Contamination
Mersin International Port (MIP)	Mersin	Mediterranean Sea	DM-16	Loading and Unloading

Approximately 1 m^3 DM sample was taken from each sampling point at a depth of 2-16 m from water, transferred by trucks and stored in hermetic (airtight), plastic cover, metal mouth, handled HDPE (high density polyethylene) barrels (0,003 m^3 = 30 L) at room temperature in TÜBİTAK MAM Environment and Cleaner Production Institute’s laboratories.

Figure 3.2. The handling and storage of DMs

The summary information regarding to the dredging operations on the basis of sampling points together with dredging dates, dredger type and (public/private sector) dredging corporation is presented in Table 3.2 and photographs related to the dredging operations are shown in Figure 3.3.

Table 3.2. General information about the dredging operations carried out in the sampling points

Sampling Points	Sampling Code	Coordinates	Dredging Dates	Dredger	Dredging Corporation
Tuzla Marina	DM-1	40° 48' 78" N 29° 19' 12" E	06.12.2013	Backhoe	Ministry of Transportation, Maritime Affairs and Communication (MTMAC) Istanbul Marine Dredging Chief Engineering (MDCE)
Ambarlı Port	DM-2	40° 57' 44" N 28° 40' 37" E	20.02.2014	Bucket-ladder	MTMAC Istanbul MDCE
Samsun Port	DM-3	41° 18' 1,24" N 36° 20' 39,8" E	27.05.2014	Backhoe	MTMAC Samsun MDCE
Alaçam Yakakent Fishery Harbour	DM-4	41° 38' 22,2" N 35° 30' 23,2" E	28.05.2014	Backhoe	MTMAC Samsun MDCE
Rize Port	DM-5	41° 02' 15,6" N 40° 30' 53,9" E	29.05.2014	Catamaran crane	MTMAC Rize Port Authority
Göcek Marina	DM-6	36° 45' 3,4" N 28° 55' 37" E	17.06.2014	Backhoe	MTMAC Izmir MDCE
Karaburun Tepeboz Village Fishery Harbour	DM-7	38° 40' 17,6" N 26° 26' 18,2" E	20.06.2014	Backhoe	MTMAC Izmir MDCE
Nemrut Gulf Batıçim Harbour	DM-8	38° 45' 36,16" N 26° 55' 15,74" E	09.07.2014	Backhoe	MTMAC Izmir MDCE
PETKİM Container Port	DM-9	38° 46' 42,78" N 26° 55' 43,83" E	09.07.2014	Bucket-ladder	DALSAN Port Building Company
Tuzla Shipyards Area	DM-10	40° 50' 37,2" N 29° 15' 50,9" E	20.08.2014	Catamaran crane	DALSAN Port Building Company
Eskihisar Fishery Harbour	DM-12	40° 46' 7,5" N 29° 25' 40" E	24.09.2014	Backhoe	MTMAC Istanbul MDCE
TÜPRAŞ Yarımca Port	DM-13	40° 45' 18" N 29° 45' 22" E	24.09.2014	Backhoe	MTMAC Istanbul MDCE
Erdemli METU Campus Port	DM-14	36° 33' 49,4" N 34° 15' 19,9" E	29.09.2014	Backhoe	MTMAC Izmir MDCE
Erdemli Fishery Harbour	DM-15	36° 36' 18,80" N 34° 19' 19,25" E	29.09.2014	Backhoe	Erdemli Seafood Cooperative
Mersin International Port (MIP)	DM-16	36° 48' 12,37" N 34° 38' 40,16" E	30.09.2014	Portable crane	The Management of MIP

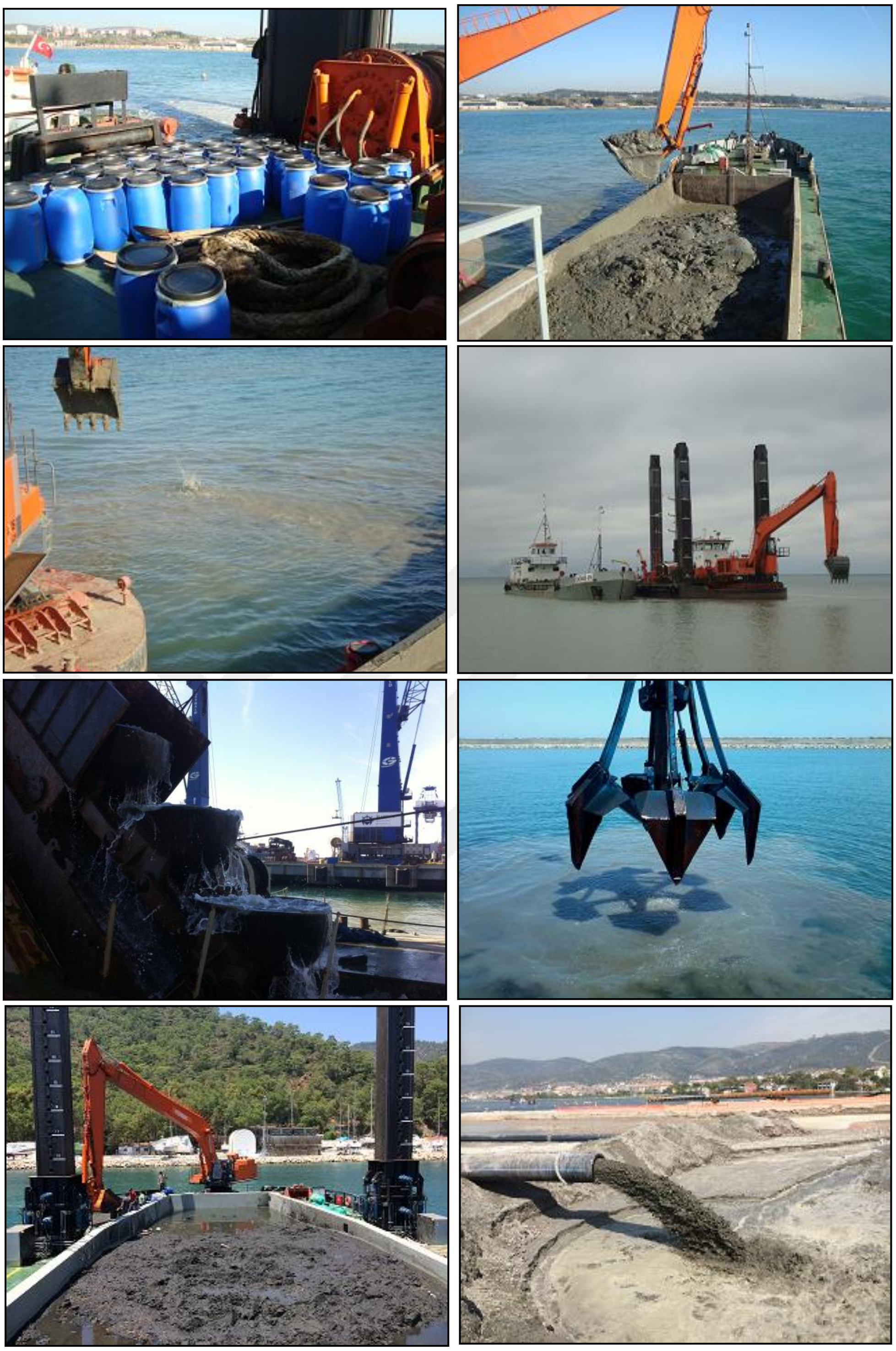


Figure 3.3. Dredging operations carried out in the sampling points

Natural soil used as a control specimen was taken from TÜBİTAK MAM Agriculture Department. Peat was purchased from peat facility in Yeniçağ/Bolu in a pure form in 10-liters-packages. Sheep manure was obtained locally from Gebze-Pelitli Village/Kocaeli in order to ameliorate the organic contents and to improve the physical structures of MTs.

3.2 The Characterization Study of DMs

3.2.1 Materials

In the scope of characterization study of DMs in accordance with AYY-Appendix-3B, ADDDY-Appendix-2 and EKAÇTKY-Appendix-IIB, information about the used chemicals and instruments in the analysis are pointed out in Table 3.3, Table 3.4 and Table 3.5, respectively.

Table 3.3. Chemicals used in characterization study

Chemical substances	Usage Purpose
HCl, HNO_3, argon gas and ICP-OES calibration std.	Heavy metal determination
HCl, potassium biphthalate ($C_8H_5KO_4$), Na_2CO_3, $NaHCO_3$, dry air tube.	Total organic carbon (TOC)/Dissolved organic carbon (DOC) determination
Press. air, chloride IC std., fluoride IC std., sulfate IC std.	Anion determination
n-heptane, Na_2SO_4, acetone, florisil, n-decane, n-tetracontane, helium and dry air gases, hydrocarbon GC std.	Mineral oil determination
methyl orange indicator, H_3PO_4, stock phenol solution, NaOH, NaCl, HCl, $CHCl_3$, Na_2SO_4, KI, $K_3Fe(CN)_6$, 4-aminoantipyrine, starch	Phenol determination
Kjeldahl catalyst, H_2SO_4	Nitrogen determination
$HClO_4$, ammonium molybdate, H_2SO_4, NaOH	Phosphorus determination
CH_2Cl_2, acetonitrile, cyclohexane, silica gel, hexane, dimethylformamide, nitrogen gas, PAH calibration std.	Polyaromatic hydrocarbon (PAH) determination
BTEX calibration std., helium and dry air gases	Benzene, Toluene, Ethylbenzene, Xylene (BTEX) determination
Hexane, acetone, toluene, silica gel, alumina oxide, tetradecane, nitrogen and helium gases, PCB calibration std.	Polychlorinated biphenyl (PCB) determination
Toluene, CH_2Cl_2, hexane, extraction std. syringe std.	Dioxin/Furan (PCDD/F) determination
Acetonitrile, Metachlorine internal std., PSA column, $MgSO_4$	Pesticide/Tributyltin determination
Hexane	Oil-grease determination
pH4, pH7 and pH10 buffer solution	pH measurement

Table 3.4. Instruments used in characterization study

Instruments	Features	Usage Purpose
Gas Chromatography-Flame Ionization Dedector (GC-FID)	GC 6890N Agilent, Agilent FID Detector	Mineral oil determination
Gas Chromatography-Mass Spectrometry (GC-MS)	Thermo Finnigan GC Ultra, AS 3000 Autosampler, Al 3000 Autoinjector, Thermo DSQ MS	Hydrocarbon determination
GC-MS	Headspace GC-MS Agilent 5975 MSD-7697 HS	Volatile organic carbon (VOC) determination
Gas Chromatography-Electron Capture Detector (GC-ECD)	Thermo Finnigan GC Ultra, Thermo AS 3000 Autosampler, Thermo Al 3000 Autoinjector, $_{63}$Ni-ECD Thermo Dedector	PCB determination
GC-FID	GC 6890N Agilent, Agilent FID Detector (OI-Analytical Eclipse Model 4660)	BTEX determination
GC-MS	Headspace GC-MS Agilent 5975 MSD-7697 HS	PAH determination
Gas Chromatography-High Resolution Mass Spectrometry (GC-HRMS)	Agilent GC-Micromass trademark Autospec premier model	PCDD/F determination
GC-MS	Headspace GC-MS Agilent 5975 MSD-7697 HS	Pesticide determination
Liquid Chromatography-Mass Spectrometry Mass Spectrometry (LC-MSMS)	Agilent 6460 Triple Quadrupole	Tributyltin determination
TOC Analyzer	Shimadzu TOC-V CSH TOC Analyzer, SSM-5000A Solid Material module, ASI-V Autosampler	TOC and DOC determination
Ion Chromatography	Dionex ICS-1000 Ion Chromatography	Anion determination
Inductively Coupled Plasma-Optical Emission Spectrometry (ICP-OES)	Perkin-Elmer ICP-OES 8300 DV, Microwave Digestion Device	Metal analysis in solid matrix
Inductively Coupled Plasma-Mass Spectrometry (ICP-MS)	Perkin Elmer ICP-MS NexION 300XX	Metal analysis in leachate
X-Ray Diffractometer (XRD)	Shimadzu XRD-6000	Determination of inorganic material species (Qualitative phase)
X-Ray Fluorescence Spectrometer (XRF)	Philips PW-2404	Semi-quantitative elemental analysis

Table 3.5. Instruments used in characterization study (Table 3.4 continued)

Instruments	Features	Usage Purpose
Scanning Electron Microscope (SEM)	JEOL 6335F	Morphological analysis
Bomb Calorimeter	LECO-AC350	Upper heating value determination
CHN-S Elemental Analyzer	LECO Truspec	Elemental analysis (Total S)
Fourier Transform-Infrared Spectroscopy (FT-IR)	Perkin Elmer Spectrum One	Functional group analysis of organic matter
UV spectrophotometer	CADAS 200 Dr. Lange	Phenol and phosphorus determination
Horizontal Shaker	Braun Biotech Int., Certomat RM	Hydrocarbon analysis
Rotating Shaker	Behr Labor Technik GmbH	Eluate preparation (24 h)
Moisture Analyzer	Sartorious MA 45	Water Content
Clean-up Set	SUPELCO	Sample preparation for determination of organic pollutants
Rotary Evaporator	Heidolph	Solvent evaporation
Oven	Binder	Drying
Analytical Balance	Mettler Toledo	Weighing
Muffle Furnace	Carbolite	Loss on ignition determination
pHmeter	WTW Inolab Multi level1	pH measurement
Conductivity meter	WTW Multi parameter	EC measurement
Vibratory sieve shaker	Retsch AS 200	Particle size distribution
Ecotoxicity Instrument	ToxAlert 100 toxicity instrument and bioluminescence bacteria	Toxicity determination
Nitrogen Analyzer	Gerhardt Vapodest 50 Nitrogen Analyzer	Nitrogen determination
Ultra-pure Water Apparatus	Millipore Milli-Q	For pure water

3.2.2 Methods

DMs obtained from the fifteen sampling points through dredging operations for the evaluation of beneficial use alternatives were analyzed and evaluated in accordance with the principles of "AYY-Appendix-3B (02/07/2015 dated and Official Gazette No: 29314)" whether they show the hazardous waste characteristics or not. The physico-chemical, organic testing of DMs and analysis methods are presented in Table 3.6 and Table 3.7.

Table 3.6. Physico-chemical and toxicological analysis methods of DMs in accordance with AYY-Appendix 3B

Parameters	Methods
Physico-chemical analysis	
Appearance/Odor	Visual/Sensory
pH (aq.sol.)	TS 8753 EN 12176:2009
EC (mS/cm) (aq.sol.)	SM-2510 B
Total dissolved solids (mgL^{-1})	SM-2540 C
Water/Solid content (w %)	TS 9546 EN 12880:2002
Organic/Inorganic matter content (w %)	TS 8336:2008
Type of inorganic matter	In-house method (XRD-Rietveld), in-house method (XRF)
Type of organic matter	EPA 8260 GC-MS (hexane extraction) ASTM E1252 FT-IR spectrometer
High heating value (HHV) (kcal/kg)	ASTM D 5865
Total sulfur (%)	ASTM D4239
Oil-grease (mg/kg)	SM-5220 F Soxhlet extraction
Total nitrogen (mg/kg)	SM-4500 N
Total phosphorus (mg/kg)	In-house method (Wet combustion)
Unit weight (kg/m^3) (wet)	TS EN 1097-6:2002
Water absorption (%)	TS EN 1097-6:2002
Particle size distribution (%)	Wet Sieving (In-house method)
Loss on ignition (LOI) (%)	DS/EN 12879, TS EN 12879 :2003
Organic Analysis	
PAH (mg/kg)	ISO 11338
PCDD/F (ng/kg I-TEQ)	EPA 1613
Total Pesticides (mg/kg)	EPA 8081, EPA 8141
Tributyltin (mg/kg)	In-house method
VOC	EPA 8310

Table 3.7. Physico-chemical and toxicological analysis methods of DMs in accordance with AYY-Appendix IIIB (Table 3.6 continued)

Parameters	Methods
Toxicological analysis	
Ecotoxicity	ISO/EN/DIN 11348
Acute Toxicity (Fish)	92/69/EEC- C.1
Acute Toxicity (Rat)	Acute Oral Toxicity-Fixed Doze, OECD TG 423
Heavy Metal analysis	
Pb (mg/kg)	ISO 11885
Cd (mg/kg)	ISO 11885
Cr (mg/kg)	ISO 11885
Cu (mg/kg)	ISO 11885
Ni (mg/kg)	ISO 11885
Zn (mg/kg)	ISO 11885
Hg (mg/kg)	EPA 7473
As (mg/kg)	ISO 11885

DMs were dried at 105°C; and then, they were burned at 550°C until constant weight was obtained in accordance with TS 8336:1990 method. The amount of organic matter (%) was calculated with the difference between the first and last weighing values divided by the first weight value while the amount of the inorganic material (%) was computed with the last weighing value divided by the first weighing value.

The pH and EC values were measured with WTW Inolab Multimeter. HHV value and total sulfur content were measured by using LECO-AC350 bomb calorimeter and LECO Truspec elemental analyzer, respectively. Standard Methods (2012) were used for the determination of total nitrogen, total phosphorus and oil-grease.

Certain amount of raw DM sample (200 g) was taken for the determination of particle size distribution and characters of DMs. They were passed through automatic vibratory sieve shaker (10 min) having different sieve sizes (2 mm, 200 µm and 63 µm) (Figure 3.4) by using pressurized water according to the "wet sieving method". After sieving occurs, the DM fractions retained on each sieve were dried at 105°C and weighed until constant weight. Finally, particle size distribution was found by using the amount of (original) DM, the amount of dried sample remaining on each sieve and water content (%) of DM.

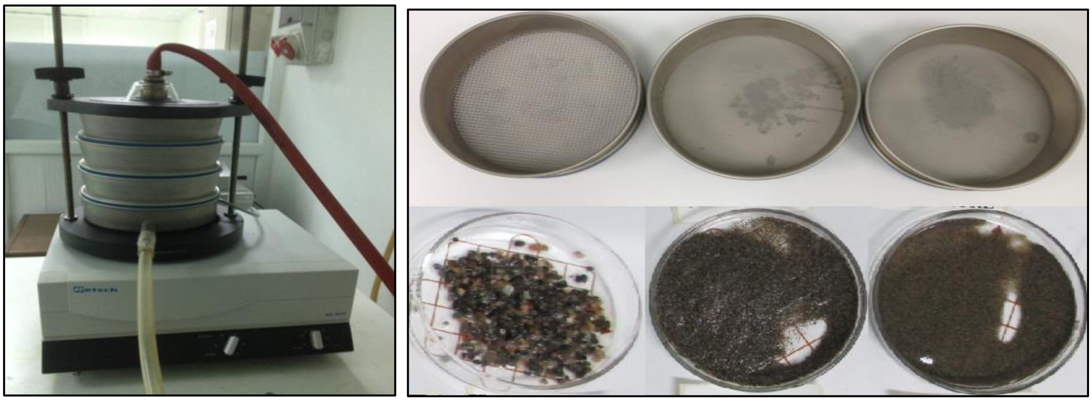


Figure 3.4. Vibratory sieve shaker and standard test sieves used during sieve analysis

The type of inorganic matter was performed by metal screening in ICP-OES in order to clarify the structure of the inorganic portion of DMs and with the aim of detection of possible heavy metals and/or the important other components in terms of risk factor to be present in the inorganic structure of the samples. They were prepared in a strongly acidic medium (9 mL HNO_3 + 3 mL HCl) by disposing the organic contents in microwave digestion device; then, an ideal dissolution was obtained, they were given to the liquid phase according to the ISO 11885 standard by using Perkin-Elmer ICP-OES 8300 DV.

For the determination of organic matter type of DMs, the functional groups in the composition of sample were detected by hexane extraction and using FT-IR in the wavelength range of 400-4000 cm^{-1} in accordance with the ASTM E1252 method. Furthermore, Headspace GC-MS Agilent 5975 MSD-7697 HS model GC-MS (column size: 60 m, column diameter: 0.25 mm, film thickness: 0.25 m) was used for the determination of VOCs in 1 g of original parts obtained from DM sample without any pre-treatment. Concentrations of PCDD/Fs, PAHs, total pesticides and Tributyltin compounds were also specified by chromatographic techniques using GC-HRMS, GC-MS and LC-MSMS, respectively.

The qualitative phase (mineralogical) analysis of the DM specimens was carried out by Shimadzu XRD-2 6000 XRD Diffractometer, using Cu kα radiation (λ=1.5405°A). The quantitative analysis of inorganic elements in the chemical composition of the DM was made with Philips PW-2404 models with wavelength dispersive XRF Spectrometer. Morphological analysis was performed by JEOL

6335F SEM Microscope. Sample, if it is needed, was examined chemically with semi-quantitative micro-analytical method by using Oxford Instruments Energy Dispersive Spectrometer (EDS).

Acute toxicity tests on fish and rat were carried out in order to identify the toxicological properties of DMs. Ecotoxicity analysis of DMs was performed using ToxAlert 100 toxicity equipment and bioluminescence bacteria in accordance with ISO/EN/DIN 11348 method. For extraction of solid DM samples, 10 g of sample/100 ml of deionized water mixture was shaken with a circular motion shaker for 24 hours and the resulting extract was centrifuged at 4000 rpm for 15 minutes according to the DIN 38414-S4 method.

Dilutions for the test were prepared as 80%, 50%, 25%, 12.5% and 6.25% sample concentration. These dilutions were taken into account in the calculation. The contact time of test was 30 minutes and two measurements were made from each sample. At the end of the test, % inhibition value and EC_{50} values of samples corresponding to each dilution were calculated. Acute toxicity for fish was expressed in terms of the average lethal concentration (LC_{50}) that 50% of the test fish died. This analysis method was continued for at least 96 hours and fish deaths were monitored for 24 hours apart. At the end of the test, the concentration at which 50% of the fish were died was recorded as LC_{50} values. One to ten diluted aqueous solutions (100 g/L) of DMs were subjected to 92/69/EEC Method C.1: “Acute toxicity in Fish-toxicity dilution factor (TDF)”. There is no criterion in the water pollution control Regulation (SKKY) for TDF value of DMs. However, when all sectors are evaluated according to SKKY, the upper limit value is TDF: 8. Acute oral toxicity of DM samples were carried out by "OECD TG 423: Acute toxic class method” on laboratory test for rat in TÜBİTAK MAM Genetic Engineering and Biotechnology Institute and assessed according to United Nations Globally Harmonized System of Classification and Labelling of Chemicals (GSH) Part 3 Health Hazards Part. Laboratory rat/Balb/c were used as test animal. Samples were tested using 8-12 weeks (less than ± 20% difference between weight) three male rats/Balb/c as recommended in the experimental protocol.

The leachabilities of DMs were identified according to the “TS EN 12457-4:2004 leaching test” in order to determine the landfill class and the potential of possible pollutants passing to the eluate in accordance with the principles of “ADDDY-Appendix 2” given in Table 3.8 with the related analysis methods.

Table 3.8. "ADDDY-Appendix 2" quality criteria and methods

Parameters	Methods
Physico-chemical Analysis	
Arsenic (As mg/L)	
Barium (Ba mg/L)	
Cadmium (Cd mg/L)	EPA 6020A 2007
Chromium (Cr mg/L)	
Copper (Cu mg/L)	
Mercury (Hg mg/L)	SM-3112
Molybdenum (Mo mg/L)	
Nickel (Ni mg/L)	
Lead (Pb mg/L)	EPA 6020A 2007
Antimony (Sb mg/L)	
Selenium (Se mg/L)	
Zinc (Zn mg/L)	
Chloride (Cl^- mg/L)	
Fluoride (F^- mg/L)	SM-4110B Ion Chromatography
Sulfate (SO_4^{2-} mg/L)	
DOC (mg/L)	SM-5310B High Heating Comb.
Total dissolved solid (TDS mg/L)	SM-2540C Gravimetric
Phenol (C_6H_5OH mg/L)	SM-5530D Photometric
Organic Analysis	
TOC (mg/kg)	SM-5310B
BTEX (mg/kg)	EPA 8015C
PCBs (mg/kg)	ISO 10382
Mineral oil (mg/kg)	BS EN 14039:2004
LOI (%)	TS EN 12879:2003

Samples are prepared for analysis in accordance with TS EN 12457-4 standard with principles of "ADDDY". According to TS EN 12457-4:2004, 100 g dry sample was extracted in 1 L distilled water with shaking for 24 hours (Figure 3.5). After extraction process, solid and liquid phases were separated via centrifugation or filtration from each other. The liquid phase was analyzed in accordance with the "ADDDY-Appendix 2: Acceptance criteria for landfilling of solid waste".

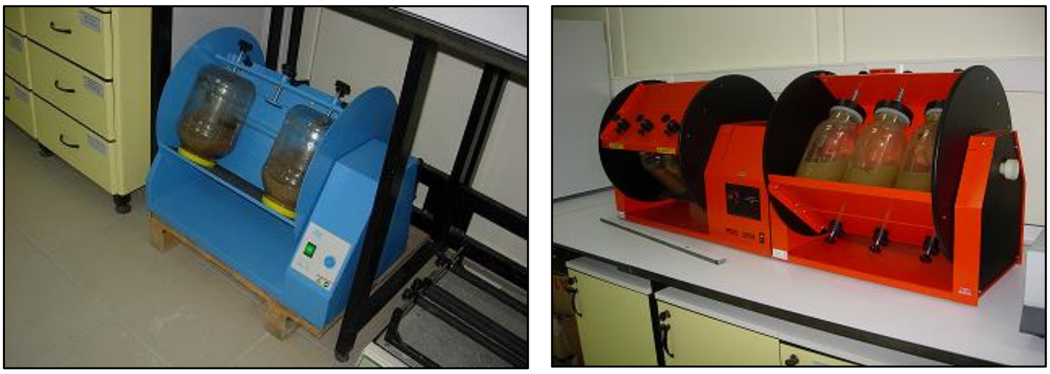


Figure 3.5. Preparation of eluate (extraction solution) in the laboratory

The usability of DMs in soil was examined in accordance with the principles of "The Regulation on Use of Domestic and Urban Treatment Sludge in Soil (EKAÇTKY)-Appendix IIB" dated August 3, 2010 and published in the Official Gazette No: 27661" whether they cause a risk or not. The analysis parameters and methods of stabilized sludge in accordance with this regulation are presented in Table 3.9.

Table 3.9. The Analysis parameters and methods of the "EKAÇTKY- Appendix IIB"

Parameters	Methods
Lead (Pb mg/kg) Cadmium (Cd mg/kg) Chromium (Cr mg/kg) Copper (Cu mg/kg) Nickel (Ni mg/kg) Zinc (Zn mg/kg)	EPA 6020 A 2007
Mercury (Hg mg/kg)	TS 2537 EN 1483:1999
Total kjeldahl nitrogen (TKN mg/kg)	SM-4500-Norg.B
Phosphorus (P mg/kg)	Wet combustion method (Olsen and Sommers (1982)
Halogenated organic compounds (AOX mg/L)	DIN 38409/14 Titration
Detergent (mg/L) (LAS)	SM- 5540 C (GC-FID)
Di(2-ethylhexyl) phthalate (DEHP) (mg/kg)	In-house method (GC-FID)
Nonyl phenol ethoxylate (NPE) (mg/kg)	In-house method (GC-FID)
PAH (mg/kg)	EPA 8310 (HPLC)
PCB (mg/kg)	ISO 10382 (GC-ECD)
PCDD/F (ng TEQ/kg Solid matter)	TS EN 1948/2-3:2006 (GC-HRMS)
pH	TS 12072:2003
C/N	ASTM D 5373
Water, solid content (%)	TS 9546 EN 12280:2002
LOI, organic matter (%)	TS EN 13039:2011
EC (mS/cm)	TS ISO 11265:1996
E.Coli (EMS/g)	NF-ISO 166492

3.3 The Production of MT For The Beneficial Use of DM

3.3.1 Materials

Detailed information about the used chemicals and instruments in the analysis under the production studies of MT from DM are illustrated in Table 3.10 and Table 3.11.

Table 3.10. Chemicals used in the production of MT from DM

Chemical substances	Usage Purpose
Triethanolamine, DTPA (diethylenetriaminepentaacetic acid), HCI, $CaCl_2$,$2H_2O$	Micronutrient determination in soil
CH_3COOH, NH_4OH, CH_3COONH_4, KCl	Macronutrient determination in soil
HCl, potassium biphthalate ($C_8H_5KO_4$), Na_2CO_3, $NaHCO_3$	TOC determination
HCl, HNO_3, argon gas and ICP-OES calibration std	Heavy metal determination
methyl orange indicator, H_3PO_4, stock phenol solution, H_3PO_4, H_2SO_4, $K_2Cr_2O_7$, iron(II) sulfate, iron(II) sulfate, std. solution, barium diphenylamine sulfonate, Ag_2SO_4, o-phenanthroline ferrous sulfate complex	Organic matter content determination
Salicylic acid/Sulfuric acid solution, K_2SO_4 catayst, $Na_2S_2O_3.5H_2O$, H_2SO_4, bromocresol green, H_2SO_4, NaOH, H_3BO_3	Nitrogen determination
$NaHCO_3$, NaOH, ammonium molybdate, HCl, KH_2PO_4, $SnCl_2.2H_2O$	Phosphorus determination in soil
CH_2Cl_2, acetonitrile, cyclohexane, silica gel, hexane, dimethylformamide, nitrogen gas, PAH calibration std	PAH determination
BTEX calibration std., helium and dry air gases	BTEX determination
Hexane, acetone, toluene, silica gel, alumina oxide, tetradecane, nitrogen and helium gases, PCB calibration std.	PCB determination
Toluene, CH_2Cl_2, hexane, extraction std. syringe std.	PCDD/F determination
Acetonitrile, Metachlorine internal std., PSA column, $MgSO_4$	Tributyltin and pesticide determination
Distilled water, HCl, $CaCO_3$	Determination of lime content
KCI solution, distilled water	Total salt determination
NH_4NO_3, distilled water	Exchangeable cation determination
Vibratory sieve shaker, sieves having different opening	Particle size distribution determination
Sodium hexametaphosphate, distilled water	Soil texture determination
pH4, pH7 and pH10 buffer solution	pH measurement

Table 3.11. Instruments used in the production studies of MT from DM

Instruments	Features	Usage Purpose
pHmeter	WTW Inolab Multi level1	pH measurement
EC meter	WTW Multi parameter	Conductivity measurement
Oven	Binder	Drying
Analytical Scale	Metler Toledo	Weighing
ICP-OES	Perkin-Elmer ICP-OES 8300 DV, Microwave Digestion Device	Macronutrient and micronutrient determination in soil
GC-MS	Headspace GC-MS Agilent 5975 MSD-7697 HS	Volatile organic content determination
GC-ECD	Thermo Finnigan GC Ultra, Thermo AS 3000 Autosampler, Thermo Al 3000 Autoinjector, $_{63}$Ni-ECD Thermo Dedector	PCB determination
GC-FID	GC 6890N Agilent, Agilent FID Dedector (OI-Analytical Eclipse Model 4660)	BTEX determination
GC-MS	Headspace GC-MS Agilent 5975 MSD-7697 HS	PAH determination
GC-HRMS	Agilent GC-Micromass trademark Autospec premier model	PCDD/F determination
GC-MS	Headspace GC-MS Agilent 5975 MSD-7697 HS	Pesticide determination
LC-MSMS	Agilent 6460 Triple Quadrupole	Tributyltin Analysis
Nitrogen Analyzer	Gerhardt Vapodest 50 Nitrogen Analyzer	Total Nitrogen Analysis in Soil
UV spectrophotometer	CADAS 200 Dr. Lange	Total phosphorus determination in soil
Moisture Analyzer	Sartorious MA 45	Water content
Clean-up Set	SUPELCO	Cleaning of sample
Rotary Evaporator	Heidolph	solvent evaporation
FT-IR	Perkin Elmer Spectrum One	Functional group determination of organic matter
Vibratory sieve shaker	Retsch AS 200	Particle size distribution
Hydrometer	Bouyoucos Hydrometer	Determination of soil texture
Muffle Furnace	Carbolite	Organic matter content determination
Shaker	Braun Biotech Int., Certomat RM	Soil texture determination
Rotating Shaker	Behr Labor Technik GmbH	Eluate preparation
Ultra-pure Water Apparatus	Millipore Milli-Q	For pure water
Mercury Analyzer	ATS Scientifics DMA80-Direct Mercury Analyzer	Mercury determination in soil

3.3.2 Methods

Due to the fact that raw DMs showed moderate water content, slightly saline and high alkaline nature, and low organic matter content, they are inadequate for plant growth; thus, DMs require significant pretreatment procedure for MT topsoil production.

Experimental methodology for the beneficial use of DM as MT in landscaping is illustrated in Figure 3.6. First of all, five mixtures ($DM_{Mixture}$ samples) were prepared from a total of fifteen DM samples having the identical particle size distribution. Desalination (washing), dewatering, organic amelioration (mixing with peat and sheep manure) and pH adjustment for nutrient availability were performed, respectively, in order to investigate the utilization of DM as MT. Both washed and unwashed DMs were used to produce MT for the comparison of plant growth.

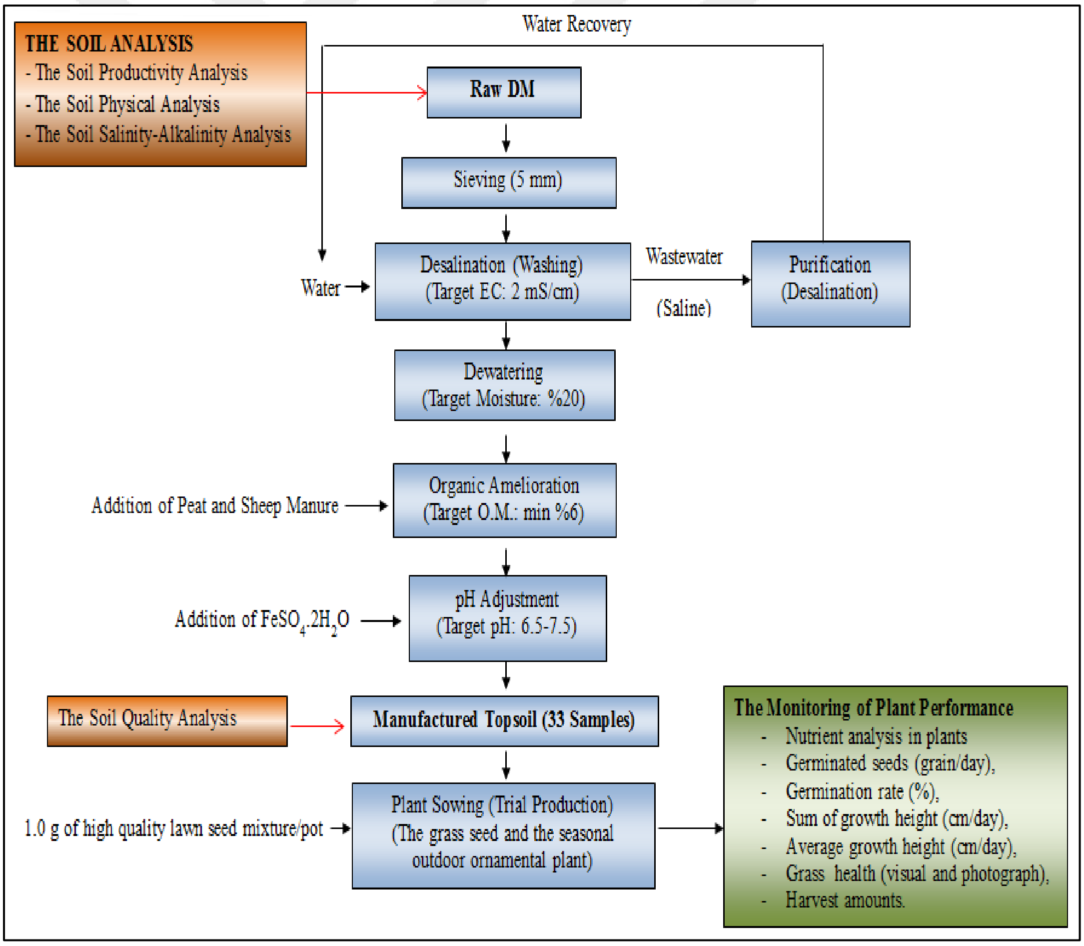


Figure 3.6. Experimental methodology used for the production of MT samples from DMs

3.3.2.1 The Preparation of DM$_{Mixture}$ Samples

Five different DM$_{Mixture}$ samples (DM$_{Mixture-A}$, DM$_{Mixture-B}$, DM$_{Mixture-C}$, DM$_{Mixture-D}$ and DM$_{Mixture-E}$) were prepared from fifteen DM specimens with the aim of decreasing the total number of samples by mixing equal amounts of DMs having the identical particle size distributions regardless of the fact that these fifteen sampling points are far from each other and economic aspect is also ignored. At first, DM samples were sieved from 5 mm sieve before mixing. Figure 3.7 illustrates the whole sampling points of the study with the related pie charts showing the average particle size distributions of DMs.

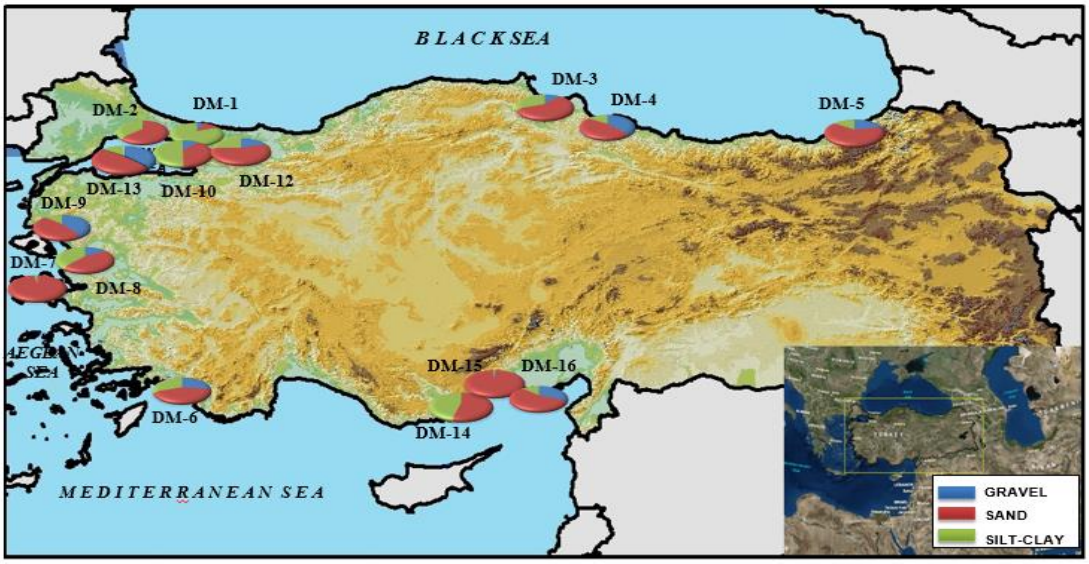


Figure 3.7. Whole sampling points of the study with the related pie charts showing the average particle size distributions of DMs (DIPTAR, 2016)

3.3.2.2 Soil Quality Analysis of DM$_{Mixture}$ Samples, Natural Soil, Peat and Sheep Manure

In the main headings, the soil quality analysis of DM$_{Mixture}$ samples, natural soil (control), peat and sheep manure to be used in the preparation of MT samples are listed as follows:

- The soil productivity analysis (in Table 3.12),
- The soil salinity-alkalinity analysis (in Table 3.13) and
- The soil physical analysis (in Table 3.14).

Table 3.12. "The soil productivity analysis" parameters and methods

Parameters	Methods
Water/solid content (w %)	TS 9546 EN 12880:2002
pH (aqueous solution)	TS ISO 10390:2013
EC (at saturation) (mS/cm)	TS ISO 11265:1996
Total salt (%) (soil satu. with water)	TS 8334:1990
Particle size distribution;	
Gravel (>2 mm) (%):	
Coarse sand (2 mm-200 µm) (%):	TS 3530 EN 933-1:2007
Fine sand (200 µm-63 µm) (%):	
Silt-clay mixture (<63 µm) (%):	
Soil texture;	ASTM D422-63:2007 Bouyoucos
Sand, silt and clay (%):	hydrometer
Organic/inorganic matter content (w %)	TS 8336:2008 (Walkley black method)
LOI (%)	TS EN 12879: 2003
Available potassium (K_2O kg/da)	TS 8341:1990 (Ammonium acetate)
Available phosphorus (P_2O_5 kg/da)	TS 8340:1990/ Olsen method
TOC (mg/kg)	SM-5310 B High temp. combustion
Total nitrogen (mg/kg)	TS 8337 ISO 11261:1996
Total phosphorus (mg/kg)	SM-4500 P
C/N ratio	By calculation
N/P ratio	By calculation
Lime content (%$CaCO_3$)	TS EN ISO 10693:2014
Available Micronutrients	
Fe (mg/kg)	
Cu (mg/kg)	
Zn (mg/kg)	TS ISO 14870/T1:2009 (DTPA method)
Mn (mg/kg)	
Al (mg/kg)	
Available Macronutrients	
Ca (mg/kg)	
Mg (mg/kg)	TS 8341:1990 (Ammonium acetate)
Na (mg/kg)	
K (mg/kg)	
Heavy Metals	
Available B (mg/kg)	
Pb (mg/kg)	
Cd (mg/kg)	
Cr (mg/kg)	
Cu (mg/kg)	ISO 11885 (Nitric acid extrac.)
Ni (mg/kg)	
Zn (mg/kg)	
As (mg/kg)	
Hg (mg/kg)	EPA 7473 (Mercury analyzer)
Organic Pollutants	
PAH (mg/kg)	ISO 11338 (GC-MS)
PCDD/F (ng/kg I-TEQ)	EPA 1613 (GC-HRMS)
Total pesticides (mg/kg)	EPA 8081, EPA 8141 (GC-MS)
PCB (mg/kg)	ISO 10382 (GC-ECD), EPA 3540C
Tributyltin (mg/kg)	In-house method (LC-MSMS)
VOC (mg/kg)	EPA 8310 (Head space GC-MS)

At first, $DM_{Mixture}$ samples, natural soil (control), peat and sheep manure were dried at 105°C for the determination of water/solid contents according to TS 9546 EN 12880:2002. One to five (w/v) aqueous solutions of these dried samples were prepared in order to measure the pH and EC values with WTW Inolab Multimeter. They were ignited at 550°C in the muffle furnace in order to identify the organic/inorganic matter content. Bouyoucos hydrometer set and automatic vibratory sieve shaker having different sieve sizes according to the "wet sieving method" were utilized under pressurized water so as to determine the particle size distributions of samples of concern.

In the determination of quantities of available macronutrients (Ca, Mg, Na and K) entire samples were treated with ammonium acetate extraction solution and were filtered with filter paper having 0.45 µm pore size. At the end of the extraction process, aqueous solutions were obtained in accordance with the TS 8341:1990. In addition, micronutrients (Fe, Cu, Zn, Mn, Al) of all samples were taken into the aqueous solution by treating with DTPA extraction solution. Also, heavy metal concentrations of whole samples were determined by preparing strong acidic medium (9 mL HNO_3 + 3 mL HCl) via disposing the organic contents in microwave digestion device. At the end of the digestion process, ideal dissolutions were obtained and they were given to the liquid phase according to the ISO 11885 standard. Perkin-Elmer ICP-OES 8300 DV was used for the measurement of heavy metals.

Table 3.13. "The soil salinity-alkalinity analysis" parameters and methods

Parameters	**Methods**
pH (aq.sol.)	TS ISO 10390:2013
EC (at saturation) (mS/cm)	TS ISO 11265: 1996
Saturation with water (water holding capacity) (%)	TS 8333:1990
Total salt (%) (from graph)	TS 8334:1990
Particle size distribution;	
Gravel (>2 mm) (%):	
Coarse sand (2 mm-200 μm) (%):	TS 3530 EN 933-1:2007
Fine sand (200 μm-63 μm) (%):	
Silt-clay mixture (<63 μm) (%):	
Soil texture;	ASTM D422-63:2007
Sand, silt and clay (%):	Bouyoucos hydrometer
Density (g/mL)	Pycnometer
Extractable cations	
Na (mg/kg)	
Mg (mg/kg)	BS 3882: 2015
Ca (mg/kg)	
K (mg/kg)	
Exchangeable cations	
Exchangeable Na (NaX) (meq/100g)	
Exchangeable Mg (MgX) (meq/100g)	BS 3882: 2015
Exchangeable Ca (CaX) (meq/100g)	
Exchangeable K (KX) (meq/100g)	
Cation exchange capacity (CEC) (mEq/100g)	Calculation (Richards (1954))
Exchangeable sodium percentage (ESP) (%)	BS 3882:2007
Sodium adsorption ratio (SAR)	Calculation (Richards (1954))

The determination of VOC in 1 g of raw sample was performed with Headspace GC-MS Agilent 5975 MSD-7697 HS model GC-MS (column size: 60 m, column diameter: 0.25 mm, film thickness: 0.25 μm). Concentrations of PCDD/Fs, PAHs, total pesticides and tributyltin compounds were identified by chromatographic techniques using GC-HRMS, GC-MS and LC-MSMS, respectively. The functional groups in the composition of the samples in the wavelength range of 400-4000 cm^{-1} were determined in organic phase extracted with hexane by using Perkin Elmer Spectrum One FT-IR in accordance with the ASTM E1252 method.

Table 3.14. "The soil physical analysis" parameters and methods

Parameters	Methods
Particle size distribution; Gravel (>2 mm) (%): Coarse sand (2 mm-200 μm) (%): Fine sand (200 μm-63 μm) (%): Silt-clay mixture (<63 μm) (%):	TS 3530 EN 933-1:2007
Soil texture; Sand%: Silt%: Clay%:	ASTM D422-63:2007 Bouyoucos hydrometer
Soil Structure; Type (figure and orientation of aggregates) Class (size of aggregates) Grade (strength of aggregates) Specific gravity (particle density) (g/cm^3) Bulk density (g/cm^3) Porosity (%)	FAO (2010)
Soil colour	Munsell color scale
Soil temperature	Thermometer
Soil air	FAO (2010)

3.3.2.3 The Improvement of DM$_{Mixture}$ Samples

3.3.2.3.1 Desalination of DM$_{Mixture}$ Samples

EC is a signal for the amount of dissolved salts and these salts can decrease plant germination success and plant growth (Horneck et al., 2007). DMs and also DM$_{Mixture}$ samples have certain salinity values. When considering the production of the MT from DMs for urban landscaping applications, the salinity values must be reduced to an appropriate range.

DM samples were split into two portions to observe the effect of salinity on plant growth. Desalination (washing) process was performed for one portion of DM$_{Mixture}$ samples in order to reduce EC value below 2 mS/cm (saltless) which is appropriate level for plant germination in the production of MTs. "Shaking washing method" was carried out on the related DM$_{Mixture}$ samples. Firstly, 100 g of DM$_{Mixture}$ sample was weighed into 1 L sample container. Then, the specified amount of tap water was added onto the sample. The cap of the sample container was closed well tightened. The prepared sample containers were placed in the shaking unit. Samples containing six different washing water volumes (0, 20, 40, 60, 80, and 100 mL) were shaken well for three different washing periods (5, 10 and 15 minutes) at 170 rpm in HS 501 model KIKA-WERKE shaking machine. At the end of the shaking process, the sample containers were removed from the shaking unit. The washed $DM_{Mixture}$ samples were filtered through Buchner funnel using filter paper. At the end of the washing process, pH and EC values of the washed $DM_{Mixture}$ samples were measured and optimum amount of washing water volume (mL) together with optimum washing time (min.) were founded. The other portion of $DM_{Mixture}$ samples were left as saline for comparison.

3.3.2.3.2 Organic Amelioration of $DM_{Mixture}$ Samples

Washed and unwashed $DM_{Mixture}$ samples were blended with peat and Sheep manure in different mixing ratios (33%, 50% and 66% $DM_{Mixture}$) in order to enhance their physical properties and organic contents. These mixing ratios included **1/3 $DM_{Mixture}$ (unwashed or washed) + 1/3 peat + 1/3 s. manure**; **1/2 $DM_{Mixture}$ (unwashed or washed) + 1/4 peat + 1/4 s. manure**; and **2/3 $DM_{Mixture}$ (unwashed or washed) + 1/6 peat + 1/6 s. manure**, respectively. Control samples (without $DM_{Mixture}$) were also prepared at the same mixing ratios by using natural soil instead of $DM_{Mixture}$ to compare the plant growth performances (Figure 3.8). Each mixture was prepared as a total of 2 L in plastic pots.

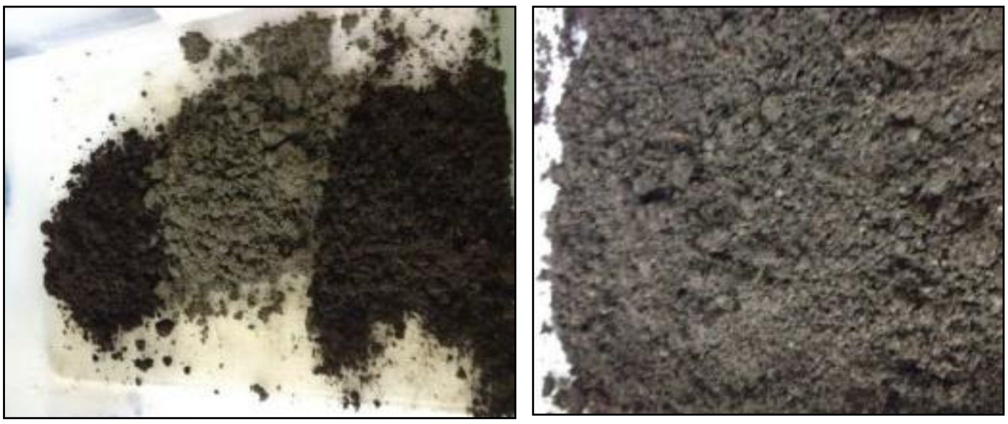


Figure 3.8. The organic amelioration of $DM_{Mixture}$ samples with peat and sheep manure

3.3.2.3.3 pH Adjustment in MT Samples Prepared by $DM_{Mixture}$ Samples

$DM_{Mixture}$ samples have high pH values (pH=8.50-9.50) and shows "alkaline" property. Low and/or high pH value restricts the movement of plant nutrients in the soil. Plants are fed by taking especially macronutrients and micronutrients from the soil. pH of soil must be within a certain range in order to receive the maximum amount of these nutrients by plants from soil. Therefore, target pH range was chosen between **6.50** and **7.50** (neutral pH range) (Sheehan et al., 2010) in the MT samples for potential nutrient availability. The addition of $FeSO_4.2H_2O$ (Iron (II) Sulfate dihydrate) was actualized to adjust pH value into each MT sample by performing neutralization reaction. The related reactions (Wallace and Terry, 1998) are shown below (Figure 3.9).

$$FeSO_4 + 2H_2O \longrightarrow H_2SO_4 + Fe(OH)_2 \quad (14)$$

$$H_2SO_4 + CaCO_3 \longrightarrow CaSO_4 + H_2O + CO_2 \quad (15)$$

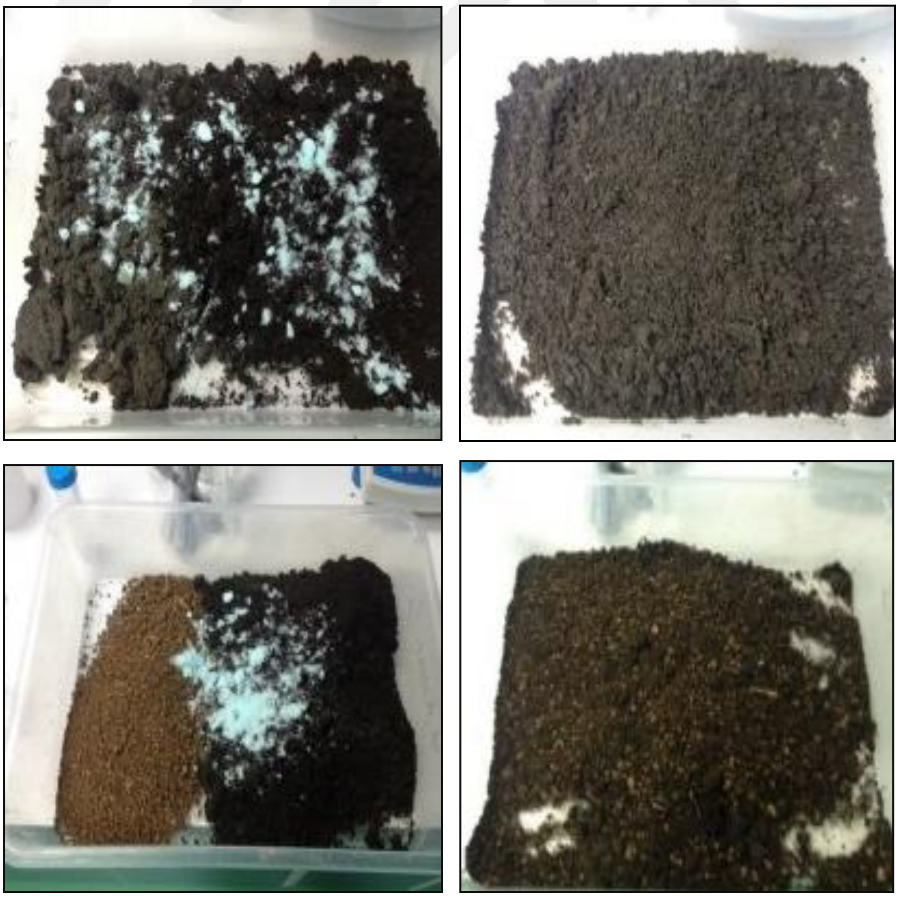


Figure 3.9. pH adjustment of MT samples with $FeSO_4.2H_20$

3.3.2.4 The Soil Quality Analysis of MT Samples before Grass Seed Planting

The physical and chemical properties of MT samples should be determined to have more clear knowledge about the content of soil before grass planting. Thus, soil productivity analysis was performed in all MT samples before the planting process. Furthermore, MT samples were assessed in accordance with "EKAÇTKY-Appendix IIB analysis" to get information about the usability of these soils in landscaping.

"The soil quality analysis" and "EKAÇTKY-Appendix IIB analysis" of the related MT samples before sowing grass seeds are illustrated in Table 3.15 and Table 3.16.

Table 3.15. "The Soil quality" analysis parameters for the assessment of MTs

Parameters	Methods
Water/solid content (w %)	TS 9546 EN 12880:2002
pH (aq.sol.)	TS ISO 10390:2013
EC (at saturation) (mS/cm)	TS ISO 11265:1996
Soil texture; Sand, Silt and Clay (%):	ASTM D422-63:2007 Bouyoucos hydrometer
Organic matter content (w %)	TS 8336:1990 (Walkley black method)
TOC (mg/kg)	SM-5310 B High temp. combustion
Total nitrogen (mg/kg)	TS 8337 ISO 11261:1996
Total phosphorus (mg/kg)	SM-4500 P
Available Micronutrients	
Fe (mg/kg) Cu (mg/kg) Zn (mg/kg) Mn (mg/kg) Al (mg/kg)	TS ISO 14870/T1 (DTPA method)
Available Macronutrients	
Ca (mg/kg) Mg (mg/kg) Na (mg/kg) K (mg/kg)	TS 8341:1990 (Ammonium acetate)

Table 3.16. “EKAÇTKY-Appendix IIB” analysis parameters for the assessment of MT samples

Parameters	Methods
Lead (Pb mg/kg) Cadmium (Cd mg/kg) Chromium (Cr mg/kg) Copper (Cu mg/kg) Nickel (Ni mg/kg) Zinc (Zn mg/kg)	EPA 6020A 2007
Mercury (Hg mg/kg)	EPA 7473
TKN (mg/kg)	SM-4500-Norg.B
Phosphorus (P mg/kg)	Wet combustion method (Olsen and Sommers (1982))
AOX (mg/L)	In house method (AOX analyzer)
Detergent (mg/L) (LAS) DEHP (mg/kg) NPE (mg/kg)	In house method (GC-FID)
PAH (mg/kg)	ISO 11338-2 (GC-MS)
PCB (mg/kg)	ISO 10382 (GC-ECD), EPA 3540C
PCDD/F (ng TEQ/kg solid matter)	EPA 1613 (GC-HRMS)
pH (aq.sol.)	TS 12072:2003
C/N	ASTM D 5373
Water/solid content (w %)	TS 9546 EN 12280:2002
LOI (%)	TS EN 13039:2011
Organic matter (%)	TS 8336:1990
EC (at saturation) (mS/cm)	TS ISO 11265:1996
E.Coli (EMS/g)	NF-ISO 166492

3.3.2.5 Plant Growing Studies in the MT Samples

3.3.2.5.1 Grass Growing

3.3.2.5.1.1 Planting of the Grass Seeds

A control sample was prepared containing natural soil instead of $DM_{Mixture}$ samples for the MT samples. Control and MT samples were put into 2 L plastic pots and 1.0 g of high quality lawn seed mixture (Figure 3.10) was planted into each pot. The plants were irrigated with the same volume (50 mL) of tap water (TÜBİTAK MAM Gebze campus tap water) periodically.

Figure 3.10. High quality lawn seed mixture (English grass seed) and plastic pot used for plant growth in the MT samples produced

High quality lawn seed mixture used for planting included the following components:

- %20 Lolium perenne STRAVINSKY (is a grass from the family Poaceae),
- %30 Lolium perenne TROYA (is a winter grass and is a good wear tolerance),
- %35 Festuca rubra rubra CORAIL (is a species of grass and can tolerate many habitats and climates),
- %15 Poa pratensis EVORA (is a perennial species of grass and forms a valuable pasture plant).

Grass seeds were planted 1.5 to 2.0 cm below from the surface of the MT samples in each plastic pots (Figure 3.11).

Figure 3.11. Planting of grass seeds into the plastic pots filled with MT samples

3.3.2.5.1.2 Monitoring of Grass Growth Performances

In all MT samples as well as control samples, grass growth performances were monitored daily on the basis of the following parameters:

- Number of germinated seeds (grain/day),
- Germination rate (%),
- Sum of growth height (cm/day),
- Average growth height (cm/day),
- Grass health (visual and photograph).

Temperature of both irrigation water and ambient were also recorded regularly. All the pots were positioned periodically so as to take advantage of the sunlight and humidity in the room evenly. Moreover, the directions of all the pots were changed each week.

3.3.2.5.1.3 The Analysis of Irrigation Water (TÜBİTAK MAM Gebze Campus Tap Water)

3.3.2.5.1.3.1 Materials

In the scope of characterization study of irrigation water (TÜBİTAK MAM Gebze campus tap water), the list of used chemicals and instruments in the analysis are reported in Table 3.17 and Table 3.18.

Table 3.17. Chemicals used in the analysis of irrigation water

Chemical substances	Usage Purpose
pH4, pH7 and pH10 buffer solution	pH Measurement
1 NTU, 6 NTU, 30 NTU and 100 NTU verification std.	Turbidity determination
Phosphate buffer solution, magnesium sulfate solution, calcium chloride solution, ferric chloride solution, acid and alkali solutions, glucose-glutamic acid solution, 2-chloro-6-(trichloromethyl) pyridine, allylthiourea solution, ammonium chloride solution	Biological oxygen Demand (BOD) determination
HCl, HNO_3, argon gas and ICP-OES calibration standard (std).	Metal determination
Pressurized air, chloride IC std., fluoride IC std.,	Anion determination
KI, CH_3COOH, Starch, $Na_2S_2O_3 \cdot 5H_2O$	Free chlorine determination
Agar media, ultra-distilled water	Fecal Coliform determination

Table 3.18. Instruments used in the analysis of irrigation water

Instruments	Features	Usage Purpose
pHmeter	WTW Inolab Multi level1	pH measurement
Electrical Conductivity	WTW Multi parameter	Conductivity Measurement
Turbidimeter	HACH 2100AN Turbidieter	Turbidity determination
Filtration Set	MF-Millipore Filtration Set	TDS determination
Ion Chromatography	Dionex ICS-1000 Ion Chromatography	Anion determination
ICP-OES	Perkin-Elmer ICP-OES 8300 DV, Microwave Digestion Device	Metal determination
ICP-MS	Perkin Elmer ICP-MS NexION 300XX	Metal determination
Titrator	Life Science & Laboratory Titrator	Free Chlorine determination
Hot Plate	LabTech Magnetic Hot Plate	BOD determination
Membrane Filtration	Sartorius Membrane Filtration	Fecal coliform determination
Oven	Binder	Drying
Analytical Scale	Mettler Toledo	Weighing
Water Purification	Millipore Milli-Q	For pure water

3.3.2.5.1.3.2 Methods

TUBITAK MAM Gebze campus tap water was used for the irrigation of plants in the MT samples and its characteristics were examined in accordance with "Notification of Wastewater Plant Technical Methods Appendix-7 (E7.1, E7.2 and E7.7)" in Table 3.19, Table 3.20 and Table 3.21.

Table 3.19. The analysis parameters and methods of purified wastewater back to be used for irrigation "Notification of Wastewater Plant Technical Methods" App.-E7.1

Parameters	Methods
pH	SM-4500- H+ B Electrometric method
BOD (mg/L)	SM-5210 B 5 Daily
Turbidity (NTU)	SM-2130 B Turbidimeter
Fecal coliform (kob/100 ml)	Membrane filtration
Free chlorine (S. Cl_2 mg/L)	Free & Total chlorine test kit

Table 3.20. The chemical quality analysis parameters and methods of irrigation water "Notification of Wastewater Plant Technical Methods" App.-E7.2

Parameters	Methods
Salinity	
EC (µS/cm)	SM-2510 B
TDS (mg/L)	SM-2540 C
Permeability	
SAR_{Tad}	ISO 11885 (ICP-OES) + calculation
Calcium (Ca mg/L)	ISO 11885 (ICP-OES)
Magnesium (Mg mg/L)	ISO 11885 (ICP-OES)
Specific ion toxicity	
Sodium (Na mg/L)	ISO 11885 (ICP-OES)
Chloride (Cl^- mg/L)	SM-4110 B (Ion chromatography)
Boron (B mg/L)	ISO 11885 (ICP-OES)

Table 3.21. Maximum permissible heavy metals and toxic elements analysis in irrigation water "Notification of Wastewater Plant Technical Methods" App.-E7.7

Parameters (mg/L)	Methods
Aluminum	
Arsenic	
Beryllium	
Boron	
Cadmium	EPA 6020A 2007 (ICP-MS)
Chromium	
Cobalt	
Copper	
Fluoride	SM-4110 B (Ion chromatography)
Iron	
Lead	
Lithium	
Manganese	
Molybdenum	EPA 6020A 2007 (ICP-MS)
Nickel	
Selenium	
Vanadium	
Zinc	

The pH and EC values of irrigation water were measured with WTW Inolab Multimeter. Its turbidity measurement was made using 1 NTU, 6 NTU, 30 NTU and 100 NTU verification standards. For the determination of concentrations of metals in ICP-OES, irrigation water was treated with a strongly acidic medium (9 mL HNO_3 + 3 mL HCl) in microwave digestion device. The solution was diluted to 50 mL. The metals' concentrations were identified with Perkin-Elmer ICP-OES 8300 DV and Perkin Elmer ICP-MS NexION 300XX in accordance with the ISO 11885 and EPA 6020A standards. The quantities of chloride and fluoride anions were determined using Dionex ICS-1000 Ion chromatography. The content of fecal coliform was observed by using different agar media in TÜBİTAK MAM Food Institute. The amounts of TDS in the samples were identified gravimetrically. The free chlorine concentration was carried out by titrating the sample with sodium thiosulfate.

3.3.2.5.1.4 The Harvesting of Grass and Monitoring of the Harvest Performances

Germination happened within 2-3 weeks. Grasses grown in the MT samples were harvested at 5 cm above from the soil surface at once a month during six-months period (Figure 3.12) and six harvests were carried out for each mixture. Only one replication was performed in each harvest period. The following parameters followed in order to determine the harvest performances are:

- Sum of harvest height (cm),
- Average harvest height (cm),
- Biomass production (fresh and dry) (kg/cm^2).

Figure 3.12. Harvesting of grasses in the MT samples

3.3.2.5.1.5 The Analysis of Plant Nutrients in Harvested Grasses

In the scope of work, available macronutrients (N, P, K, Ca, Mg, S) and micronutrients (Fe, Cu, Zn, Mn) analysis were conducted in the grass samples obtained at the end of the harvesting operation once a month. Parameters and methods for these analyses are illustrated in Table 3.22.

Table 3.22. "Plant Analysis" parameters and methods for the harvested grasses

Parameters	Methods
Nitrogen (%)	TS 8337, ISO 11261:1996
Phosphorus (%)	SM-4500 P
Potassium (%)	
Calcium (%)	EPA 3052:1996
Magnesium (%)	
Sulfur (%)	ASTM D 4239
Iron (ppm)	
Copper (ppm)	EPA 3052:1996
Manganese (ppm)	
Zinc (ppm)	
N/S Ratio	By calculation
N/P Ratio	By calculation

Plant analysis was performed with the dry grass sample. So, harvested grass samples were oven-dried at 105°C at first. Standard Method (2012) was used for the determination of amount of phosphorus in grass samples. Gerhardt Vapodest 50 Nitrogen Analyzer was used to identify the quantity of nitrogen according to ISO 11261:1996. The sulfur content of grass samples was specified by using high-temperature tube furnace combustion in accordance with ASTM D 4239. Macronutrients and micronutrients were measured in the Perkin-Elmer ICP-OES 8300 DV according to the EPA 3052 standard. 0.20 g samples were dissolved in a strongly acidic medium (6 mL HNO_3 + 2 mL HCl) by using microwave digestion device. Then, the solution was diluted to 50 mL.

3.3.2.5.2 The Seasonal Outdoor Ornamental Plant Growing

3.3.2.5.2.1 Planting of Outdoor Ornamental Plant Seeds

After six harvests in the landscaping work done with high-quality grass seed mixture (English grass), the seasonal outdoor ornamental plants were planted in the MT samples having the best performances. Marigold and Geranium as summer season outdoor ornamental plants and Carnation as winter season outdoor ornamental plant were preferred to be grown as shown in Figure 3.13.

At first, the seeds of seasonal outdoor ornamental plants were put into tiny seed pots for performing the seedling. Then, the seedlings of seasonal ornamental plants were taken into the main pot and performances were monitored.

Figure 3.13. Summer (geranium and marigold) and winter (carnation) season outdoor ornamental plants

Two different methods were applied in the cultivation of the related outdoor ornamental plants. These were:

- “Transplanting Seedling” method,
- “Displacement” method.

3.3.2.5.2.2 Monitoring of the Outdoor Ornamental Plant Growth Performances

The performance of outdoor ornamental plants was monitored daily on the basis of the following parameters:

- Average number of leaves,
- Average plant body height,
- Plant health (visual and photograph).

Monitoring of the growth performances of seasonal outdoor ornamental plants was continued during the three months. Each week, the direction of the pots was changed in order to benefit the same amount of sunlight. 7-8 drops of water were given two times a day both in the morning and towards the evening.

3.3.2.6 The Soil Quality Analysis of MT Samples at the End of Grass Growth Period

At the end of six-month grass growth period, the physical and chemical properties of MT samples were identified by soil productivity analysis. Parameters related to the soil quality and their analysis methods are reported in Table 3.23.

Table 3.23. The soil quality analysis parameters for MT samples at the end of the grass growth season

Parameters	Methods
pH (aq.sol.)	TS ISO 10390:2013
EC (at saturation) (mS/cm)	TS ISO 11265:1996
Total nitrogen (mg/kg)	TS 8337 ISO 11261:1996
Total phosphorus (mg/kg)	SM-4500 P
N/P	By calculation
C/N	By calculation
Organic matter content (w %)	TS 8336:1990 (Walkley black method)
TOC (mg/kg)	SM-5310 B High temp. combustion
Pore volume (m^3/m^3)	ASTM D4404
Specific gravity (g/cm^3)	
Bulk density (g/cm^3)	FAO (2010)
Porosity (%)	
Available Macronutrients	
Ca (mg/kg)	
Mg (mg/kg)	TS 8341:1990 (Ammonium acetate)
Na (mg/kg)	
K (mg/kg)	

3.4 Design of DM Pre-Treatment Plant (Theoretical)

The non-uniform particle size distribution and high salt content of DMs are important in the beneficial use of DMs as MT in landscaping. Because, they may lead to physical and chemical effects on the plants that grow in the soil. In this part of the thesis, several studies were conducted for the theoretical design of a stationary (permanent) DM pre-treatment plant prior to the beneficial use of DMs as MT in landscaping applications and for the determination of the characterization and management of possible washing wastewater emerged from the laboratory-scale DM washing-sieving attempts.

3.4.1 The Laboratory-Scale DM Washing-Sieving Experiments

The laboratory-scale DM washing-sieving experiments were carried out by considering the optimum washing water volume for each DM sample.

The following procedures were employed in the scope of laboratory-scale DM washing-sieving process in order to stimulate the industrial scale DM pre-treatment plant and to obtain washing wastewater sample to be characterized:

1. **Separation of Gravel-Coarse Material by Washing Under Vibratory Sieving Device:** 500 g of raw DM sample on the basis of initial and target EC values was sieved from 4 mm vibratory sieve by washing water having a flow rate of 180 dm^3/h in each trial. At this stage, gravel-coarse material was provided to be separated from the sample.
2. **Separation of Sand by Centrifuge:** After the washing process was performed with vibratory sieving device, watery material containing sand-silt-clay passing under 4 mm sieve was centrifuged at 300 rpm for 1 min with Eppendorf brand centrifuge device. Sand phase was separated from silt-clay phase.
3. **Separation of Silt-Clay by Precipitation Process:** After the separation of the sand, watery material containing silt-clay was subjected to gravity precipitation in order to remove the silt-clay phase. For this purpose, watery material was aged for 1 hour to precipitate and water in the upper phase was taken into different container by draining. The characterization study was performed in the upper phase to determine the nature of wastewater to be discharged.

Images of laboratory-scale experiments about DM washing-sieving are illustrated in Figure 3.14 and schematic diagram of the related to the DM washing-sieving process is shown in Figure 3.15.

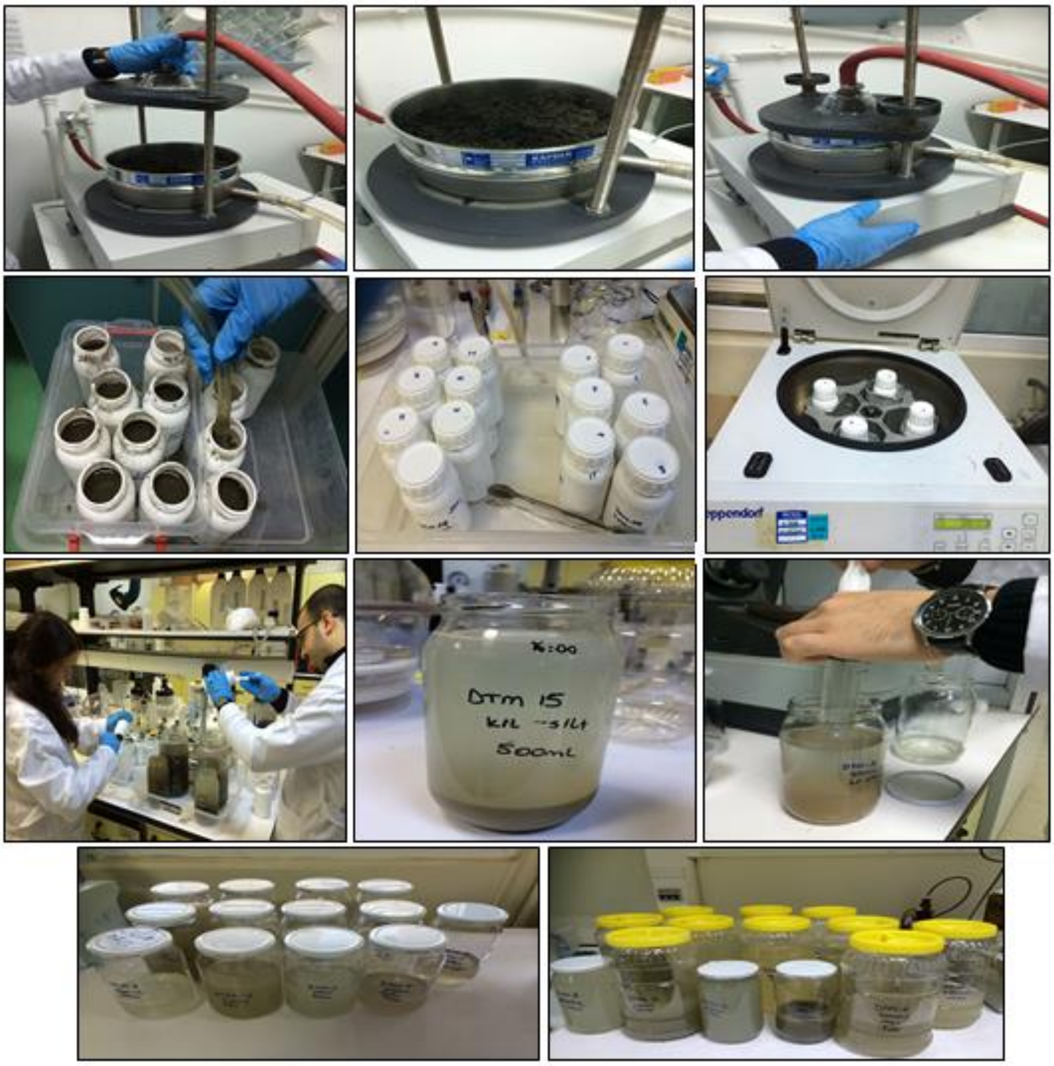


Figure 3.14. Images related to the laboratory-scale DM washing-sieving experiments

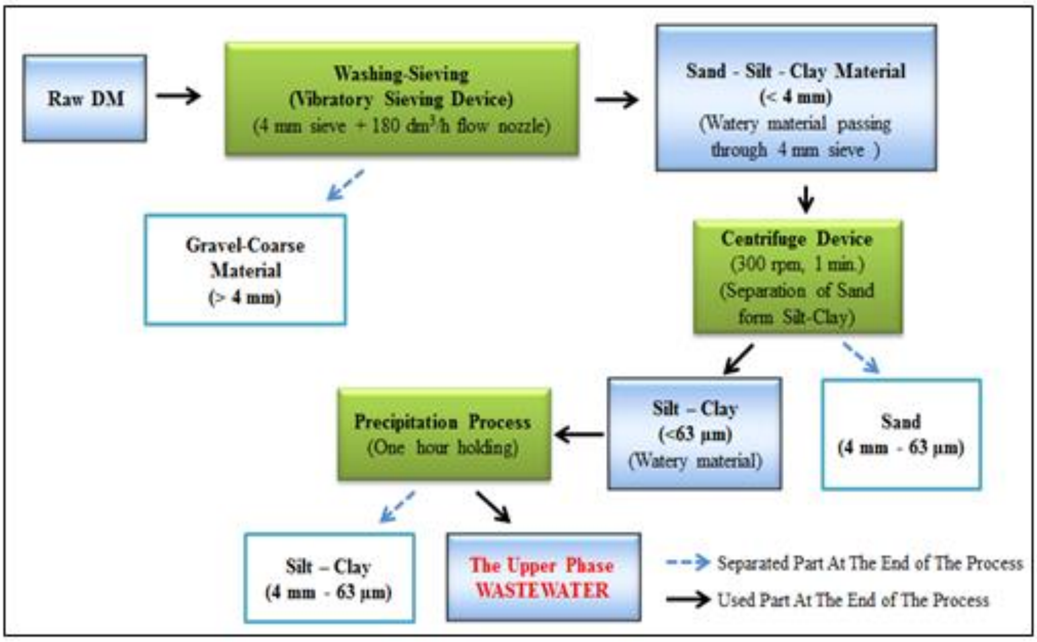


Figure 3.15. A schematic diagram of laboratory-scale DM washing-sieving process

The laboratory-scale DM washing-sieving experiments were performed with the same amount of washing water volumes for each DM sample. After the washing and sieving processes (respectively the separation of gravel-coarse material, sand material and silt-clay material) of DM were occurred, the characterization of wastewater taken from the upper phase was made.

3.4.2 The Characterization of Wastewater Emerged from Laboratory-Scale DM Washing-Sieving Process

3.4.2.1 Materials

The characterization study of wastewater generated from the laboratory-scale DM washing-sieving process was conducted. List of used chemicals and instruments in the characterization of the wastewater of interest are pointed out in Table 3.24 and Table 3.25.

Table 3.24. Chemicals used in the analysis of wastewater as a result of laboratory-scale DM washing-sieving process

Chemical substances	Usage Purpose
pH4, pH7 and pH10 buffer solution	pH measurement
HCl, HNO_3, argon gas and ICP-OES calibration standard (std).	Metal determination
Pressurized air, chloride IC std., sulfate IC std.,	Anion determination
HCl, potassium biphthalate ($C_8H_5KO_4$), Na_2CO_3, $NaHCO_3$, dry air tube.	TOC determination
Kjeldahl catalyst, H_2SO_4	TKN determination
$HClO_4$, ammonium molybdate, H_2SO_4, NaOH	Phosphorus determination

Table 3.25. Instruments used in the analysis of wastewater generated from the laboratory-scale DM washing-sieving process

Instruments	Features	Usage Purpose
pHmeter	WTW Inolab Multi level1	pH measurement
EC	WTW Multi parameter	Conductivity measurement
Filtration Set	MF-Millipore Filtration Set	Total Suspended Solid (TSS) determination
Ion Chromatography	Dionex ICS-1000 Ion Chromatography	Anion determination
ICP-OES	Perkin-Elmer ICP-OES 8300 DV, Microwave Digestion Device	Metal determination
Mercury Analyzer	DMA-80 Direct Mercury Analyzer	Mercury determination
TOC Analyzer	Shimadzu TOC-V CSH TOC Analyzer, SSM-5000A Solid Material module, ASI-V Autosampler	TOC determination
Nitrogen Analyzer	Gerhardt Vapodest 50 Nitrogen Analyzer	TKN determination
UV spectrophotometer	CADAS 200 Dr. Lange	Total phosphorus determination
Oven	Binder	Drying
Water Purification	Millipore Milli-Q	For pure water

3.4.2.2 Methods

In the SKKY came into force in 2004, there is no any discharge criteria related to the wastewater emerged from the washing-sieving of DM. Therefore, the parameter selection was made by taking into consideration "sand washing plant criteria (SKKY-Table 7.5)", "deep sea discharge criteria (SKKY-Table 22)" and "general quality criteria for seawater (SKKY-Table 4)" situated in SKKY in order to determine the characteristics of wastewaters resulting from the laboratory-scale DM washing-sieving process. The characterization results of raw DMs were also considered in the parameter selection. The selected parameters of concern are presented in Table 3.26.

Table 3.26. The analysis parameters and methods for the characterization of DM washing-sieving process's wastewater

Parameters	Methods
pH	SM-4500- H+ B Electrometric method
EC (mS/cm)	SM-4500- H+ B Electrometric method
Total salt (%) (from graph)	TS 8334:1990
TSS (mg/L)	SM-2540
TKN (mg/L)	SM-4500 N
Total phosphorus (mg/L)	SM-4500 P
Chloride (Cl^- mg/L)	SM-4110B Ion chromatography
Sulfate (SO_4^{2-} mg/L)	
TOC (mg/L)	SM-5310B
Arsenic (As mg/L)	EPA 6020A 2007 ICP-OES
Cadmium (Cd mg/L)	
Chromium (Cr mg/L)	
Lead (Pb mg/L)	
Zinc (Zn mg/L)	
Nickel (Ni mg/L)	
Silver (Ag mg/L)	
Copper (Cu mg/L)	
Mercury (Hg mg/L)	SM-3112 Direct mercury analyzer

SM: Standard Methods for the Examination of Water and Wastewater (SM, 2012)

In the scope of characterization of wastewater of interest, the pH and EC values of wastewater were measured with WTW Inolab Multimeter. The concentrations of metals such as As, Cd, Cr, Cu, Ni, Zn, Pb, Ag and Hg were identified with Perkin-Elmer ICP-OES 8300 DV after treating with a strongly acidic medium (9 mL HNO_3 + 3 mL HCl) by in microwave digestion device. The amounts of Cl^- and SO_4^{2-} anions were determined with Dionex ICS-1000 Ion Chromatography. The quantity of TSS was identified in accordance with SM-2540. Standard Methods (2012) were used for the determination of the amount of TKN, total phosphorus and TOC in the wastewater sample. Gerhardt Vapodest 50 Nitrogen analyzer was utilized to identify the quantity of nitrogen according to SM-4500 N. The measurement of total phosphorus was made with CADAS 200 Dr. Lange UV Spectrophotometer in accordance with SM-4500 P and the quantity of TOC in the sample was specified with Shimadzu TOC-V CSH TOC Analyzer with respect to SM-5310B.

3.4.3 The Optimization of Precipitation Time

After the removal of coarse and fine material from laboratory-scale DM washing-sieving process, the most important pollutant remaining in the wastewater phase is TSS. Thus, wastewater formed after washing-sieving process was placed into the Imhoff funnel in order to optimize the removal of TSS precipitation with gravity, and time-dependent precipitation and accordingly the removal rate of macronutrients and TSS solid was investigated (Figure 3.16).

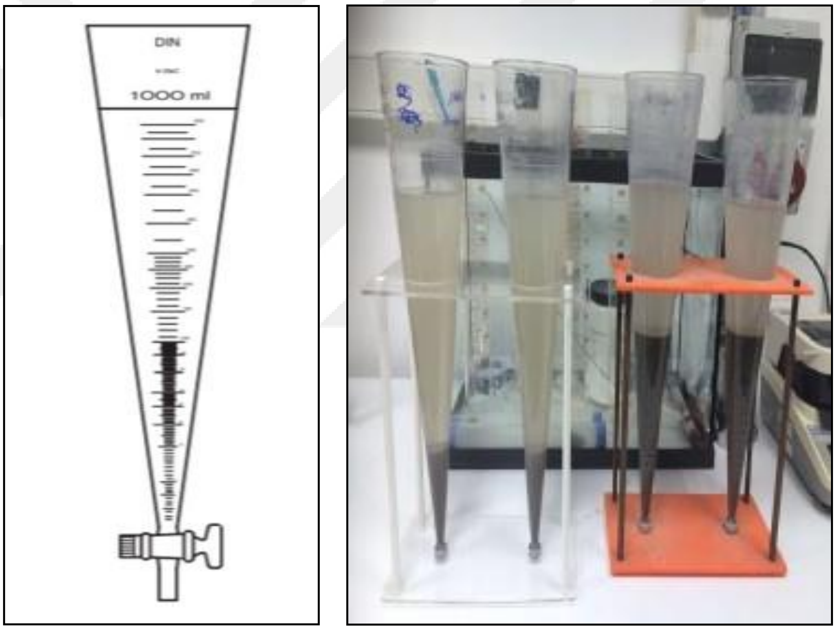


Figure 3.16. Imhoff (Sedimentation) funnel and the appearance of settleable solids in the imhoff funnel

DM washing-sieving process’s wastewater obtained at laboratory-scale experiment was taken into imhoff funnel by draining. The quantities of settleable solids found in the upper phase of wastewater in the Imhoff funnel were measured at the end of 0 min., 2 hours and 7 hours according to parameters given in Table 3.27.

Table 3.27. The analysis parameters and methods of wastewater in the Imhoff funnel

Parameters	Methods
TSS (mg/L)	SM-2540
Volatile suspended solid (VSS) (mg/L)	SM-2540
TKN (mg/L)	SM-4500 N
Total phosphorus (mg/L)	SM-4500 P
TOC (mg/L)	SM-5310B

3.4.4 Proposing of Treatment Technologies for Possible DM Pre-Treatment Plant Wastewater

According to SKKY, wastewater treatment technologies to be implemented for the discharge of possible wastewater emerged from DM pre-treatment plant to sewage system and/or sea were developed by evaluating the characterization results of laboratory-scale DM washing-sieving wastewater. The design of possible industrial-scale DM pre-treatment plant was performed theoretically.

In the thesis, the design of industrial-scale stationary "DM pre-treatment plant" having 1500 m^3/day of raw DM washing-sieving capacity was carried out theoretically in order to improve DM's quality. The units of facility, flow diagram, the first investment and operating costs were given by considering various assumptions. Previous designs of both sand washing-sieving plants in our country and DM pre-treatment plants in abroad were taken into consideration in the design of industrial-scale DM pre-treatment plant. Also, the most appropriate ports/harbours for the establishment of this stationary DM pre-treatment plant on the basis of four seas in Turkey across were suggested.

3.5 The Summary of Experimental Study

Experimental studies carried out in the thesis study are summarized in the main headings in Figure 3.17.

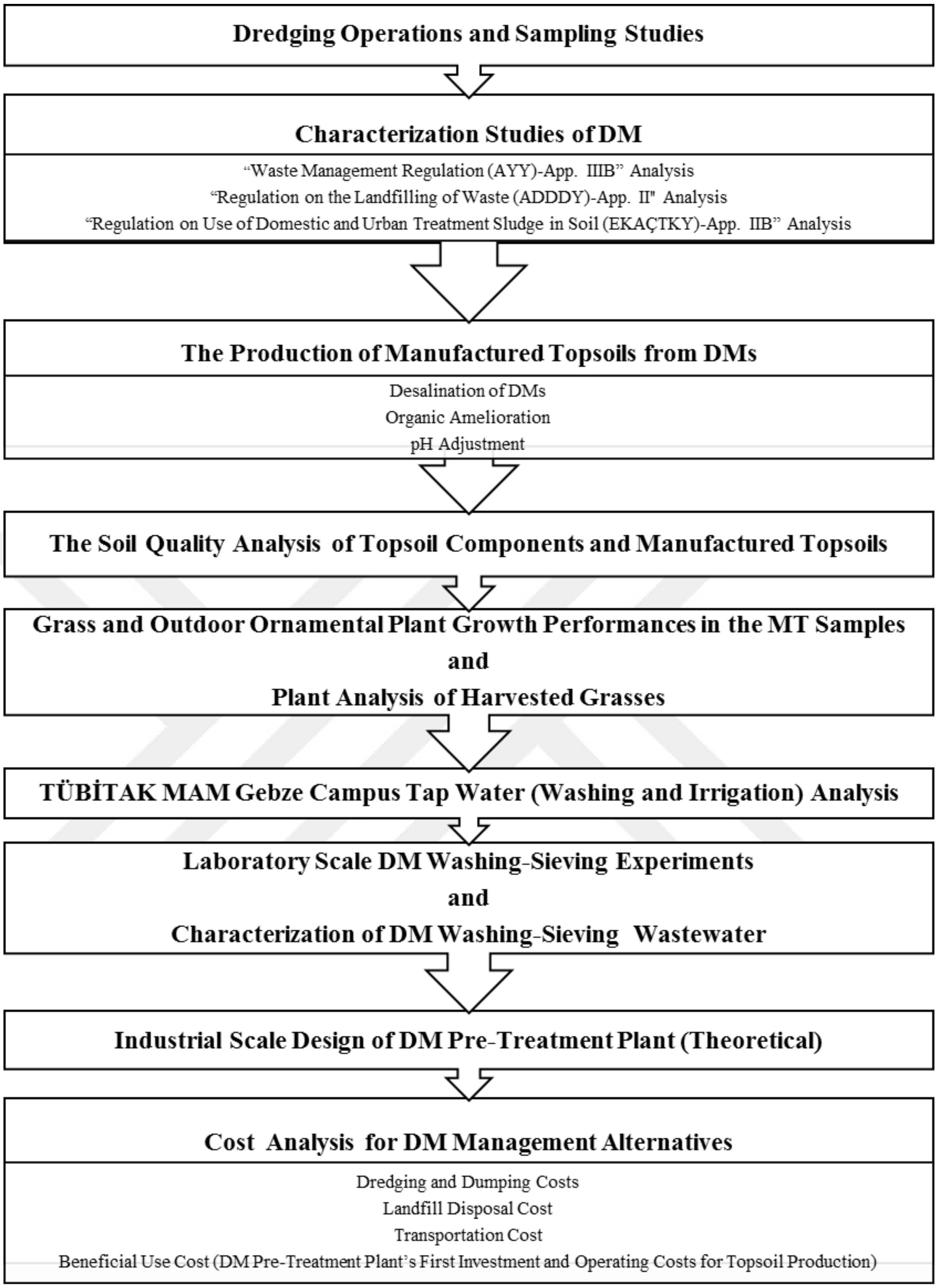


Figure 3.17. Systematic diagram of experimental studies in the frame of the thesis

4. RESULTS AND DISCUSSIONS

4.1 The Characterization of DMs

Within the context of the characterization of DMs excavated from the fifteen different sampling points throughout Turkey, physico-chemical, morphological and toxicological properties, leaching potentials and usability characteristics in soil were investigated; analysis results were compared pursuant to the relevant Turkish Legislations of "The Waste Management Regulation (AYY)-App.3B", "The Regulation on the Landfilling of Waste (ADDDY)-App.2" and "The Regulation on Use of Domestic and Urban Treatment Sludge in Soil (EKAÇTKY)-App.IIB" limit values.

4.1.1 "AYY" Analysis Results of DMs (AYY-App.3B)

Firstly, DMs dredged from the fifteen sampling points across Turkey were analyzed and evaluated in accordance with the principles of "AYY-App.3B" whether they show hazardous waste characteristics or not.

DM sample with a waste code of "dredging spoil containing dangerous substances 17 05 05 (*)" is defined under (17) coded "construction and demolition wastes (including excavation taken out from contaminated sites)" by a sub-code of 17 05 "soil (including excavation removed in contaminated places), rocks and dredging sludge" and is expressed in (M) code with respect to "AYY-App.4-List of Wastes (LoW)".

Wastes assigned with (M) code (mirror entry) under the "AYY-App.4-LoW" might be allocated to a hazardous waste or to a non-hazardous waste depending on the AYY-App.3B hazardous waste threshold limit values.

4.1.1.1 Physico-chemical and Toxicological Analysis of DMs

The physico-chemical and toxicological analysis results of DMs are presented in Table 4.1 and Table 4.2, respectively. It is observed that DM samples are commonly (dark) grey in colour and some of them have slightly undesirable odour due to historical pollution by wastewater drainage. They have low to moderate water content (23.92-51.76%) due to type of dredgers and (slightly) alkaline nature (pH: 7.90-9.38) because of seashell fragments existence which are well-known $CaCO_3$ sources. Moderate to high EC values (1.85-8.39 mS/cm) are comparatively acceptable when considering the saline character. However, DMs require salt reduction prior to beneficial use in landscaping application in order to provide nutrient availability of plants (Sheehan et al., 2010a). Specific gravities of DMs are ranged from 2.04 to 2.62 g/cm^3 which are lower than those of silica sand (2.64 g/cm^3) due to impurities. It is seen that DM specimens have low organic matter content (<0.01-12.07%) as well as low HHV (~10.0 kcal/kg) and low oil-grease content (<180-405 mg/kg); therefore, they show inorganic character and are unsuitable for disposal via incineration. It is clear that the fluctuations in the organic contents of DMs are an expected result (USACE, 2001). Although some of DMs (DM-1, DM-3, DM-4, DM-5, DM-6 and DM-12) have been exposed to domestic wastewater discharge for long years, physicochemical structures of these samples indicate the decomposition of organic content in the length of time. DM samples contain moderate nitrogen (80.0-994.9 mg/kg) and phosphorus (280-717 mg/kg) contents (Jones and Lee, 1981); but, relatively high phosphorus concentration of DM-9 sample reveals the probable marine pollution.

Table 4.1. Physico-chemical and toxicological analysis results of DMs

Parameters	**DM-1**	**DM-2**	**DM-3**	**DM-4**	**DM-5**	**DM-6**	**DM-7**	**DM-8**
Physico-chemical properties								
Appearance/odor	Grey/ Odourless	Fumed/Mild odorous	Fumed/Mild odorous	Fumed/Mild odorous	Fumed/Mild odorous	Black/Mild odorous	Grey/ Odourless	Fumed/Bad odorous
pH (aq.sol.)	8.20	9.38	8.91	8.77	8.87	8.56	8.16	8.35
EC (mS/cm) (aq.sol.)	3.36	2.28	2.70	1.86	1.93	5.02	4.08	8.39
TDS (mg/L)	1,50	1,20	1,56	1,12	1,51	2,96	2,39	4,93
Water content (w%)	37.2	26.6	40.3	29.53	33.3	27.0	26.0	51.3
Solid content (w%)	62.8	73.9	59.7	70.5	66.7	73.0	74.0	48.2
Organic matter content (w%)	2.56	2.26	2.90	2.46	4.28	12.07	5.84	4.71
Inorganic matter content (w%)	60.24	71.59	56.75	68.01	62.43	60.93	68.17	43.53
HHV* (kcal/kg)	11	8	7	9	10	9	11	13
Total sulfur (%)	0.28	0.06	0.53	0.13	0.14	2.08	0.99	1.44
Oil-grease (mg/kg)	<180	<180	405	<180	<180	<180	<180	<180
Total nitrogen (mg/kg)	507.3	113.6	731.0	400.4	705.0	470.2	174.0	597.3
Total phosphorus (mg/kg)	343	397	717	470	455	284	280	294
Specific gravity (kg/m^3)	2.32	2.62	2.51	2.24	2.04	2.50	2.46	2.38
LOI (%)	4.92	< 2.30	4.19	3.44	7.17	5.63	< 2.30	8.43
Toxicological properties								
Ecotoxicity	No toxic effect on marine bactery *vibrio fischeri*							
Acute toxicity (fish)	No acute risk for fishes							
Acute toxicity (rat)	Category 5-GHS or unclassified (LD_{50} >5000 mg/kg b.w.)							

* Dried sample at 105˚C

Table 4.2. Physico-chemical and toxicological analysis results of DMs (Table 4.1 continued)

Parameters	DM-9	DM-10	DM-12	DM-13	DM-14	DM-15	DM-16
Physico-chemical properties							
Appearance/odor	Brown/Mild odourless	Fumed/Mild odourless	Fumed/Mild odourless	Fumed/Mild odourless	Fumed/Mild odourless	Grey/Mild odourless	Fumed/Mild odourless
pH (aq.sol.)	8.92	8.76	8.62	7.90	8.49	8.89	9.11
EC (mS/cm) (aq.sol.)	3.76	3.16	2.27	1.85	4.77	3.48	2.86
TDS (mg/L)	2,04	1,71	1,21	1,10	446	2,006	1,564
Water content (w%)	24.0	32.6	32.0	23.9	31.9	30.6	29.1
Solid content (w%)	76.0	67.4	68.0	76.1	68.1	69.4	70.9
Organic matter content (w%)	5.01	3.45	< 0.01	< 0.01	6.32	1.18	< 0.01
Inorganic matter content (w%)	70.99	63.97	67.99	76.08	61.76	68.23	70.84
HHV* (kcal/kg)	8	9	9	10	8	12	9
Total sulfur (%)	0.19	0.34	1.34	0.28	0.14	0.07	0.26
Oil-grease (mg/kg)	< 180	< 180	< 180	< 180	< 180	< 180	< 180
Total nitrogen (mg/kg)	80.0	406.3	994.9	226.8	603.6	354.5	146.6
Total phosphorus (mg/kg)	1,347	684	398	710	235	320	419
Specific gravity (kg/m^3)	2.47	2.36	2.31	2.46	2.05	2.54	2.34
LOI (%)	4.72	< 2.30	4.27	3.42	3.94	4.11	4.44
Toxicological properties							
Ecotoxicity	No toxic effect on marine bactery *vibrio fischeri*						
Acute toxicity (fish)	No acute risk for fishes						
Acute toxicity (rat)	Category 5-GHS or unclassified (LD_{50} >5000 mg/kg b.w.)						

* Dried sample at 105˚C

Additionally, it is found that DM samples have no toxic effect on marine bacteria *vibrio fischeri*. Furthermore, no acute risk for fishes was detected. DM samples also showed no acute risk for rat (LD50 > 5000 mg/kg b.w.) and were identified as Category 5 (GHS 5) or unclassified. Chronic effects for fishes and rat were not considered within this survey.

On the other hand, particle size distributions (sieve analysis results) of relevant DMs taken from a total of the fifteen sampling points are also pointed out in Table 4.3.

According to Udden-Wentworth particle size scale and classification, particle sizes are identified as follows:

- under 4 microns (<4 μm) particle sizes equal to the "**Clay**",
- between 4 microns and 63 microns (63 μm - 4 μm) particle sizes are equal to the "**Silt**",
- between 63 microns and 200 microns (200 μm - 63 μm) particle sizes equal to the "**Fine Sand**",
- between 2 mm and 200 microns (2 mm - 200 μm) particle sizes are equal to the "**Coarse Sand**" and
- 2 mm above (> 2 mm) particle sizes are equal to the "**Granular-Gravel**" (Kaymakçı, 2001).

In accordance with the results of the sieve analysis, the dominant particle size characters of DMs were observed as "**Sand (Fine and Coarse)**" and "**Silt-Clay Mixture**". Elevated concentrations of TDS for DM specimens confirm this particle size distribution of concern.

Table 4.3. Particle size distributions of DMs

Sample Code	Sampling Point	Water Content (%)	(>2mm) (%)	(2mm-200µm) (%)	(200µm-63µm) (%)	(<63µm) (%)	Dominant Particle Size Distribution
			Gravel	**Coarse Sand**	**Fine Sand**	**Silt-Clay**	
DM-1	Tuzla Marina	37.2	5.1	6.3	7.3	**81.3**	1) Silt-Clay mixture
DM-2	Ambarlı Port	26.2	1.0	**26.8**	**34.9**	**37.3**	1) Silt-Clay mixture 2) Sand
DM-3	Samsun Port	40.4	10.6	11.9	**45.9**	**31.6**	1) Fine Sand, 2) Silt-Clay mixture
DM-4	Alaçam Yakakent Fishery Harbour	29.5	0.6	13.0	**61.2**	**25.2**	1) Fine Sand, 2) Silt-Clay mixture
DM-5	Rize Port	33.3	**21.6**	**22.9**	**40.6**	14.9	1) Sand, 2) Gravel
DM-6	Göcek Marina	27.0	**23.4**	**20.8**	**29.2**	**26.6**	1)Fine Sand, 2) Silt-Clay mixture, 3) Gravel, 4) Coarse Sand
DM-7	Karaburun Tepeboz Village Fishery Harbour	26.0	1.0	**36.8**	**60.1**	2.1	1) Fine Sand, 2) Coarse Sand
DM-8	Nemrut Gulf Batıçim Harbour	51.8	16.0	**24.2**	**20.6**	**39.2**	1) Silt-Clay mixture, 2) Sand
DM-9	PETKIM Container Port	24.0	**40.4**	**36.9**	10.1	12.7	1) Gravel, 2) Coarse Sand
DM-10	Tuzla Shipyards Area	32.6	11.1	**25.3**	13.3	**50.3**	1) Silt-Clay mixture, 2) Coarse Sand
DM-12	Eskihisar Fishery Harbour	32.0	19.7	17.7	**37.2**	**25.4**	1) Fine Sand, 2) Silt-Clay mixture
DM-13	TUPRAS Yarımca Port	23.9	**38.4**	**36.5**	10.3	14.8	1) Coarse Sand, 2) Gravel
DM-14	Erdemli METU Campus Port	31.9	0.3	6.0	**47.3**	**46.4**	1) Fine Sand, 2) Silt-Clay mixture
DM-15	Erdemli Fishery Harbour	30.6	0.7	**39.6**	**58.2**	1.5	1) Fine Sand, 2) Coarse Sand
DM-16	Mersin International Port (MIP)	29.1	**31.9**	**28.2**	**27.4**	12.5	1) Gravel, 2) Sand

4.1.1.2 Organic Content Analysis of DMs

For the determination of the organic matter content in DMs, the functional groups in the composition of samples were determined in hexane-extracted organic phase by using FT-IR in accordance with the ASTM E1252 method. It was found out that no notable peaks were observed on FT-IR spectra. On the other hand, Headspace GC-MS analysis in compliance with EPA Method 3810 was performed for the determination of (volatile) organic compounds existed in DM samples. No considerable volatile organic compounds were determined in DMs. Thus, FT-IR and GC-MS analysis results confirmed the low organic content of DM samples. Additionally, the concentrations of persistent organic pollutants (POPs), PCDD/F, PCB, PAH, Tributyltin and Total pesticides were also determined in DMs and are given in Table 4.4 and Table 4.5 together with the categories of danger, risk phrases, hazards and the relevant AYY-App.3B threshold limits.

The concentrations of POPs of PCDD/F, PAH, PCB, Tributyltin and Total Pesticides are determined in the range of 0.001 and 0.635 ng/kg I-TEQ, 0.009-0.732 mg/kg, <0.1 mg/kg, <0.009-0.124 mg/kg and <0.005-0.025 mg/kg, respectively. POPs are classified as Carc. Cat. 3: R40 (H7), Carc. Cat. 1 and 2: R45 (H7), Repr. Cat. 1 and 2: R61 (H10), Xn: R20/21/22 (H5), Xi (R36/37/38) (H4), N: R50/53 (H14) giving thresholds of 1%, 0.1%, 0.5%, 25%, 20%, 0.25% (w/w), respectively (Anonymous, 2015; Environment Agency, 2011). Considering the potential worst case for these threshold levels of POPs, it is seen that POPs' concentrations are below limits and DM samples indicate non-hazardous character in terms of organic matter content with respect to AYY-App.3B hazardous waste threshold limits.

4.1.1.3 Inorganic Content Analysis of DMs

Quantitative phase (mineralogical) analysis of DMs was performed with Rietveld technique in X-Ray Diffractometer, using Cu kα radiation (λ=1.5405°A) for the clarification of the inorganic structure of DMs. The quantitative phase analysis results of DM specimens are reported in Table 4.6 and Table 4.7 on the basis of

Table 4.4. Organic content analysis results of DMs

Parameters	DM-1	DM-2	DM-3	DM-4	DM-5	DM-6	DM-7	DM-8	Category of danger, Risk phrase(s) and Hazards	AYY-App.3B Threshold limits
PAH (mg/kg)	0.096	0.098	0.347	0.155	0.560	0.162	0.085	0.058	R40 (H7) Carc. Cat 1 and 2: R45 (H7) Repr. Cat 1 and 2: R61 (H10) Xn: R20/21/22 (H5) Xi: R36/37/38 (H4) N: R50/53 (H14)	1 % 0.1 % 0.5 % 25 % 20 % 0.25 %
PCDD/F (ng/kg I-TEQ)	0.014	0.032	0.029	0.006	0.009	0.001	0.001	0.008		
PCB (mg/kg)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
Total pesticides (mg/kg)	<0.005	<0.005	0.025	<0.005	<0.005	<0.005	<0.005	<0.005		
Tributyltin (mg/kg)	<0.009	<0.009	<0.009	<0.009	0.124	<0.009	<0.009	<0.009		

Table 4.5. Organic content analysis results of DMs (Table 4.4 continued)

Parameters	DM-9	DM-10	DM-12	DM-13	DM-14	DM-15	DM-16	Category of danger, Risk phrase(s) and Hazards	AYY-App.3B Threshold limits
PAH (mg/kg)	0.732	0.018	0.067	0.776	0.167	0.114	0.009	R40 (H7) Carc. Cat 1 and 2: R45 (H7) Repr. Cat 1 and 2: R61 (H10) Xn: R20/21/22 (H5) Xi: R36/37/38 (H4) N: R50/53 (H14)	1 % 0.1 % 0.5 % 25 % 20 % 0.25 %
PCDD/F (ng/kg I-TEQ)	0.029	0.012	0.365	0.635	0.123	0.049	0.313		
PCB (mg/kg)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
Total pesticides (mg/kg)	<0.005	0.012	<0.005	0.010	0.011	<0.005	<0.005		
Tributyltin (mg/kg)	<0.009	0.018	<0.009	<0.009	<0.009	<0.009	0.027		

Table 4.6. Quantitative phase analysis results of DMs by XRD-Rietveld

Compound	DM-1	DM-2	DM-3	DM-4	DM-5	DM-6	DM-7	DM-8	Category of danger, Risk phrase(s) and Hazards	AYY App.3B Hazardous waste Threshold limits
Quartz, SiO_2	44.8	40.4	30.2	32.2	12.6	8.3	63.1	13.8	Xn, T: R48/20 (-)	25%
Illite, $(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$	21.2	16.8	16.3	20.7	13.8	4.8	11.2	20.1	-	-
Feldspar	16.1	25.5	30.1	20.2	52.3	13.8	10.1	39.1	-	-
Calcite, $CaCO_3$	9.5	13.7	11.6	15.0	12.5	27.8	4.2	10.4	Xi: R41 (H4) Xi: R37/38 (H4)	10% 20%
Almandine, $Fe_3Al_2(SiO_4)_3$	4.3	-	5.1	4.1	1.2	-	-	-	-	-
Anhydrite, $CaSO_4$	2.6	-	1.3	2.3	2.0	3.0	3.7	2.8	Xi: R36/37 (H4)	20%
Hematite, Fe_2O_3	1.5	2.1	1.1	1.2	1.3	3.8	0.8	3.2	Xi: R36/37/38 (H4)	20%
Potassium Magnesium Cl, $KMgCl_3$	-	1.5	-	-	-	-	-	-	-	-
Magnesioferrite, $MgFe_2O_4$	-	-	4.3	4.3	4.3	-	3.2	-	Xi: R36/37/38 (H4)	20%
Forsterite, Mg_2SiO_4	-	-	-	-	-	19.1	-	-	Xn: R20 (H5) Xi: R36/37/38 (H4)	25% 20%
Enstatite, $MgSiO_3$	-	-	-	-	-	14.1	-	4.8	Xn: R20 (H5) Xi: R36/37/38 (H4)	25% 20%
Potassium Chlorate, $K(ClO_3)$	-	-	-	-	-	1.5	-	1.0	O: R9 (H2) Xn: R20/22 (H5) N: R51/53 (H14)	- 25% 2.5%
Diopside, $CaMg(SiO_3)_2$	-	-	-	-	-	-	-	1.9	-	-
Lizardite, $Mg_3Si_2O_5(OH)_4$	-	-	-	-	-	-	-	-	-	-
Calcium Iron Oxide Chloride, $CaFeClO_2$	-	-	-	-	-	-	-	-	-	-

Table 4.7. Quantitative phase analysis results of DMs by XRD-Rietveld (Table 4.6 continued)

Compound	DM-9	DM-10	DM-12	DM-13	DM-14	DM-15	DM-16	Category of danger, Risk phrase(s) and Hazards	AYY App.3B Hazardous waste Threshold limits
Quartz, SiO_2	12.1	36.0	46.1	9.4	17.2	16.2	+	Xn, T: R48/20 (-)	25%
Illite, $(K,H_3O)Al_2Si_3AlO_{10}(OH)_2$	12.8	20.5	17.7	4.7	10.1	4.7	+	-	-
Feldspar	61.1	7.3	10.2	6.7	10.4	11.4	+	-	-
Calcite, $CaCO_3$	0.9	10.3	5.3	71.6	39.3	44.8	+	Xi: R41 (H4) Xi: R37/38 (H4)	10% 20%
Almandine, $Fe_3Al_2(SiO_4)_3$	-	-	-	-	-	-	-	-	-
Anhydrite, $CaSO_4$	2.7	2.5	4.4	-	1.9	-	+	Xi: R36/37 (H4)	20%
Hematite, Fe_2O_3	1.2	6.4	5.7	2.2	8.1	4.5	+	Xi: R36/37/38 (H4)	20%
Potassium Magnesium Cl, $KMgCl_3$	-	-	-	-	-	-	-	-	-
Magnesioferrite, $MgFe_2O_4$	3.9	-	-	-	-	-	-	Xi: R36/37/38 (H4)	20%
Forsterite, Mg_2SiO_4	-	-	-	-	3.5	1.9	-	Xn: R20 (H5) Xi: R36/37/38 (H4)	25% 20%
Enstatite, $MgSiO_3$	2.7	10.0	-	-	9.5	-	-	Xn: R20 (H5) Xi: R36/37/38 (H4)	25% 20%
Potassium Chlorate, $K(ClO_3)$	1.0	7.0	-	-	-	-	-	O: R9 (H2) Xn: R20/22 (H5) N: R51/53 (H14)	- 25% 2.5%
Diopside, $CaMg(SiO_3)_2$	1.6	-	8.0	-	-	4.5	-	-	-
Lizardite, $Mg_3Si_2O_5(OH)_4$	-	-	-	-	-	9.8	-	-	-
Calcium Iron Oxide Chloride, $CaFeClO_2$	-	-	-	-	-	2.2	-	-	-

weight percentages with the combination of categories of danger, risk phrases and danger/hazard properties, respectively.

On the other hand, quantitative phase (mineralogical) analysis of DM-16 could not be performed via XRD-Rietveld technique due to interferences. Therefore, semi-quantitative elemental analysis was carried out by Wavelength Dispersive XRF Spectrometer for DM-16 specimen and the analysis result is tabulated in Table 4.8.

Table 4.8. XRF analysis result of DM-16

Compound (%)	Compound (%)
O=38.97	Ti=0.37
Na=0.85	Cr=0.19
Mg=4.89	Mn=0.09
Al=4.18	Fe=4.48
Si=15.43	Ni=0.19
P=0.07	Cu=0.05
S=0.49	Zn=0.02
Cl=1.64	Sr=0.08
K=1.18	Zr=0.03
Ca=26.73	W=0.07

The results of mineralogical analysis indicate that quartz (sand) minerals are remarkably dominant in many DMs followed by feldspar (silt) and illite (clay) minerals in common. Fe_2O_3 (Hematite), $MgFe_2O_4$ (Magnesioferrite), Forsterite (Mg_2SiO_4), $MgSiO_3$ (Enstatite), Fe_3O_4 (Magnetite) and MgS (Niningerite) minerals found in DM structures are H4-irritant (Xi) and have a risk code of R36/37/38 (Irritating to eyes, respiratory system and skin). The AYY-App.3B: hazardous waste threshold limit for R36/37/38 is 20.0%; therefore, contents of these minerals do not exceed the limit value (Environment Agency, 2011; Anonymous, 2015). DMs also indicate non-hazardous character in terms of inorganic matter content. Due to the risk code of R48/20 (Harmful: serious health damage by prolonged exposure via inhalation) for quartz and R37/38-41 (irritating to respiratory system and skin, risk of serious damage to eyes) for calcite, a dust mask/respirator and eye/face protection should be worn in case of contacting with DM.

Heavy metal contents of DMs were determined by ICP-OES after acid digestion. It is obvious that the elevated concentrations of heavy metals in DMs require pre-treatment prior to beneficial use in urban landscaping applications as indicated in other studies (Lin et al., 2011; Krachai and Hadjel, 2014). The results of heavy metal with their categories of danger class, risk phrases and hazards are pointed out in Table 4.9 and Table 4.10, respectively.

All DM samples have low contents of heavy metals that do not cause any environmental risk when considering the relevant AYY-App.3B hazardous waste threshold limits given in Table 4.9 and Table 4.10 (Anonymous, 2015; Environment Agency, 2011). It is seen that DM samples indicate non-hazardous character in terms of inorganic matter content with respect to AYY-App.3B hazardous waste threshold limits.

4.1.1.4 Morphological Analysis of DMs

Morphological analysis of all DM samples was performed by SEM and the related SEM images of DMs are illustrated in Figure 4.1. It is clearly seen that the SEM images of DMs have angular and irregular shaped structures in their quartz-silt-clay particles. This suppots their structures.

4.1.1.5 General Assessment of AYY-App.3B Analysis Results

The following outcomes are drawn in compliance with AYY-App.3B: Hazardous waste threshold limits:

- It is observed that DM samples are commonly (dark) grey in colour and some of them have slightly undesirable odour due to historical pollution by wastewater drainage.
- They have low to moderate water content due to type of dredgers.
- They also have (slightly) alkaline nature and moderate to high EC values.
- Specific gravities of DMs are lower than those of silica sand due to impurities.

Table 4.9. Heavy metal analysis results of DMs

Parameters	DM-1	DM-2	DM-3	DM-4	DM-5	DM-6	DM-7	DM-8	Category of danger, Risk phrase(s) and Hazards	AYY-Appendix 3B Hazardous waste Threshold limit values
Pb (mg/kg)	13.1	11.8	35.4	10.6	40.6	2.1	5.5	19.8	(-): R33 (-) Repr. Cat. 1 and 2: R61 (H10) Repr. Cat. 3: R62 (H10) Xn: R20/22 (H5) T+: R26/27/28 (H6) N: R50/53 (H14)	- 0.5% (5,000 mg/kg) 5% (50,000 mg/kg) 25% (250,000 mg/kg) 0.1% (1,000 mg/kg) 0.25% (2,500 mg/kg)
Cd (mg/kg)	<0.10	<0.10	0.17	<0.10	0.77	<0.10	<0.10	0.11	T+: R26 (H6) Carc. Cat 1 and 2: R45 (H7) Repr. Cat. 3: R62, R63 (H10) Muta. Cat. 3: R68 (H11) Xn, T: R48/23/25 (-) N: R50/53 (H14)	0.1% (1,000 mg/kg) 0.1% (1,000 mg/kg) 5% (50,000 mg/kg) 1% (10,000 mg/kg) 3% (30,000 mg/kg) 0.25% (2,500 mg/kg)
Cr (mg/kg)	46	85	111	47	14	2,287	94	52	F: R11 (H3A) Carc. Cat. 3: R40 (H7) N: R52 (H14)	- 1% (10,000 mg/kg) 25% (2,500 mg/kg)
Cu (mg/kg)	26	15	46	24	139	13	12	16	F: R11 (H3A) N: R52 (H14) Xi: R36/37/38 (H4)	- 25% (250,000 mg/kg) 20% (200,000 mg/kg)
Ni (mg/kg)	11	37	55	28	95	1834	35	28	Carc. Cat. 3: R40 (H7) Xi: R43 (H13) Xn, T: R48/23 (-) N: R52/53 (H14)	1% (10,000 mg/kg) 1% (10,000 mg/kg) 3% (30,000 mg/kg) 25% (250,000 mg/kg)
Zn (mg/kg)	58	42	77	51	238	39	36	36	F: R15, R17 (H3A) N: R50/53 (H14)	0.3% (3,000 mg/kg) 0.25% (2,500 mg/kg)
Hg (mg/kg)	0.005	0.030	0.090	0.050	0.040	0.012	0.178	0.558	T+: R26 (H6) Repr. Cat. 1 and 2: R61 (H10) Xn, T: R48/23 (-) N: R50/53 (H14)	0.1% (1,000 mg/kg) 0.5% (5,000 mg/kg) 3% (30,000 mg/kg) 0.25% (2,500 mg/kg)

Table 4.10. Heavy metal analysis results of DMs (Table 4.9 continued)

Parameters	DM-9	DM-10	DM-12	DM-13	DM-14	DM-15	DM-16	Category of danger, Risk phrase(s) and Hazards	AYY-Appendix-3B Hazardous waste Threshold limit values
Pb (mg/kg)	13.0	5.3	42.3	7.8	7.8	5.6	31.9	(-): R33 (-) Repr. Cat. 1 and 2: R61 (H10) Repr. Cat. 3: R62 (H10) Xn: R20/22 (H5) T+: R26/27/28 (H6) N: R50/53 (H14)	- 0.5% (5,000 mg/kg) 5% (50,000 mg/kg) 25% (250,000 mg/kg) 0.1% (1,000 mg/kg) 0.25% (2,500 mg/kg)
Cd (mg/kg)	0.43	0.31	0.36	0.09	0.14	0.11	0.36	T+: R26 (H6) Carc. Cat 1 and 2: R45 (H7) Repr. Cat. 3: R62, R63 (H10) Muta. Cat. 3: R68 (H11) Xn, T: R48/23/25 (-) N: R50/53 (H14)	0.1% (1,000 mg/kg) 0.1% (1,000 mg/kg) 5% (50,000 mg/kg) 1% (10,000 mg/kg) 3% (30,000 mg/kg) 0.25% (2,500 mg/kg)
Cr (mg/kg)	140	54	40	17	9	905	599	F: R11 (H3A) Carc. Cat. 3: R40 (H7) N: R52 (H14)	- 1% (10,000 mg/kg) 25% (2,500 mg/kg)
Cu (mg/kg)	23	43	31	12	21	17	38	F: R11 (H3A) N: R52 (H14) Xi: R36/37/38 (H4)	- 25% (250,000 mg/kg) 20% (200,000 mg/kg)
Ni (mg/kg)	132	43	31	9	423	687	251	Carc. Cat. 3: R40 (H7) Xi: R43 (H13) Xn, T: R48/23 (-) N: R52/53 (H14)	1% (10,000 mg/kg) 1% (10,000 mg/kg) 3% (30,000 mg/kg) 25% (250,000 mg/kg)
Zn (mg/kg)	128	87	79	79	40	35	105	F: R15, R17 (H3A) N: R50/53 (H14)	0.3% (3,000 mg/kg) 0.25% (2,500 mg/kg)
Hg (mg/kg)	2.330	0.033	0.140	1.301	0.017	<0.010	0.025	T+: R26 (H6) Repr. Cat. 1 and 2: R61 (H10) Xn, T: R48/23 (-) N: R50/53 (H14)	0.1% (1,000 mg/kg) 0.5% (5,000 mg/kg) 3% (30,000 mg/kg) 0.25% (2,500 mg/kg)

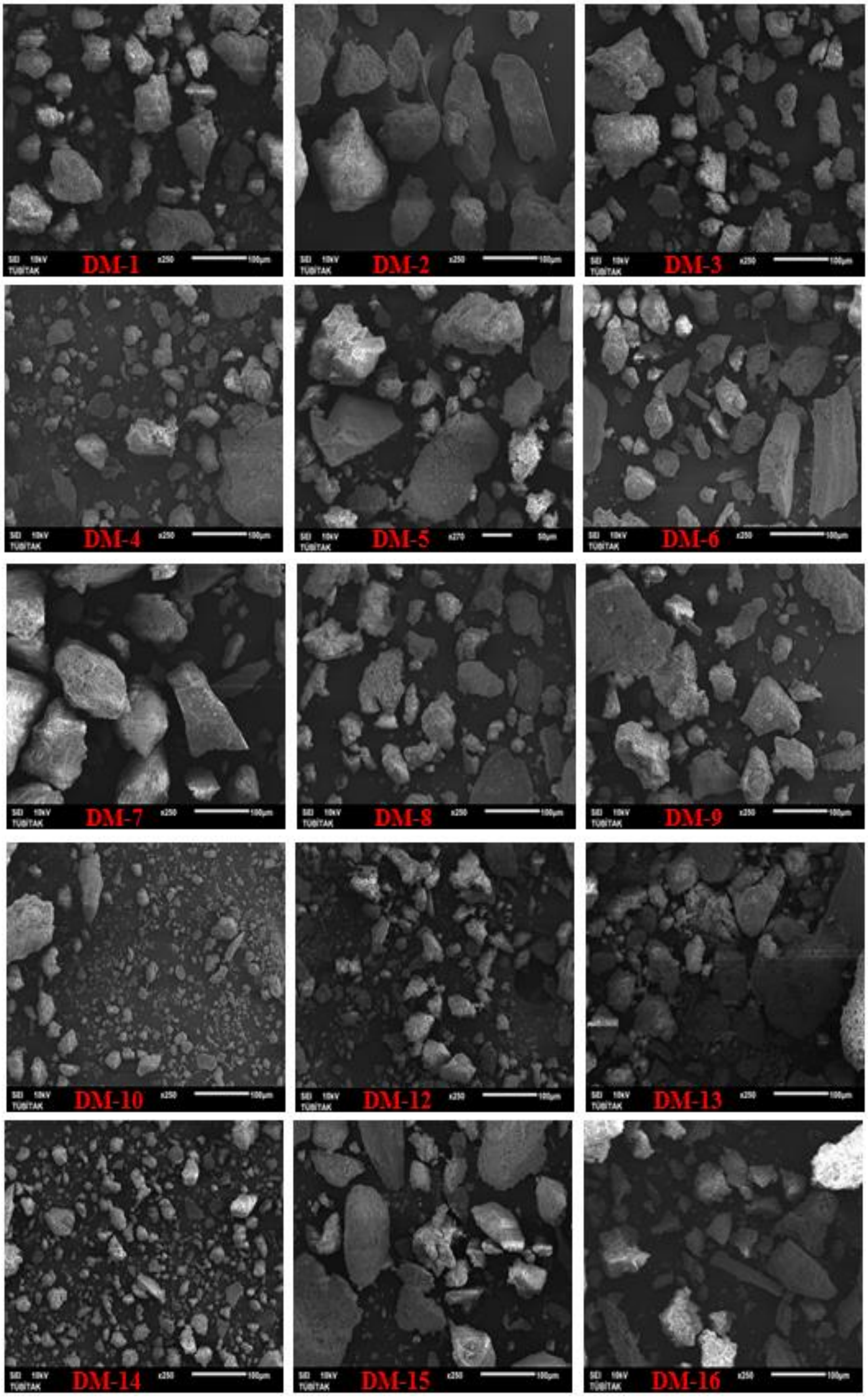


Figure 4.1. Images for the morphological structure of DMs

- DM samples indicate nonhazardous character in terms of organic and inorganic matter content.
- DMs can be considered as sandy resource material, which are mainly composed of fine and coarse sand.
- It is found that DM samples have no toxic effect on marine bacteria *vibrio fischeri*, as well as no acute risk for fishes and rat. Chronic effects were not considered within this survey.
- DMs can be identified as “nonhazardous waste” and categorized as 17 05 06 (dredging spoil other than 17 05 05).

Consequently, physico-chemical and toxicological characterization results showed that marine DMs collected from Turkey's commercial ports/marinas and fishery harbours can be defined as “**non-hazardous waste**” and categorized as **17 05 06** (**dredging spoil other than 17 05 05**) in spite of the heavy commercial, vessel traffic and fishing activities conducted in these ports/harbours. Except remediation purposes for the significant contamination, waste materials generated from dredging operations would usually be classified as nonhazardous according to the chemical criteria of the European Waste Catalogue (Köthe and De Boer, 2003; Casper, 2008).

4.1.2 “ADDDY” Analysis Results of DMs (ADDDY-App.2)

The leachabilities of DMs taken from the fifteen sampling points are given in Table 4.11, Table 4.12 and Table 4.13 with the limit values stated in "ADDDY-App.2: The acceptance criteria of the landfilling of waste" (Anonymous, 2010). According to the “TS EN 12457-4 leaching test” results of DMs, following findings can be deduced;

- The eluate concentrations of Cl^-, F^-, SO_4^{2-}, TDS, Cu, Ni, Mo and Sb were determined in accordance with the limit values of **Class II: non-hazardous waste** landfill sites. Due to high Cl^- concentrations, DM-8 can be disposed at **Class I: hazardous waste** landfill sites.
- High Cl^- and TDS contents for the materials originated from marine (saline) environment having high EC are acceptable (Lloyd and Heathcote, 1985).
- Due to the low organic contents of DMs, the possibility of organo-chlorine compounds generation is very low.

- Fluorides are usually chemically inactive and couldn’t be thought as DM contaminant for landfills (Morris and Wong, 2005).
- Due to being the second most abundant anion in sea water after Cl^- ion, high concentrations of SO_4^{2-} ion in DM samples can be expected.

4.1.3 EKAÇTKY” Analysis Results of DMs (App.IIB)

DMs were also analyzed and evaluated in accordance with the principles of "EKAÇTKY-App.IIB” in order to investigate the usability characteristics in soil. Even though the mentioned National Regulation has been applied for the sewage sludges, the use of DMs as a conditioner in the soil can also be considered under this regulation of concern.

The EKAÇTKY-App.IIB analysis results of DM samples were assessed on the basis of EKAÇTKY-) “App.IB: The maximum permissible heavy metal content in the stabilized sewage sludge to be used in the soil, App.IC: Concentrations of organic compounds and limits of dioxins in the stabilized sewage sludge to be used in the soil and App.ID: Microbiological Analysis" limit values, respectively and are demonstrated in Table 4.14 and Table 4.15.

Table 4.11. Leachabilities of DMs and "ADDDY-App.2" quality criteria

Parameters	DM-1	DM-2	DM-3	DM-4	DM-5	Inert Waste (Class III)	Non-Hazardous Waste (Class II)	Hazardous Waste (Class I)
Leachate (L/S=10 L/kg)								
As (mg/L)	0.0052	0.0127	0.0118	0.0132	0.0118	0.05	**0.2**	**2.5**
Ba (mg/L)	0.0489	0.0467	0.0505	0.0307	0.0496	2	**10**	**30**
Cd (µg/L)	0.00012	<0.00010	0.00011	0.00013	0.00061	0.004	**0.1**	**0.5**
Cr (mg/L)	0.0095	<0.0001	0.0088	0.0061	0.0085	0.05	**1**	**7**
Cu (mg/L)	0.0119	0.0084	0.0311	0.0355	**0.3730**	0.2	**5**	**10**
Hg (µg/L)			<0.00013			0.001	**0.02**	**0.2**
Mo (µg/L)	0.0490	0.0059	0.0202	0.0105	<0.0005	0.05	**1**	**3**
Ni (mg/L)	0.0057	0.0017	0.0116	0.0079	0.0132	0.04	**1**	**4**
Pb (mg/L)	0.0047	0.0011	0.0172	0.0098	0.0586	0.05	**1**	**5**
Sb (mg/L)	**0.0071**	0.0025	**0.0061**	0.0025	0.0014	0.006	**0.07**	**0.5**
Se (µg/L)	0.0018	0.0027	<0.0010	<0.0010	0.0013	0.01	**0.05**	**0.7**
Zn (mg/L)	0.0182	<0.0050	0.0419	0.0299	0.2970	0.4	**5**	**20**
Cl^- (mg/L)	**671.4**	**600.6**	**704.8**	**456.3**	**436.9**	80	**1,500**	**2,500**
F^- (mg/L)	**1.05**	0.20	0.34	0.31	0.68	1	**15**	**50**
SO_4^{2-} (mg/L)	98.5	**102.9**	94.7	64.3	**100.9**	100 (600)	**2,000**	**5,000**
DOC (mg/L)	4.8	<0.5	4.1	1.8	1.9	50	**80**	**100**
TDS (mg/L)	**1,497**	**1,204**	**1,559**	**1,120**	**1,510**	400	**6,000**	**10,000**
Phenol (mg/L)			<0.07			0.1	-	-
Solid Matrix								
TOC (mg/kg)	<1,884	<1,884	9,078	5,960	26,270	30,000	**50,000**	**60,000**
BTEX (mg/kg)			<0.5			6	-	-
PCBs (mg/kg)			<0.1			1	-	-
Mineral oil (mg/kg)	<65	79	162	<65	85	500	-	-
LOI (%)	4.92	<2.30	4.19	3.44	7.17	-	-	**100,000**

Table 4.12. Leachabilities of DMs and "ADDDY-App.2" quality criteria (Table 4.11 continued)

Parameters	DM-6	DM-7	DM-8	DM-9	DM-10	Inert Waste (Class III)	Non-Hazardous Waste (Class II)	Hazardous Waste (Class I)
Leachate (L/S=10 L/kg)								
As (mg/L)	0.0098	0.0053	0.0236	0.0287	0.0065	0.05	**0.2**	**2.5**
Ba (mg/L)	0.0289	0.0302	0.0482	0.0508	0.1160	2	**10**	**30**
Cd (µg/L)	0.00029	0.00022	0.00048	<0.00005	0.00007	0.004	**0.1**	**0.5**
Cr (mg/L)	0.0012	<0.0001	0.0014	0.0001	0.0007	0.05	**1**	**7**
Cu (mg/L)	0.0181	0.0160	0.0113	0.0149	0.0127	0.2	**5**	**10**
Hg (µg/L)			<0.00013			0.001	**0.02**	**0.2**
Mo (µg/L)	**0.1301**	**0.1032**	**0.5371**	0.0374	0.0240	0.05	**1**	**3**
Ni (mg/L)	0.0367	0.0077	0.0064	0.0082	0.0022	0.04	**1**	**4**
Pb (mg/L)	0.0016	0.0017	0.00147	0.0012	0.0014	0.05	**1**	**5**
Sb (mg/L)	**0.0120**	**0.0070**	0.026	0.0029	**0.0084**	0.006	**0.07**	**0.5**
Se (µg/L)	0.0011	<0.0010	0.0020	0.0011	0.0023	0.01	**0.05**	**0.7**
Zn (mg/L)	0.0251	0.0201	0.0089	0.0155	0.01132	0.4	**5**	**20**
Cl^- (mg/L)	**1,397.9**	**1,103.2**	**2,274.2**	**950.1**	**843.2**	80	**1,500**	**2,500**
F^- (mg/L)	**7.06**	**2.58**	0.74	0.67	**1.27**	1	**15**	**50**
SO_4^{2-} (mg/L)	**221.1**	**164.2**	**357.3**	186.4	**125.1**	100 (600)	**2,000**	**5,000**
DOC (mg/L)	1.9	<0.5	5.7	2.1	3.2	50	**80**	**100**
TDS (mg/L)	**2,960**	**2,388**	**4,934**	**2,040**	**1,712**	400	**6,000**	**10,000**
Phenol (mg/L)			<0.07			0.1	**-**	**-**
Solid Matrix								
TOC (mg/kg)	1,209	<1,884	8,162	2,318	4,731	30,000	**50,000**	**60,000**
BTEX (mg/kg)			<0.5			6	-	-
PCBs (mg/kg)			<0.1			1	-	-
Mineral oil (mg/kg)	<65	82	<65	<65	<65	500	-	-
LOI (%)	5.63	<2.30	8.43	4.72	<2.30	-	-	**100,000**

Table 4.13. Leachabilities of DMs and "ADDDY-App.2" quality criteria (Table 4.11 continued)

Parameters	DM-12	DM-13	DM-14	DM-15	DM-16	Inert Waste (Class III)	Non-Hazardous Waste (Class II)	Hazardous Waste (Class I)
Leachate (L/S=10 L/kg)								
As (mg/L)	0.0050	0.0050	0.0031	0.0027	0.0044	0.05	**0.2**	**2.5**
Ba (mg/L)	0.0759	0.0404	0.0538	0.0182	0.0595	2	**10**	**30**
Cd (µg/L)	0.00033	0.00013	0.00011	0.00006	0.00012	0.004	**0.1**	**0.5**
Cr (mg/L)	0.0022	0.0004	0.0265	0.0003	0.0009	0.05	**1**	**7**
Cu (mg/L)	0.0098	0.0064	0.0167	0.0077	0.0069	0.2	**5**	**10**
Hg (µg/L)			<0.00013			0.001	**0.02**	**0.2**
Mo (µg/L)	0.1350	0.0320	0.0231	0.0069	0.0288	0.05	**1**	**3**
Ni (mg/L)	0.0035	0.0017	**0.0784**	0.0051	0.0047	0.04	**1**	**4**
Pb (mg/L)	0.0032	0.0009	0.0041	0.0008	0.0015	0.05	**1**	**5**
Sb (mg/L)	**0.0157**	**0.0089**	0.0019	0.0008	0.0058	0.006	**0.07**	**0.5**
Se (µg/L)	<0.0010	0.0012	<0.0010	0.0011	<0.0010	0.01	**0.05**	**0.7**
Zn (mg/L)	0.0226	0.0126	0.0344	0.00678	0.01384	0.4	**5**	**20**
Cl^- (mg/L)	**545.1**	**474.4**	**94.1**	**1,000.1**	**768.2**	80	**1,500**	**2,500**
F^- (mg/L)	0.78	0.99	0.20	0.97	0.78	1	**15**	**50**
SO_4^{2-} (mg/L)	41.9	93.8	37.2	**155.4**	**162.2**	100 (600)	**2,000**	**5,000**
DOC (mg/L)	10.3	3.3	3.9	1.5	2.9	50	**80**	**100**
TDS (mg/L)	**1,212**	**1,104**	**446**	**2,006**	**1,564**	400	**6,000**	**10,000**
Phenol (mg/L)			<0.07			0.1	**-**	**-**
Solid Matrix								
TOC (mg/kg)	10,708	2,319	<1,884	<1,884	3,085	30,000	**50,000**	**60,000**
BTEX (mg/kg)			<0.5			6	-	-
PCBs (mg/kg)	<0.1	<0.1	0.6	0.5	0.4	1	-	-
Mineral oil (mg/kg)			<65			500	-	-
LOI (%)	4.27	3.42	3.94	4.11	4.44	-	**-**	**100,000**

Table 4.14. "EKAÇTKY-App.IIB" analysis results of DMs and the relevant limit values

Parameters	DM-1	DM-2	DM-3	DM-4	DM-5	DM-6	DM-7	DM-8	App. IB, IC, ID Limit Values
Pb (mg/kg)	13.1	11.8	35.4	10.6	40.6	2.1	5.5	19.8	750
Cd (mg/kg)	<0.10	<0.10	0.17	<0.10	0.77	<0.10	<0.10	0.11	10
Cr (mg/kg)	46	85	111	47	14	2287	94	52	1000
Cu (mg/kg)	26	15	46	24	139	13	12	16	1000
Ni (mg/kg)	11	37	55	28	95	1834	35	28	300
Hg (mg/kg)	0.005	0.030	0.090	0.050	0.040	0.012	0.178	0.558	10
Total nitrogen (mg/kg)	507.3	113.6	731.0	400.4	705.0	470.2	174.0	597.3	-
Total phosphorus (mg/kg)	343	397	717	470	455	284	280	294	-
AOX (mg/kg)	cannot be done.								500
LAS (mg/kg)	cannot be done.								2600
DEHP (mg/kg)	cannot be done.								100
NPE (mg/kg)	cannot be done.								50
PAH (mg/kg)	0.096	0.098	0.347	0.155	0.560	0.162	0.085	0.058	6
PCB (mg/kg)	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	0.8
PCDD/F (ng/kg I-TEQ)	0.014	0.032	0.029	0.006	0.009	0.001	0.001	0.008	100
C/N (%)	25.75	28.60	23.38	23.07	11.24	38.96	10.95	5.91	-
Solid content (%)	62.80	73.85	59.65	70.47	66.71	73.00	74.01	48.24	-
Water content (%)	37.20	26.15	40.35	29.53	33.29	27.00	25.99	51.76	-
pH	8.20	9.38	8.91	8.77	8.87	8.56	8.16	8.35	-
EC (mS/cm)	3.36	2.28	2.70	1.86	1.93	5.02	4.08	8.39	-
Organic matter (%)	2.56	2.26	2.90	2.46	4.28	12.07	5.84	4.71	-
LOI (%)	4.92	< 2.30	4.19	3.44	7.17	5.63	< 2.30	8.43	-
E.Coli (EMS/g)	not found/g								2Log10 (%99)

Table 4.15. "EKAÇTKY-App.IIB" analysis results of DMs and the relevant limit values (Table 4.14 continued)

Parameters	DM-9	DM-10	DM-12	DM-13	DM-14	DM-15	DM-16	App. IB, IC, ID Limit Values
Pb (mg/kg)	13.0	5.3	42.3	7.8	7.8	5.6	31.9	750
Cd (mg/kg)	0.43	0.31	0.36	0.09	0.14	0.11	0.36	10
Cr (mg/kg)	140	54.3	40.2	16.9	9.25	1002	599	1000
Cu (mg/kg)	23.0	42.8	30.5	12.0	20.7	17.4	37.8	1000
Ni (mg/kg)	132	43.2	30.9	8.6	423	687	251	300
Hg (mg/kg)	2.330	0.033	0.140	1.301	0.017	<0.010	0.025	10
Total nitrogen (mg/kg)	80.0	406.3	994.9	226.8	603.6	354.5	146.6	-
Total phosphorus (mg/kg)	1347	684	398	710	235	320	419	-
AOX (mg/kg)				cannot be done.				500
LAS (mg/kg)				cannot be done.				2600
DEHP (mg/kg)				cannot be done.				100
NPE (mg/kg)				cannot be done.				50
PAH (mg/kg)	0.732	0.018	0.067	0.776	0.167	0.114	0.009	6
PCB (mg/kg)	< 0.1	< 0.1	0.17	< 0.1	0.57	0.49	0.39	0.8
PCDD/F (ng/kg I-TEQ)	0.029	0.012	0.365	0.635	0.123	0.049	0.313	100
C/N (%)	4.083	2.690	3.180	12.80	6.521	11.77	11.75	-
Solid content (%)	76.00	67.42	67.99	76.08	68.08	69.41	70.86	-
Water content (%)	24.00	32.58	32.01	23.92	31.92	30.59	29.14	-
pH	8.92	8.76	8.62	7.90	8.49	8.89	9.11	-
EC (mS/cm)	3.76	3.16	2.27	1.85	4.77	3.48	2.86	-
Organic matter (%)	5.01	3.45	< 0.01	< 0.01	6.32	1.18	< 0.01	-
LOI (%)	4.72	< 2.30	4.27	3.42	3.94	4.11	4.44	-
E.Coli (EMS/g)				not found/g				2Log10 (%99)

AOX, LAS, DEHP and NPE analysis couldn't have been done because of the method development studies and technical problems emerged at TÜBİTAK MAM Environment and Cleaner Production Institute's laboratories (AOX analyzer failure).

Pursuant to EKAÇTKY-App.IIB analysis results, it is seen that there is no substantial risk for DMs in order to be used in soil applications.

4.2 The Evaluation of Beneficial Use of DM as MT

4.2.1 The Preparation of $DM_{Mixture}$ Samples

As mentioned previously in Section 3.3.2.1, DMs have different particle sizes and characters due to the fact that they are excavated from the fifteen different sampling points in the shores of Turkey. Due to the elevated numbers of sampling points, it is decided to classify DMs by mixing them in equal amounts (w/w), as given in Table 4.16, with respect to their particle size distributions showing identical characters in order to reduce the plant growth monitoring trials within MT samples prepared from the relevant DM specimens.

Table 4.16. Classification of DMs with respect to their particle size distributions

Name of Mixture	DMs within The Mixture	Particle Size Distribution
$DM_{Mixture-A}$	DM-7 Izmir Karaburun Tepeboz Village Fishery Harbour (FH) DM-15 Mersin Erdemli Fishery Harbour	Gravel (%): 1.14 Coarse Sand (%): 48.44 Fine Sand (%): 39.59 Silt-Clay Mixture (%): 10.83
$DM_{Mixture-B}$	DM-5 Rize Port DM-6 Muğla Göcek Marina DM-16 Mersin International Port (MIP)	Gravel (%): 18.21 Coarse Sand (%): 24.12 Fine Sand (%): 35.96 Silt-Clay Mixture (%): 21.71
$DM_{Mixture-C}$	DM-9 Izmir PETKIM Container Port DM-13 Kocaeli TÜPRAŞ Yarımca Port	Gravel (%): 58.98 Coarse Sand (%): 23.67 Fine Sand (%): 11.65 Silt-Clay Mixture (%): 5.70
$DM_{Mixture-D}$	DM-2 Istanbul Ambarlı Port DM-3 Samsun Port DM-8 Izmir Nemrut Gulf Batıçim Harbour DM-14 Mersin Erdemli METU Campus Port	Gravel (%): 5.01 Coarse Sand (%): 15.81 Fine Sand (%): 48.49 Silt-Clay Mixture (%): 30.69
$DM_{Mixture-E}$	DM-1 Tuzla Marina DM-4 Samsun Alaçam Fishery Harbour DM-10 Istanbul Tuzla Shipyards Area DM-12 Kocaeli Eskihisar Fishery Harbour	Gravel (%): 3.93 Coarse Sand (%): 10.12 Fine Sand (%): 20.03 Silt-Clay Mixture (%): 65.92

4.2.2 The Assessment of $DM_{Mixture}$ Samples, Natural Soil, Peat and Sheep Manure

For the beneficial use trials of DMs as MT in landscaping applications, various soil quality analyses were performed in raw $DM_{Mixture}$ samples that are listed under the main headings as follows:

- The soil productivity analysis,
- The soil salinity-alkalinity analysis and
- The soil physical analysis.

The soil quality analysis under three groups as mentioned above were also applied to natural soil used as control sample, peat used as the soil physical structure improver and sheep manure used as an organic improver, respectively and the relevant analysis results for the entire $DM_{Mixtures}$, natural soil, peat and sheep manure are given in Table 4.17, Table 4.18, Table 4.19 and Table 4.20 with the related limit values of interest.

The assessment of $DM_{Mixture}$ samples in terms of soil quality is as follows:

- The soil texture classes are commonly identified as sand, sandy loam and clay loam soil, respectively. The weight percentages of sand fractions in DM mixtures are 88% for Mix-A, 72% for Mix-B, 78% for mix-C, 68% for Mix-D, and 46% for Mix-E, respectively.
- The soil structures are specified as“angular-block-thin” and “granular-medium-very thin” soil.
- According to Munsell Color Scale; $DM_{Mixture-C}$ enters into 5N 3/0 color group while the others fall within 5N 2/0 color group.
- The solid contents are ranged between 65-80%.
- They have (very) high alkaline nature (pH>8.5).
- They possess “moderately salty” (EC: 4-8 mS/cm) content.
- Their organic matter contents are found in “normal” level (2-6%).

Table 4.17. "The soil productivity analysis" results of $DM_{Mixture}$ samples, natural soil, peat and sheep manure

Parameters		$DM_{Mixture-A}$	$DM_{Mixture-B}$	$DM_{Mixture-C}$	$DM_{Mixture-D}$	$DM_{Mixture-E}$	PEAT	SHEEP MANURE	NATURAL SOIL
Water content (%)		21.23	34.49	20.31	34.31	34.02	30.32	60.34	5.05
Solid content (%)		78.77	65.51	79.69	65.69	65.98	69.68	39.66	94.95
pH (Aq. Sol.)		8.65	8.55	9.26	8.68	8.87	7.35	7.63	7.88
EC (at sat.) (mS/cm)		4.53	6.25	2.97	5.68	4.66	3.66	1.83	0.35
Saturation with water (%) (Water Holding Capacity)		33	36	40	35	53	84	80	28
Total salt (%)		0.10	0.15	0.08	0.13	0.18	0.13	0.10	0.01
Particle size distribution;									
Gravel (%):		1.1	18.2	59.0	5.0	3.9	32.1	55.2	31.1
Coarse sand (%):		48.4	24.1	23.6	15.8	10.1	11.6	29.9	29.1
Fine sand (%):		39.6	36.0	11.7	48.5	20.0	10.0	10.3	10.6
Silt-clay mixture (%):		10.9	21.7	5.7	30.7	65.9	46.3	4.6	29.2
Soil texture;		(Sand)	(Sandy loam)	(Sandy loam)	(Sandy loam)	(Clay loam)	(Clay)	(Clay)	(Sandy loam)
Sand (%):		88	72	78	68	47	25	30	74
Silt (%):		8	15	12	18	28	11	9	11
Clay (%):		4	13	10	14	25	64	61	15
Organic matter (%)		3.17	5.78	4.60	4.42	4.09	37.68	28.70	2.61
LOI (%)		6.68	3.98	8.66	0.25	< 0.10	26.95	21.37	3.37
Available micronutrients; (mg/kg)	Fe	10.69	18.35	6.077	9.493	21.57	25.42	6.589	1.804
	Cu	1.12	3.43	0.79	2.78	5.20	0.62	0.64	0.25
	Zn	1.55	13.34	10.68	2.19	6.78	4.29	17.65	1.12
	Mn	2.95	6.39	2.27	2.46	14.74	0.53	4.74	1.31
	Al	0.38	0.22	0.25	0.15	0.51	0.22	< 0.05	0.29
Available macronutrients; (mg/kg)	Ca	4,842	5,541	3,671	6,172	5,628	7,661	9,121	24,760
	Mg	601	1,108	1,073	1,346	885	519	1805	216
	Na	1,398	3,436	2,366	4,306	3,352	320	175	61
	K	2252	713	691	1167	631	1865	1582	225

Table 4.18. "The soil productivity analysis" results of $DM_{Mixture}$ samples, natural soil, peat and sheep manure (Table 4.17 continued)

Parameters	$DM_{Mixture-A}$	$DM_{Mixture-B}$	$DM_{Mixture-C}$	$DM_{Mixture-D}$	$DM_{Mixture-E}$	PEAT	SHEEP MANURE	NATURAL SOIL
Available K (K_2O kg/da)	676	214	207	350	189.2	559.5	474.6	67.5
Available P (P_2O_5 kg/da)	172	221	589	235	269.7	1289.8	3173.4	275.4
TC (mg/kg)	5,562	29,378	48,584	40,394	24,475	191,671	211,496	7,690
TOC (mg/kg)	393	16,980	18,662	18,526	9,388	188,754	211,496	2,978
IC (mg/kg)	5,169	12,398	2,992	21,868	15,087	2,917	0	4,712
Total nitrogen (mg/kg)	160	510	154	511	578	10,700	24,234	687
Total phosphorus (mg/kg)	300	386	1029	411	471	2,253	5,543	481
C/N ratio	35	58	122	79	42	18	89	11
N/P ratio	0.53	1.32	0.15	1.25	1.23	4.75	4.37	1.43
Lime content (% $CaCO_3$)	16.7	16.7	27.6	11.30	6.5	1.4	1.3	1.2
(Available) B (mg/kg)	97.4	127.5	91.6	80.4	111.8	97.5	76.8	60.8
Pb (mg/kg)	5.6	24.9	10.4	18.7	17.8	6.7	73.1	57.9
Cd (mg/kg)	< 0.10	0.30	0.26	0.13	0.29	0.40	1.19	< 0.10
Cr (mg/kg)	548	967	78	64	47	60	29	21
Cu (mg/kg)	14.7	63.3	12.5	24.5	30.9	38.9	68.5	16.3
Ni (mg/kg)	361.1	726.7	70.3	135.8	28.2	46.2	15.6	9.9
Zn (mg/kg)	35	127	104	49	69	84	294	84
As (mg/kg)	14	10	176	13	16	27	11	5
Hg (mg/kg)	0.094	0.026	1.815	0.174	0.057	0.038	0.065	0.019
PAH (mg/kg)	0.099	0.244	0.754	0.168	0.084	< 0.005	< 0.005	< 0.005
Pesticides (mg/kg)	< 0.005	< 0.005	0.006	0.033	< 0.005	< 0.005	< 0.005	< 0.005
Tributyltin (mg/kg)	< 0.009	0.052	< 0.009	< 0.009	0.010	< 0.009	< 0.009	< 0.009
PCB (mg/kg)	0.27	0.16	< 0.10	0.18	< 0.10	< 0.10	< 0.10	< 0.10
PCDD/F (ngTEQ/kg)	0.025	0.108	0.332	0.048	0.095	< 0.001	< 0.001	< 0.001

Table 4.19. “The soil salinity-alkalinity analysis” results of $DM_{Mixture}$ samples, natural soil, peat and sheep manure

Parameters		**$DM_{Mixture-A}$**	**$DM_{Mixture-B}$**	**$DM_{Mixture-C}$**	**$DM_{Mixture-D}$**	**$DM_{Mixture-E}$**	**PEAT**	**SHEEP MANURE**	**NATURAL SOIL**
pH (Aq. Sol.)		8.65	8.55	9.26	8.68	8.87	7.35	7.63	7.88
EC (at sat.) (mS/cm)		4.53	6.25	2.97	5.68	4.66	3.66	1.83	0.35
Saturation with water (%) (Water Holding Capacity)		33	36	40	35	53	84	80	28
Total Salt (%)		0.10	0.15	0.08	0.13	0.18	0.13	0.10	0.01
Particle size distribution;									
Gravel (%):		1.1	18.2	59.0	5.0	3.9	32.1	55.2	31.1
Coarse sand (%):		48.4	24.1	23.6	15.8	10.1	11.6	29.9	29.1
Fine sand (%):		39.6	36.0	11.7	48.5	20.0	10.0	10.3	10.6
Silt-clay mixture (%):		10.9	21.7	5.7	30.7	65.9	46.3	4.6	29.2
Soil texture;		(Sand)	(Sandy loam)	(Sandy loam)	(Sandy loam)	(Clay loam)	(Clay)	(Clay)	(Sandy loam)
Sand (%):		88	72	78	68	47	25	30	74
Silt (%):		8	15	12	18	28	11	9	11
Clay (%):		4	13	10	14	25	64	61	15
Density (g/ml)		1.27	1.16	1.16	1.04	1.09	0.49	0.48	1.22
Extractable cation concentrations (mg/L)	Na	1,501	1,562	783	1,009	1,278	70	18	13
	Mg	246	293	179	223	209	81	195	57
	Ca	319	322	319	323	324	995	620	528
	K	104	198	112	143	167	302	296	33
Exchangeable Cation Concentrations (meq/100g)	NaX	5.14	5.85	2.93	4.22	5.10	0.62	0.16	0.05
	MgX	1.60	2.08	1.27	1.84	1.58	1.37	3.35	0.38
	CaX	1.26	1.38	1.37	1.55	1.48	10.12	6.44	2.16
	KX	0.21	0.44	0.25	0.35	0.39	1.57	1.58	0.07
CEC (meq/100g)		8.21	9.75	5.82	7.96	8.55	13.68	11.53	2.66
SAR		114	103	70	74	101	4	2	2
ESP (%)		63	60	50	53	60	5	1	2

Table 4.20. "The soil physical analysis" results of $DM_{Mixture}$ samples, natural soil, peat and sheep manure

Parameters	$DM_{Mixture-A}$	$DM_{Mixture-B}$	$DM_{Mixture-C}$	$DM_{Mixture-D}$	$DM_{Mixture-E}$	PEAT	SHEEP MANURE	NATURAL SOIL
Particle size distribution;								
Gravel (%):	1.1	18.2	59.0	5.0	3.9	32.1	55.2	31.1
Coarse sand (%):	48.4	24.1	23.6	15.8	10.1	11.6	29.9	29.1
Fine sand (%):	39.6	36.0	11.7	48.5	20.0	10.0	10.3	10.6
Silt-clay mixture (%):	10.9	21.7	5.7	30.7	65.9	46.3	4.6	29.2
Soil texture;	(Sand)	(Sandy loam)	(Sandy loam)	(Sandy loam)	(Clay loam)	(Clay)	(Clay)	(Sandy loam)
Sand (%):	88	72	78	68	47	25	30	74
Silt (%):	8	15	12	18	28	11	9	11
Clay (%):	4	13	10	14	25	64	61	15
Soil structure;								
Type (Figure and orien. of agg.):	angular	angular	granular	angular	angular	angular	angular	granular
Class (Size of agg.):	thin	thin	medium	thin	very thin	very thin	very thin	medium
Grade (Strength of agg.):	weak	weak	strong	weak	moderate	weak	weak	strong
Specific gravity (g/cm^3)	2.87	1.72	1.96	2.03	2.05	1.33	0.85	2.50
Bulk density (g/cm^3)	1.15	1.08	0.97	1.08	1.07	0.51	0.39	1.02
Porosity (%)	59.93	37.21	51.02	46.80	47.80	61.65	54.12	59.20
Soil color	5N 2/0	5N 2/0	5N 3/0	5N 2/0	5N 2/0	5Y 1/2	5Y 1/2	5Y 3/4
Soil temperature (°C)	18	18	18	18	18	18	18	18

- They are rich in terms of available macronutrients (Ca, Mg, Na and K) and available micronutrients (Fe, Cu, Zn, Mn, Al) (enough-high), respectively.
- They contain "high" amount of available potassium (K_2O) and "very high" quantity of available phosphorus (P_2O_5), respectively.
- Whereas the contents of total phosphorus are "too much", the amounts of total nitrogen are "(very) little".
- They are found in "high risk" group in terms of SAR and ESP % values.
- Lime contents are quite high ((very) limy).
- The contents of heavy metals (Pb, Cd, Cr, Cu, Ni, Zn, As, Hg), organic pollutants (PAH, PCB, pesticides, tributyltin, PCDD/F) and the physical analysis results are below the relevant limit values and found as appropriate.

The evaluation of natural soil in terms of soil quality is as follows:

- The soil texture class is identified as sandy loam soil and the weight percentage of sand fraction is found to be 74%.
- The soil structure is specified as "granular-medium-strong" soil.
- According to Munsell Colour Scale; it falls within 5Y 3/4 colour group.
- The solid content is very high (94.95%). It has slightly alkaline nature (pH=7.5-8.5). It possesses "saltless" (EC: 0-2 mS/cm) content.
- Its organic matter content is found in "normal" level (2-6%).
- Although it has a rich content in terms of available macronutrients (Ca, Mg, Na, K) (enough-very high), it is partially poor with regard to available micronutrients (Fe, Cu, Zn, Mn, Al) (low-enough). It includes "high" amount of available potassium (K_2O) and available phosphorus (P_2O_5).
- Whereas the amount of total nitrogen is low, the content of total phosphorus is very high.
- It takes apart in "low risk" group with regard to SAR and ESP % values.
- It is found in "little limy" class in terms of lime ($CaCO_3$) content.
- The contents of heavy metals (Pb, Cd, Cr, Cu, Ni, Zn, As, Hg), organic pollutants (PAH, PCB, pesticides, tributyltin, PCDD/F) and the physical analysis results are below the relevant limit values and found as appropriate.

The assessment of peat in terms of soil quality is as follows:

Within this study, peat was used in landscaping (MT) applications in order to balance the soil textures and soil structures of MTs and to increase the physical properties and water retention capacities of soils.

- The soil texture class is identified as "clay" soil.
- The soil structure is specified as an “angular-block-very thin” soil.
- According to Munsell Color Scale; it falls within 5Y 1/2 color group.
- Its solid content is 69.68%.
- It shows neutral pH feature (pH=7.35).
- It possesses “slightly salty” (EC: 2-4 mS/cm) content.
- In contrast to natural soil and $DM_{Mixture}$ samples, its organic matter content is very high (37.68%).
- It has a rich content in terms of available macronutrients (Ca, Mg, Na and K) (enough-very high). However, the amounts of available micronutrients (Fe, Cu, Zn, Mn, Al) show fluctuation. It is a rich soil in terms of available potassium (K_2O) and available phosphorus (P_2O_5).
- Both the amount of total nitrogen and total phosphorus are very high.
- It takes apart in “low risk” group with regard to SAR and ESP % values.
- It is found in “little limy” class in terms of lime ($CaCO_3$) content.
- The contents of heavy metals (Pb, Cd, Cr, Cu, Ni, Zn, As, Hg), organic pollutants (PAH, PCB, pesticides, tributyltin, PCDD/F) and the physical analysis results are below the relevant limit values and found as appropriate.

The evaluation of sheep manure in terms of soil quality is as follows:

- The soil texture class is identified as "clay" soil.
- The soil structure is specified as “angular-block-very thin” soil.
- According to Munsell Color Scale; it falls within 5Y 1/2 color group.
- Due to the clay structure, it has a low solid content (39.66%).
- It shows slightly alkaline nature (pH=7.63).
- It possesses a “saltless” (EC: 0-2 mS/cm) content.
- Its organic matter content is very high (28.70%) like peat.

- Although it has quite a rich content in terms of available macronutrients (Ca, Mg, Na, K) (very high), it is poor in terms of Al and Mn and rich with regard to Fe, Cu and Zn, respectively. It contains high levels of available potassium (K_2O) and available phosphorus (P_2O_5), respectively.
- Both the amount of total nitrogen and total phosphorus are very high.
- It takes part in "low risk" group in terms of SAR and ESP % values.
- Its lime ($CaCO_3$) content is low (little limy).
- The contents of heavy metals (Pb, Cd, Cr, Cu, Ni, Zn, As, Hg), organic pollutants (PAH, PCB, pesticides, tributyltin, PCDD/F) and the physical analysis results are below the relevant limit values and found as appropriate.

4.2.3 The Treatment of $DM_{Mixture}$ Samples for the Production of Topsoil Samples

As mentioned previously in Section 3.3.2.1, due to the fact that raw DMs showed moderate water content, slightly saline and high alkaline nature, low total nitrogen, low organic matter content and high C/N ratio pursuant to "BS 3882:2015-Topsoil specifications", they are inadequate for plant growth; thus, DMs were required significant treatment procedure such as sieving (via 5 cm sieve), desalination (washing), dewatering, organic amelioration via peat and sheep manure and pH adjustment (Figure 3.6) in order to transform DMs into an alternative natural soil (MT soil) (BS, 2015).

4.2.3.1 Desalination (Washing) of $DM_{Mixture}$ Samples

As mentioned previously in section 3.3.2.3.1, $DM_{Mixtures}$ were split into two portions in order to observe the effect of salinity on plant growth and the desalination process was only performed in one portion of the $DM_{Mixtures}$ (washed) while the other portions were left as saline (unwashed) for comparison. The results of the laboratory-scale desalination (washing) process for each $DM_{Mixture}$ sample (100 g) are presented in Table 4.21.

Table 4.21. Laboratory-scale desalination (washing) studies of $DM_{Mixtures}$

$DM_{Mixture-A}$ ($pH_{initial}$=8.65) ($EC_{initial}$= 4.53 mS/cm)						
Parameters	**pH**			**EC (μS/cm)**		
Volume of Water /Time	**5 min.**	**10 min.**	**15 min.**	**5 min.**	**10 min.**	**15 min.**
0 mL	8.65	8.65	8.65	4,530	4,530	4,530
20 mL	8.98	9.05	9.08	**1,505**	1,976	2,080
40 mL	9.13	9.18	9.17	1276	1,448	1,715
60 mL	9.19	9.26	9.29	813	1,046	1,526
80 mL	9.16	9.38	9.37	716	741	1,231
100 mL	9.25	9.43	9.55	472	617	1,018
$DM_{Mixture-B}$ ($pH_{initial}$=8.55) ($EC_{initial}$= 6.25 mS/cm)						
Parameters	**pH**			**EC (μS/cm)**		
Volume of Water /Time	**5 min.**	**10 min.**	**15 min.**	**5 min.**	**10 min.**	**15 min.**
0 mL	8.55	8.55	8.55	6,250	6,250	6,250
20 mL	8.75	8.64	8.79	2,520	2,440	2,670
40 mL	8.87	8.76	8.83	2,090	2,170	2,310
60 mL	8.94	8.85	8.95	1,874	2,090	2,030
80 mL	9.04	8.97	9.07	**1,520**	1,884	1,762
100 mL	9.08	9.11	9.13	1,301	1,466	1,647
$DM_{Mixture-C}$ ($pH_{initial}$=9.26) ($EC_{initial}$= 2.97 mS/cm)						
Parameters	**pH**			**EC (μS/cm)**		
Volume of Water /Time	**5 min.**	**10 min.**	**15 min.**	**5 min.**	**10 min.**	**15 min.**
0 mL	9.26	9.26	9.26	2,970	2,970	2,970
20 mL	9.65	9.59	9.69	**1,468**	1,863	1,929
40 mL	9.72	9.68	9.77	1,145	1,769	1,713
60 mL	9.81	9.82	9.84	865	1,584	1,639
80 mL	9.83	9.90	9.87	703	1,413	1,433
100 mL	9.86	9.96	10.01	594	1,093	1,278
$DM_{Mixture-D}$ ($pH_{initial}$=8.68) ($EC_{initial}$= 5.68 mS/cm)						
Parameters	**pH**			**EC (μS/cm)**		
Volume of Water /Time	**5 min.**	**10 min.**	**15 min.**	**5 min.**	**10 min.**	**15 min.**
0 mL	8.68	8.68	8.68	5,680	5,680	5,680
20 mL	8.81	8.97	8.93	2,410	2,530	2,960
40 mL	8.95	9.01	9.06	2,130	2,210	2,370
60 mL	9.04	9.09	9.18	**1,569**	2,020	2,080
80 mL	9.20	9.18	9.29	1,178	1,596	1,879
100 mL	9.32	9.37	9.44	986	1,327	1,614
$DM_{Mixture-E}$ ($pH_{initial}$=8.87) ($EC_{initial}$= 4.66 mS/cm)						
Parameters	**pH**			**EC (μS/cm)**		
Volume of Water /Time	**5 min.**	**10 min.**	**15 min.**	**5 min.**	**10 min.**	**15 min.**
0 mL	8.87	8.87	8.87	4,660	4,660	4,660
20 mL	9.11	9.14	9.18	1,853	2,070	2,210
40 mL	9.18	9.21	9.23	1,683	1,987	2,130
60 mL	9.23	9.27	9.31	**1,472**	1,571	2,040
80 mL	9.33	9.33	9.38	1,283	1,402	1,741
100 mL	9.46	9.42	9.53	1,041	1,198	1,316

Optimum washing ratios of $DM_{Mixtures}$ for the desalination process was selected by considering the reduction of EC value below 2 mS/cm (saltless) which is appropriate level for plant germination in the production of MTs (Sheehan et al., 2010a). It is clear that EC values of $DM_{Mixtures}$ after desalination process must approximately be between 1.5 mS/cm and 1.6 mS/cm in order to achieve the desired EC value of 2 mS/cm for MTs due to EC values of other components (peat, sheep manure). The relevant ratios obtained for each $DM_{Mixture}$ are pointed out in Table 4.22.

Table 4.22. Optimum washing ratios of $DM_{Mixture}$ samples

Sample Name	Amount of Sample (g)	Amount of Washing Water (mL)	Optimum Washing Time (min.)	Optimum Washing Ratio
$DM_{Mixture-A}$	100	20	5	5:1
$DM_{Mixture-B}$	100	80	5	5:4
$DM_{Mixture-C}$	100	20	5	5:1
$DM_{Mixture-D}$	100	60	5	5:3
$DM_{Mixture-E}$	100	60	5	5:3

The optimum washing ratios under investigation were tested with the pre-determined volume mixing ratios of MT samples (1/3 $DM_{Mixtures}$ + **1/3 peat** + 1/3 sheep manure; 1/2 $DM_{Mixtures}$ + 1/4 peat + 1/4 sheep manure and 2/3 $DM_{Mixtures}$ + 1/6 peat + 1/6 sheep manure) including maximum peat content due to the elevated EC value (3.66 mS/cm) of peat rather than the others. Consequently, it is seen that the target EC value of MT samples is below 2.0 mS/cm (Table 4.23).

Table 4.23. Testing of Optimum washing ratios of $DM_{Mixture}$ samples

Sample Name	Amount of Sample (g)	Amount of Washing Water (mL)	Optimum Washing Ratio	pH	EC (mS/cm)
1/3 $DM_{Mixture-A}$ + 1/3 peat+ 1/3 s. manure	100	20	5:1	7.97	1.85
1/3 $DM_{Mixture-B}$ + 1/3 peat+ 1/3 s. manure	100	80	5:4	8.01	2.01
1/3 $DM_{Mixture-C}$ + 1/3 peat+ 1/3 s. manure	100	20	5:1	8.15	1.76
1/3 $DM_{Mixture-D}$ + 1/3 peat+ 1/3 s. manure	100	60	5:3	7.90	1.90
1/3 $DM_{Mixture-E}$ + 1/3 peat+ 1/3 s. manure	100	60	5:3	7.94	2.06

4.2.3.2 Organic Amelioration of $DM_{Mixture}$ Samples

It's a well-known fact that the organic content of a growing soil of plant must be adequate enough in order to maintain a healthy plant growth and healthy structure for a long time. Thus, the organic contents of $DM_{Mixture}$ samples should be improved.

The mixing ratios of $DM_{Mixture}$ samples together with peat and sheep manure in order to produce a total of 33 MT samples including control ones are given in Table 4.24. Control sample was prepared with natural soil instead of $DM_{Mixture}$ sample for each mixing ratio as a comparison.

Table 4.24. Mixing ratios of $DM_{Mixture}$ samples with peat and sheep manure

No	Mixture code name	Composition (v/v)
1	**Control-1**	1/3 natural soil + 1/3 peat + 1/3 s.manure
2	**Control-2**	1/2 natural soil + 1/4 peat + 1/4 s.manure
3	**Control-3**	2/3 natural soil + 1/6 peat + 1/6 s.manure
4	**Mixture-A1**	1/3 $DM_{Mixture-A}$ (unwashed) + 1/3 peat + 1/3 s.manure
5	**Mixture-A2**	1/2 $DM_{Mixture-A}$ (unwashed)+ 1/4 peat + 1/4 s.manure
6	**Mixture-A3**	2/3 $DM_{Mixture-A}$ (unwashed) + 1/6 peat + 1/6 s.manure
7	**Mixture-A4**	1/3 $DM_{Mixture-A}$ (washed) + 1/3 peat + 1/3 s.manure
8	**Mixture-A5**	1/2 $DM_{Mixture-A}$ (washed)+ 1/4 peat + 1/4 s.manure
9	**Mixture-A6**	2/3 $DM_{Mixture-A}$ (washed) + 1/6 peat + 1/6 s.manure
10	**Mixture-B1**	1/3 $DM_{Mixture-B}$ (unwashed) + 1/3 peat + 1/3 s.manure
11	**Mixture-B2**	1/2 $DM_{Mixture-B}$ (unwashed)+ 1/4 peat + 1/4 s.manure
12	**Mixture-B3**	2/3 $DM_{Mixture-B}$ (unwashed) + 1/6 peat + 1/6 s.manure
13	**Mixture-B4**	1/3 $DM_{Mixture-B}$ (washed) + 1/3 peat + 1/3 s.manure
14	**Mixture-B5**	1/2 $DM_{Mixture-B}$ (washed)+ 1/4 peat + 1/4 s.manure
15	**Mixture-B6**	2/3 $DM_{Mixture-B}$ (washed) + 1/6 peat + 1/6 s.manure
16	**Mixture-C1**	1/3 $DM_{Mixture-C}$ (unwashed) + 1/3 peat + 1/3 s.manure
17	**Mixture-C2**	1/2 $DM_{Mixture-C}$ (unwashed)+ 1/4 peat + 1/4 s.manure
18	**Mixture-C3**	2/3 $DM_{Mixture-C}$ (unwashed) + 1/6 peat + 1/6 s.manure
19	**Mixture-C4**	1/3 $DM_{Mixture-C}$ (washed) + 1/3 peat + 1/3 s.manure
20	**Mixture-C5**	1/2 $DM_{Mixture-C}$ (washed)+ 1/4 peat + 1/4 s.manure
21	**Mixture-C6**	2/3 $DM_{Mixture-D}$ (washed) + 1/6 peat + 1/6 s.manure
22	**Mixture-D1**	1/3 $DM_{Mixture-D}$ (unwashed) + 1/3 peat + 1/3 s.manure
23	**Mixture-D2**	1/2 $DM_{Mixture-D}$ (unwashed)+ 1/4 peat + 1/4 s.manure
24	**Mixture-D3**	2/3 $DM_{Mixture-D}$ (unwashed) + 1/6 peat + 1/6 s.manure
25	**Mixture-D4**	1/3 $DM_{Mixture-D}$ (washed) + 1/3 peat + 1/3 s.manure
26	**Mixture-D5**	1/2 $DM_{Mixture-D}$ (washed)+ 1/4 peat + 1/4 s.manure
27	**Mixture-D6**	2/3 $DM_{Mixture-D}$ (washed) + 1/6 peat + 1/6 s.manure
28	**Mixture-E1**	1/3 $DM_{Mixture-E}$ (unwashed) + 1/3 peat + 1/3 s.manure
29	**Mixture-E2**	1/2 $DM_{Mixture-E}$ (unwashed)+ 1/4 peat + 1/4 s.manure
30	**Mixture-E3**	2/3 $DM_{Mixture-E}$ (unwashed) + 1/6 peat + 1/6 s.manure
31	**Mixture-E4**	1/3 $DM_{Mixture-E}$ (washed) + 1/3 peat + 1/3 s.manure
32	**Mixture-E5**	1/2 $DM_{Mixture-E}$ (washed)+ 1/4 peat + 1/4 s.manure
33	**Mixture-E6**	2/3 $DM_{Mixture-E}$ (washed) + 1/6 peat + 1/6 s.manure

4.2.3.3 pH Adjustment of MT Samples

$DM_{Mixture}$ samples have "strongly alkaline" nature (pH=8.50-9.50) where the availability and uptake of macro- and micronutrients in/from soil can be restricted within this alkaline media. It is clear that soil pH should be within a range of 6.50-7.50 in order to receive the maximum amount of nutrients from soil (Sheehan et al., 2010).

Within this study, elevated pH values of MT samples were reduced by adding specified amounts of $FeSO_4.2H_2O$ (Iron (II) Sulfate dihydrate) into each MT samples as pointed out in Table 4.25 in order to adjust pH values.

Table 4.25. pH adjustment of MT samples

Mixture code Name/pH values	Addition of $FeSO_4.2H_2O$ amount			
	0 g	**10 g**	**20 g**	**30 g**
Control-1	**7.54**	7.13	6.71	6.40
Control-2	**7.61**	7.18	6.83	6.48
Control-3	**7.67**	7.10	6.92	6.67
Mixture-A1	7.93	7.78	7.63	**7.20**
Mixture-A2	8.01	7.84	7.59	**7.26**
Mixture-A3	8.19	7.92	7.65	**7.31**
Mixture-A4	7.98	7.82	7.61	**7.29**
Mixture-A5	8.04	7.79	7.66	**7.41**
Mixture-A6	8.14	7.82	7.67	**7.47**
Mixture-B1	7.88	7.76	7.66	**7.41**
Mixture-B2	8.08	7.85	7.71	**7.44**
Mixture-B3	8.23	7.98	7.74	**7.45**
Mixture-B4	7.86	7.71	7.60	**7.41**
Mixture-B5	8.01	7.82	7.66	**7.33**
Mixture-B6	8.11	7.94	7.72	**7.50**
Mixture-C1	8.03	7.88	7.63	**7.46**
Mixture-C2	8.26	8.01	7.74	**7.49**
Mixture-C3	8.51	8.12	7.76	**7.44**
Mixture-C4	8.08	7.92	7.68	**7.48**
Mixture-C5	8.34	7.99	7.72	**7.39**
Mixture-C6	8.44	8.06	7.78	**7.43**
Mixture-D1	7.97	7.78	7.63	**7.44**
Mixture-D2	8.03	7.76	7.58	**7.39**
Mixture-D3	8.29	7.87	7.69	**7.45**
Mixture-D4	8.02	7.78	7.61	**7.41**
Mixture-D5	8.10	7.74	7.58	**7.34**
Mixture-D6	8.14	7.81	7.62	**7.43**
Mixture-E1	8.07	7.77	7.59	**7.42**
Mixture-E2	8.19	7.86	7.67	**7.48**
Mixture-E3	8.34	7.93	7.65	**7.49**
Mixture-E4	8.10	7.85	7.63	**7.47**
Mixture-E5	8.23	7.89	7.68	**7.41**
Mixture-E6	8.41	8.05	7.70	**7.44**

Optimum amount of $FeSO_4.2H_2O$ for each specimen was found to be 30 g in order to provide neutral pH values. It's clear that $FeSO_4.2H_2O$ usually has a high degree of purity and is soluble in water. When it is applied to soils, it dissolves in soil water and hydrolyses to form sulfuric acid, which in turn supplies soluble calcium through its reaction with lime present in sodic soils; thus, reducing pH value of soil. Chemical reactions involved are as follows (Richards, 1954):

4.2.4 The Soil Quality Assessment of MT Samples Prior to Grass Seed Planting

The "Soil quality" analysis results of both control and MT samples (Figure 4.2) are presented in Table 4.26-Table 4.28 and were evaluated in compliance with the limit values given in Table A.1-Table A.3, respectively. The MT samples of interest were also evaluated within the context of EKAÇTKY- App.IIB and, the analysis results are pointed out in Table 4.29-Table 4.31, respectively.

The assessment of control and MT samples with regard to the "soil quality" is as follows:

- The soil texture classes are commonly identified as "loamy sand and sandy loam" soil for A, B, C and D-series of MT samples while “sandy-silty loam” soil for E-series of MTs, respectively.
- The weight percentages of sand fractions for MT samples are ranged between 55-75% whereas 75-83% for control samples.
- pH values of the entire MTs are found in neutral pH range (pH=6.50-7.50).
- 1^{st},2^{nd},3^{rd} numbered MT samples prepared by using unwashed $DM_{Mixtures}$ have some salt content ("moderately salty" EC: 4-8 mS/cm). However, 4^{th},5^{th},6^{th} numbered MT samples prepared with washed $DM_{Mixtures}$ have low salt content (“slightly salty” EC: 2-4 mS/cm).

Figure 4.2. Preparation stages of MT samples

Table 4.26. The "soil quality" analysis results of MT samples prior to grass growth (Control and Mixture-A topsoil samples)

Parameters/Samples		**Control -1-**	**Control -2-**	**Control -3-**	**Mix. A1**	**Mix. A2**	**Mix. A3**	**Mix. A4**	**Mix. A5**	**Mix. A6**
Water content (%)		24.43	22.96	16.93	33.46	27.39	26.76	30.93	28.84	26.07
Solid content (%)		75.57	77.04	83.07	66.54	72.61	73.24	69.07	71.16	73.93
pH (Aq. Sol.)		6.40	6.48	6.67	7.20	7.26	7.31	7.29	7.41	7.47
EC (at saturation) (mS/cm)		2.02	2.05	2.16	4.17	4.21	4.31	2.28	2.06	2.17
Soil texture;		(Sandy loam)	(Loamy sand)	(Loamy sand)	(Loamy sand)	(Loamy sand)	(Loamy sand)	(Loamy sand)	(Loamy sand)	(Loamy sand)
Sand (%):		67.9	71.1	73.3	84.1	86.4	87.1	83.7	86.1	86.8
Silt (%):		24.1	24.9	23.5	12.0	7.8	6.0	12.3	8.1	6.1
Clay (%):		8.0	4.0	3.2	3.9	5.8	6.9	4.0	5.8	7.1
Organic matter (%)		32.72	23.53	11.82	14.07	12.71	10.79	11.21	6.95	5.93
TC (mg/kg)		141,87	112,64	72,58	139,24	96,57	77,98	137,45	92,65	76,22
TOC (mg/kg)		139,43	101,69	65,35	133,55	90,26	70,97	132,75	87,221	69,10
IC (mg/kg)		2,44	10,94	7,23	5,69	6,31	7,01	4,70	5,43	7,12
Available micronutrients; (mg/kg)	Fe	357.3	342.2	306.8	156.3	162.7	138.3	192.4	217.3	125.9
	Cu	0.10	0.12	0.16	1.40	1.42	1.49	1.49	1.30	1.14
	Zn	2.42	1.39	1.19	3.25	1.96	0.07	10.51	6.10	4.10
	Mn	69.8	111.2	115.4	43.3	48.2	33.1	68.9	52.5	26.2
	Al	0.16	0.12	0.02	0.10	0.13	0.16	0.02	0.05	0.09
Available macronutrients; (mg/kg)	Ca	5898	10570	5395	7977	7822	7094	7989	8877	7576
	Mg	587	882	455	915	855	788	787	565	575
	Na	67	168	71	1618	2041	2355	997	1110	1037
	K	616	924	361	873	617	444	712	362	360
Total nitrogen (mg/kg)		5,891	3,395	2,409	4,178	3,556	1,694	5,525	3,599	1,559
Total phosphorus (mg/kg)		1455	871	643	974	814	765	1077	911	841

Table 4.27. The "soil quality" analysis results of MT samples prior to grass growth (Mixture-B and Mixture-C topsoil samples)

Parameters/Samples		**Mix. B1**	**Mix. B2**	**Mix. B3**	**Mix. B4**	**Mix. B5**	**Mix. B6**	**Mix. C1**	**Mix. C2**	**Mix. C3**	**Mix. C4**	**Mix. C5**	**Mix. C6**
Water content (%)		38.46	35.43	31.54	48.23	43.47	37.26	33.70	30.41	28.15	30.56	27.41	25.18
Solid content (%)		61.54	64.57	68.46	51.77	56.53	62.74	66.30	69.59	71.85	69.44	72.59	74.82
pH (Aq. Sol.)		7.41	7.44	7.45	7.41	7.33	7.50	7.46	7.49	7.44	7.48	7.39	7.43
EC (at saturation) (mS/cm)		4.06	4.11	4.98	2.37	2.12	2.23	4.36	4.14	4.62	2.01	2.04	2.03
Soil texture;		(Sandy loam)	(Loamy sand)	(Sandy loam)	(Sandy Loam)	(Loamy sand)	(Sandy loam)	(Loamy sand)	(Loamy sand)	(Loamy sand)	(Loamy sand)	(Loamy sand)	(Loamy sand)
Sand (%):		74.1	73.6	70.1	73.5	73.3	71.5	85.9	86.1	84.7	85.8	84.8	84.7
Silt (%):		17.9	20.0	27.0	18.3	20.3	24.4	8.4	10.9	8.7	8.3	11.10	8.8
Clay (%):		8.0	6.4	3.9	8.2	6.4	4.1	5.7	3.0	6.6	5.9	4.2	6.5
Organic matter (%)		14.73	11.17	9.08	14.71	7.48	5.12	19.44	15.67	5.97	18.05	13.72	8.31
TC (mg/kg)		147,18	128,48	87,68	145,24	130,34	86,59	152,38	127,08	101,59	151,78	124,39	105,65
TOC (mg/kg)		140,07	120,55	78,03	139,19	122,16	77,46	139,64	112,39	85,15	139,84	109,57	89,14
IC (mg/kg)		7,11	7,93	9,65	6,06	8,19	9,14	12,75	14,69	16,14	11,95	14,82	16,51
Available micronutrients; (mg/kg)	Fe	153.8	114.6	91.1	234.2	126.6	110.5	154.5	161.5	111.5	134.1	140.5	184.6
	Cu	5.79	6.44	9.78	9.29	7.64	4.28	1.89	1.74	1.78	1.49	1.72	2.13
	Zn	17.17	14.24	11.29	22.45	13.75	10.74	15.34	13.97	12.62	9.13	11.65	12.01
	Mn	70.7	36.2	31.2	108.3	48.6	27.6	85.1	83.7	60.6	66.7	82.8	94.8
	Al	0.01	0.01	0.03	0.02	0.04	0.04	0.02	0.03	0.04	0.01	0.01	0.01
Available macronutrients; (mg/kg)	Ca	10,060	7,764	7,403	9,880	8,888	7,834	9,729	8,416	8,460	8,960	7,981	8,541
	Mg	1,164	1,151	1,128	1,158	1,073	827	856	1,023	752	746	678	568
	Na	2,424	2,805	3,069	1,311	1,363	1,296	2,031	3,913	2659	1,120	1,181	1379
	K	1,044	867	720	983	757	469	887	857	593	760	558	412
Total nitrogen (mg/kg)		4,695	2,519	1,821	6,502	3,899	1,882	5,887	3,338	2,139	4,708	3,631	2,256
Total phosphorus (mg/kg)		1,410	1,035	712	1,569	1,078	834	1,866	1,319	1,030	1,275	1,172	722

Table 4.28. The "soil quality" analysis results of MT samples prior to grass growth (Mixture-D and Mixture-E topsoil samples)

Parameters/Samples		**Mix. D1**	**Mix. D2**	**Mix. D3**	**Mix. D4**	**Mix. D5**	**Mix. D6**	**Mix. E1**	**Mix. E2**	**Mix. E3**	**Mix. E4**	**Mix. E5**	**Mix. E6**
Water content (%)		41.66	38.17	36.23	47.31	44.63	42.11	42.29	38.91	33.59	45.78	43.00	37.32
Solid content (%)		58.34	61.83	63.77	52.69	55.37	57.89	57.71	61.09	66.41	54.22	57.00	62.68
pH (Aq. Sol.)		7.44	7.39	7.45	7.41	7.34	7.43	7.42	7.48	7.49	7.47	7.41	7.44
EC (at saturation) (mS/cm)		4.11	4.56	4.46	2.18	2.26	2.21	4.29	4.04	5.67	2.08	2.11	2.09
Soil texture;		(Sandy loam)	(Sandy loam)	(Sandy loam)	(Sandy loam)	(Sandy loam)	(Sandy loam)	(Sandy-Silty loam)	(Sandy Loam)	(Sandy loam)	(Sandy-Silty Loam)	(Sandy loam)	(Sandy loam)
Sand (%):		72.6	71.5	66.1	72.7	71.6	66.2	47.8	52.5	54.0	47.7	52.0	53.2
Silt (%):		24.1	24.4	24.9	23.9	24.2	24.9	50.2	43.5	41.0	49.9	44.2	42.0
Clay (%):		3.3	4.1	9.0	3.4	4.2	8.9	2.0	4.0	5.0	2.4	3.8	4.8
Organic matter (%)		8.29	5.75	4.87	10.34	7.06	4.34	9.48	6.13	4.65	8.26	7.35	4.13
TC (mg/kg)		146,85	126,99	94,12	148,01	127,46	92,62	141,55	118,03	83,02	140,32	116,64	86,12
TOC (mg/kg)		138,59	115,33	81,06	139,39	117,15	79,73	135,55	109,76	72,97	134,41	108,72	76,19
IC (mg/kg)		8,26	11,66	13,06	8,62	10,31	12,89	6,00	8,27	10,06	5,91	7,93	9,93
Available micronutrients; (mg/kg)	Fe	202.6	147.3	88.7	192.8	123.9	94.7	195.3	131.9	125.7	209.8	126.4	939
	Cu	2.65	2.67	3.78	3.06	3.31	4.20	3.80	4.08	3.53	3.70	2.85	3.10
	Zn	8.09	6.45	4.81	10.05	5.39	4.35	8.27	6.35	5.09	8.38	5.714	3.89
	Mn	76.9	57.6	31.4	90.5	55.4	31.2	106.2	61.9	56.2	105.9	74.6	37.8
	Al	0.01	0.01	0.02	0.01	0.05	0.07	0.03	0.09	0.15	0.10	0.13	0.45
Available macronutrients; (mg/kg)	Ca	9,688	10,100	8,299	9,703	8,892	8,387	9,566	10,020	8,893	9,809	9,285	7,670
	Mg	828	839	898	869	804	650	888	839	791	917	846	664
	Na	1,795	2,094	2,849	1,109	1,185	1,347	2,081	2,296	2,680	1,060	1,215	1,439
	K	789	707	639	847	627	397	883	786	641	877	760	564
Total nitrogen (mg/kg)		4,228	3,695	1,793	5,598	3,641	1,683	4,847	3,408	2,246	5,339	3,564	1,751
Total phosphorus (mg/kg)		1,346	988	695	1,102	969	812	1,228	1,015	918	1,351	1,103	904

Table 4.29. "EKAÇTKY-App.IIB" analysis results of MT samples and the relevant limit values (Control and Mixture-A topsoil samples)

Parameters/Samples	Control -1-	Control -2-	Control -3-	Mix. A1	Mix. A2	Mix. A3	Mix. A4	Mix. A5	Mix. A6	App. I-B, I-C, I-D limits
Pb (mg/kg)	<0.040	<0.040	0.111	0.694	<0.040	0.721	1.095	0.671	0.560	750
Cd (mg/kg)	0.041	<0.010	<0.010	0.051	<0.010	0.037	0.081	0.040	0.020	10
Cr (mg/kg)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	1000
Cu (mg/kg)	0.099	0.120	0.164	1.401	1.415	1.489	1.485	1.304	1.136	1000
Ni (mg/kg)	0.245	0.171	0.155	1.290	<0.020	1.422	1.143	1.289	1.198	300
Zn (mg/kg)	2.427	1.391	1.192	3.253	1.956	0.073	10.53	6.095	4.095	2500
Hg (mg/kg)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	10
TKN (mg/kg)	5,891	3,395	2,409	4,178	3,556	1,694	5,525	3,599	1,559	-
Total P (mg/kg)	1455	871	643	974	814	765	1077	911	841	-
PAH (mg/kg)	<0.005	<0.005	<0.005	0.031	0.05	0.066	0.033	0.048	0.067	6
PCB (mg/kg)	<0.1	<0.1	<0.1	0.08	0.14	0.19	0.09	0.13	0.18	0.8
PCDD/F (ng TEQ/kg)	<0.001	<0.001	<0.001	0.009	0.012	0.017	0.011	0.0105	0.018	100
pH	6.40	6.48	6.67	7.20	7.26	7.31	7.29	7.41	7.47	-
C/N (%)	24.08	33.18	30.13	33.33	27.16	46.02	24.88	25.74	48.90	-
Solid content (%)	75.57	77.04	83.07	66.54	72.61	73.24	69.07	71.16	73.93	-
LOI (%)	30.58	21.56	10.28	15.89	14.26	8.46	10.86	5.98	8.43	-
Organic matter (%)	32.72	23.53	11.82	14.07	12.71	10.79	11.21	6.95	5.93	-
EC (mS/cm)	2.02	2.05	2.16	4.17	4.21	4.31	2.28	2.06	2.17	-
Water content (%)	24.43	22.96	16.93	33.46	27.39	26.76	30.93	28.84	26.07	-
E.Coli (EMS/g)	not found/g									2Log10 (%99)

Table 4.30. "EKAÇTKY-App.IIB" analysis results of MT samples and the relevant limit values (Mixture-B and Mixture-C topsoil samples)

Parameters/Samples	**Mix. B1**	**Mix. B2**	**Mix. B3**	**Mix. B4**	**Mix. B5**	**Mix. B6**	**Mix. C1**	**Mix. C2**	**Mix. C3**	**Mix. C4**	**Mix. C5**	**Mix. C6**	**App. I-B, I-C, I-D limits**
Pb (mg/kg)	2.620	3.243	2.437	2.380	2.660	2.621	0.863	0.678	0.489	0.374	0.516	0.504	750
Cd (mg/kg)	0.127	0.079	0.070	0.139	0.070	0.052	0.092	0.051	0.028	0.019	0.039	0.044	10
Cr (mg/kg)	<0.020	<0.020	<0.020	<0.020	<0.020	<0.020	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	1000
Cu (mg/kg)	5.794	6.440	9.780	9.286	7.641	4.278	1.885	1.736	1.779	1.491	1.719	2.130	1000
Ni (mg/kg)	6.099	7.847	11.65	6.047	7.520	6.178	0.859	0.887	0.891	0.882	0.862	1.028	300
Zn (mg/kg)	17.17	14.24	11.29	22.45	13.75	10.74	15.34	13.97	12.62	9.139	11.65	12.01	2500
Hg (mg/kg)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	10
TKN (mg/kg)	4,695	25,19	1,821	6,502	3,899	1,882	5,887	3,338	2,139	4,708	3,631	2,256	-
Total P (mg/kg)	1,410	1,035	712	1,569	1,078	834	1,866	1,319	1,030	1,275	1,172	722	-
PAH (mg/kg)	0.089	0.125	0.162	0.093	0.129	0.159	0.257	0.389	0.512	0.264	0.375	0.496	6
PCB (mg/kg)	0.051	0.083	0.125	0.048	0.079	0.128	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.8
PCDD/F (ng TEQ/kg)	0.033	0.051	0.069	0.034	0.047	0.061	0.111	0.168	0.228	0.117	0.174	0.221	100
pH	7.41	7.44	7.45	7.41	7.33	7.50	7.46	7.49	7.44	7.48	7.39	7.43	-
C/N (%)	31.35	50.99	48.14	22.34	33.43	46.02	25.88	38.07	47.49	32.24	34.26	46.84	-
Solid content (%)	61.54	64.57	68.46	51.77	56.53	62.74	66.30	69.59	71.85	69.44	72.59	74.82	-
LOI (%)	13.45	10.56	8.69	13.45	8.25	4.56	18.56	14.67	4.93	17.65	12.59	7.67	-
Organic matter (%)	14.73	11.17	9.08	14.71	7.48	5.12	19.44	15.67	5.97	18.05	13.72	8.31	-
EC (mS/cm)	4.06	4.11	4.98	2.37	2.12	2.23	4.36	4.14	4.62	2.01	2.04	2.03	-
Water content (%)	38.46	35.43	31.54	48.23	43.47	37.26	33.70	30.41	28.15	30.56	27.41	25.18	-
E.Coli (EMS/g)	not found/g												2Log10 (%99)

Table 4.31. "EKAÇTKY-App.IIB" analysis results of MT samples and the relevant limit values (Mixture-D and Mixture-E topsoil samples)

Parameters/Samples	**Mix. D1**	**Mix. D2**	**Mix. D3**	**Mix. D4**	**Mix. D5**	**Mix. D6**	**Mix. E1**	**Mix. E2**	**Mix. E3**	**Mix. E4**	**Mix. E5**	**Mix. E6**	**App. I-B, I-C, I-D Limits**
Pb (mg/kg)	1.198	1.314	1.052	1.685	0.955	4.976	1.503	1.809	2.906	1.644	1.384	1.304	750
Cd (mg/kg)	0.074	0.061	0.047	0.091	0.050	0.031	0.076	0.058	0.055	0.077	0.041	0.022	10
Cr (mg/kg)	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	1000
Cu (mg/kg)	2.645	2.665	3.775	3.059	3.313	4.199	3.799	4.077	3.528	3.695	2.850	3.101	1000
Ni (mg/kg)	1.476	1.587	1.472	1.693	1.685	1.483	0.913	0.859	0.750	0.961	0.641	0.737	300
Zn (mg/kg)	8.091	6.445	4.813	10.05	5.392	4.349	8.267	6.349	5.098	8.384	5.714	3.889	2500
Hg (mg/kg)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	10
TKN (mg/kg)	4,228	3,695	1,793	5,598	3,641	1,683	4,847	3,408	2,246	5,340	3,564	1,751	-
Total P (mg/kg)	1,346	988	695	1,102	969	812	1,228	1,015	918	1,351	1,103	904	-
PAH (mg/kg)	0.841	0.564	0.115	0.823	0.547	0.121	0.028	0.041	0.053	0.029	0.037	0.051	6
PCB (mg/kg)	0.060	0.089	0.123	0.062	0.092	0.130	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.8
PCDD/F (ng TEQ/kg)	0.015	0.024	0.031	0.018	0.019	0.026	0.031	0.048	0.067	0.035	0.051	0.064	100
pH	7.44	7.39	7.45	7.41	7.34	7.43	7.42	7.48	7.49	7.47	7.41	7.44	-
C/N (%)	34.73	34.37	52.51	26.44	35.00	55.03	29.20	34.64	36.97	26.28	32.73	49.18	-
Solid content (%)	58.34	61,83	63.77	52.69	55.37	57.89	57.71	61.09	66.41	54.22	57.00	62.68	-
LOI (%)	7.68	4.59	3.68	12.56	8.14	5.49	7.89	5.96	4.91	10.87	8.96	5.64	-
Organic matter (%)	8.29	5.75	4.87	10.37	7.06	4.34	9.48	6.13	4.65	8.26	7.35	4.13	-
EC (mS/cm)	4.11	4.56	4.46	2.18	2.26	2.21	4.29	4.04	5.67	2.08	2.11	2.09	-
Water content (%)	41.66	38.17	36.23	47.31	44.63	42.11	42.29	38.91	33.59	45.78	43.00	37.32	-
E.Coli (EMS/g)	not found/g												2Log10 (%99)

- Entire MTs are rich in terms of available macronutrients (Ca, Mg, Na, K) and available micronutrients (Fe, Cu, Zn, Mn) (enough-(very) high) with DMs.
- Their organic matter contents are found quite in “high” level (4.5-32%) due to the presence of sheep anure.
- The contents of total nitrogen and phosphorus of both control and MT samples are found as “very high” because of the addition of Sheep Manure.
- According to “EKAÇTKY-App.IIB” analysis results, the contents of heavy metals (Pb, Cd, Cr, Cu, Ni, Zn, As, Hg), organic pollutants (PAH, PCB, pesticides, tributyltin, PCDD/F) and the physical analysis results are below the relevant limit values and are found as suitable.

4.2.5 The Assessment of Grass Growing Studies in the MT Samples

1.0 g of high quality lawn seed mixture was planted into each 2 L plastic pots containing MT samples prepared with washed and unwashed $DM_{Mixture}$ samples and natural soil. The plant growth performances for all MT samples were monitored during six-months period (Figure 4.3, Figure 4.4 and Figure 4.5).

Figure 4.3. The monitoring of grass growth performance in Mixture-C6 topsoil sample

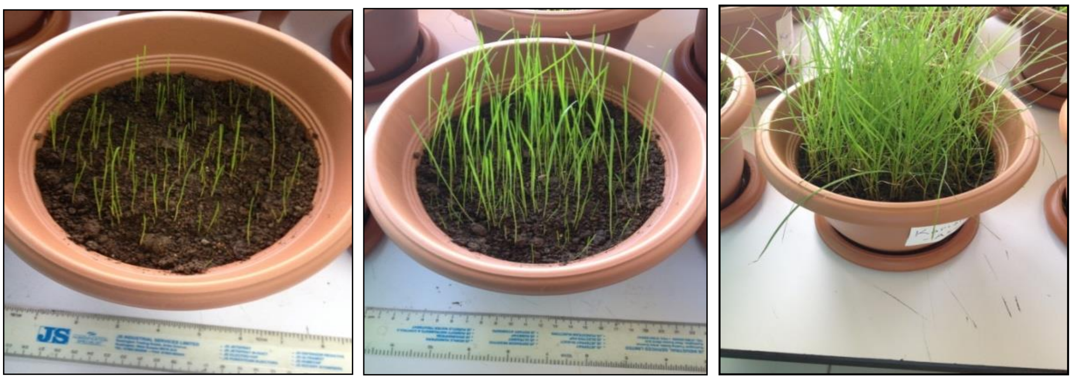


Figure 4.4. The monitoring of grass growth performance in Mixture-A4 topsoil sample

Figure 4.5. The general view for a total of 33 MT samples before and after harvest

The assessment of grass color: The colors of plants grown are evaluated with the scale ranging from 1 to 5 before each plant harvest; 1: flimsy, light yellow color, 2: light yellow-green, 3: light green, 4: green ve 5: dark green. In this scale, 1 and 2 values show the deficiency of one or more plant nutrients; 5 value gives information about the excess of plant nutrients, especially nitrogen redundancy. Plants having green colour are mainly provided by nitrogen and phosphorus elements taken from soil. The colour of grasses grown for the environmental landscaping to the scope of this study corresponds to the 4 value (green). Also, this value represents the normal growing of grasses and it is the desired plant/grass colour in the urban landscaping (Haraldsen et al., 2014). It is observed that grasses grown in all MT samples have 4 (green) colour value.

The results of plant growth performances in all MT samples for a total of six harvests are demonstrated in between Table B.1 and Table B.4 in terms of germination success rate (%), total harvest height (cm), average harvest height (cm) and biomass production (fresh and dried at 40°C) (g), respectively. The graphical representation of the relevant parameters are also illustrated in from Figure 4.6 to Figure 4.10.

As it can be seen from Figure 4.6, control sample has a maximum seed germination rate of 96.5%, as expected. Mixture-A5 and Mixture-C6 comprising washed $DM_{Mixtures}$ have better germination rates (79.8% and 76.5%) than those of Mixture-A2 and Mixture-C3 (61.2% and 30.6%) including unwashed $DM_{Mixtures}$. In addition, Mixture-A2 and Mixture-C3 possess slightly saline nature. To sum up, more grass seeds were germinated in MT samples with washed $DM_{Mixtures}$. Salts found in the soil's root zone can increase the osmotic pressure; thus, they decrease the plant productivity due to the lack of water and nutrients uptake by roots (Horneck et al., 2007).

It is seen from Figure 4.7 and Figure 4.8 that the total and average harvest heights of the entire MT samples increase dramatically in the second harvest while continue generally to enhance in the third and fourth harvests. However, growth heights decrease partially in the fifth harvest. It is not surprising that lower EC values (EC=0-2 mS/cm (salt-free)) provide easier uptake of plant nutrients and water from the root zone where MT having lower EC values (A5, C6) showed better performances than those of other MTs in terms of average and total harvest height. In addition, MT mixtures having soil texture of "loamy sand" also exhibited better plant growth rather than other MTs having "sandy loam" and etc. This result is also consistent with Woodard (1999).

Total biomass productions of MT samples, measured as sum of six harvests are illustrated in Figure 4.9. It is found that the washed mixtures of C5, C6 and A5 achieved greater biomass rather than the unwashed mixtures of C2, C3 and A2, respectively. In addition, mixtures of both A and C samples have performed better biomass production than those of other ones. These biomass results are also consistent with total and average harvest heights of each MT sample. Germination success rate (%), average and total harvest heights, and biomass production results were also in agreement with Sheehan et al. (2010).

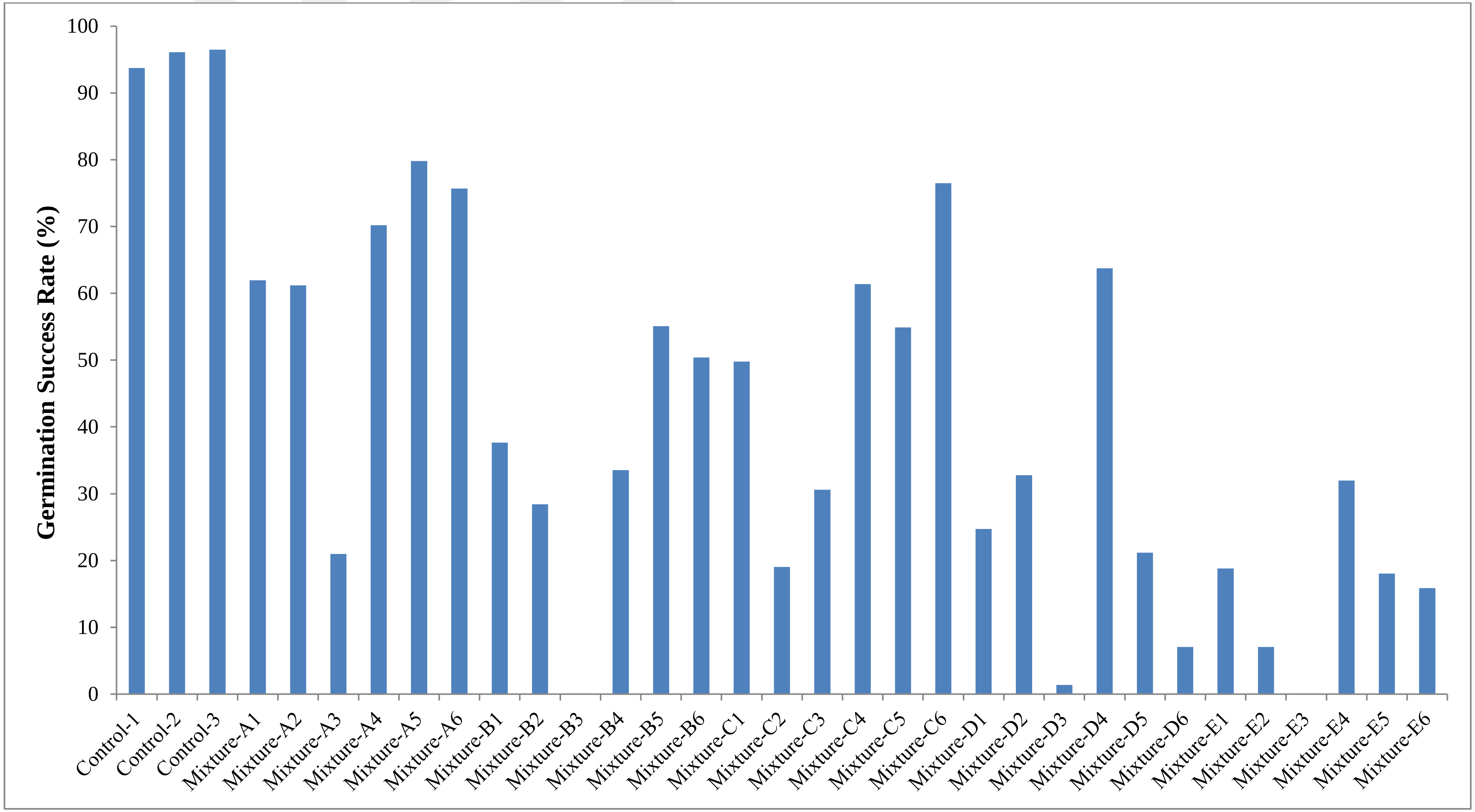


Figure 4.6. Graphical representation of seed germination success rates of MT samples

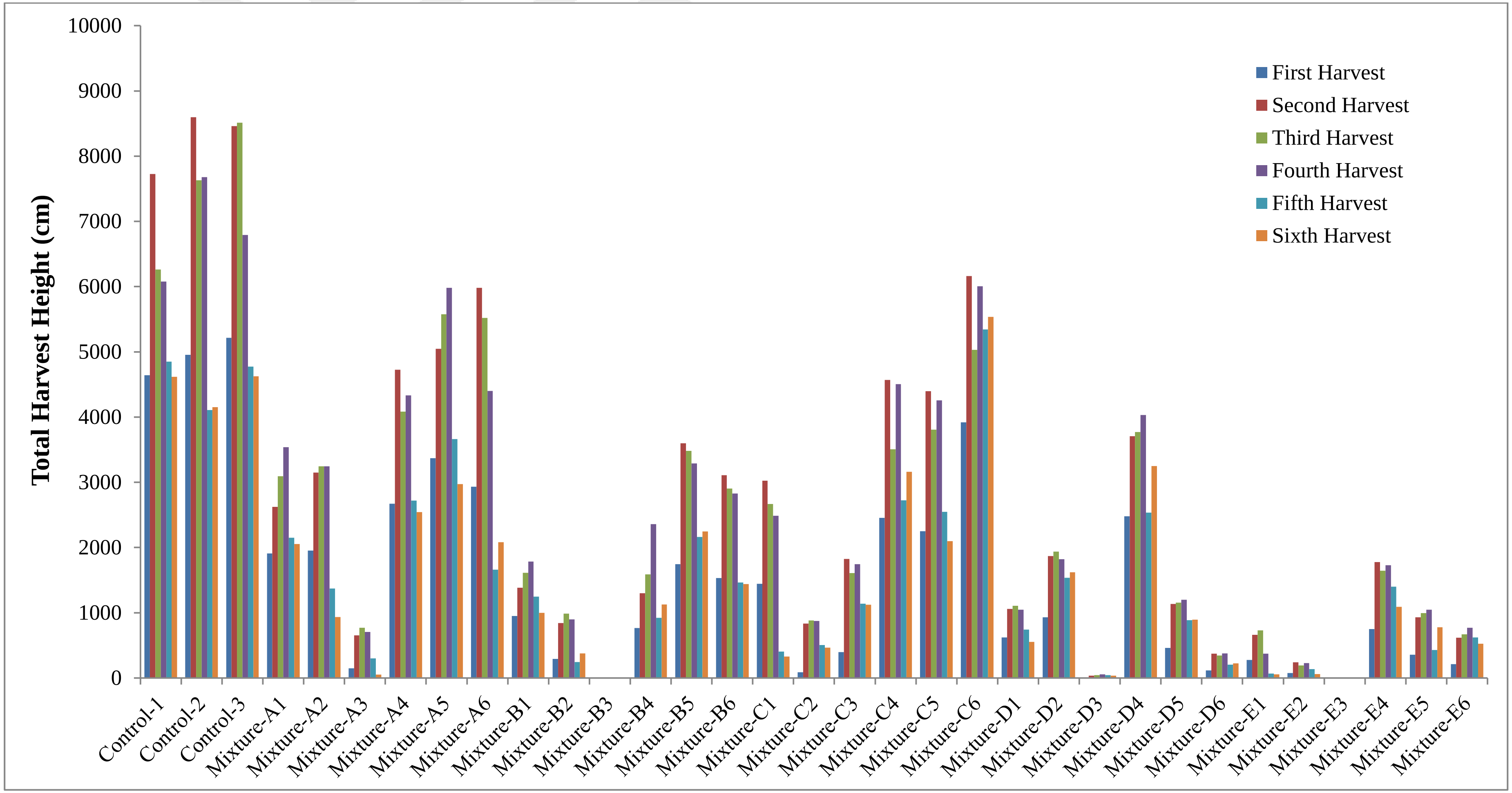


Figure 4.7. Graphical representation of total harvest heights of MT samples

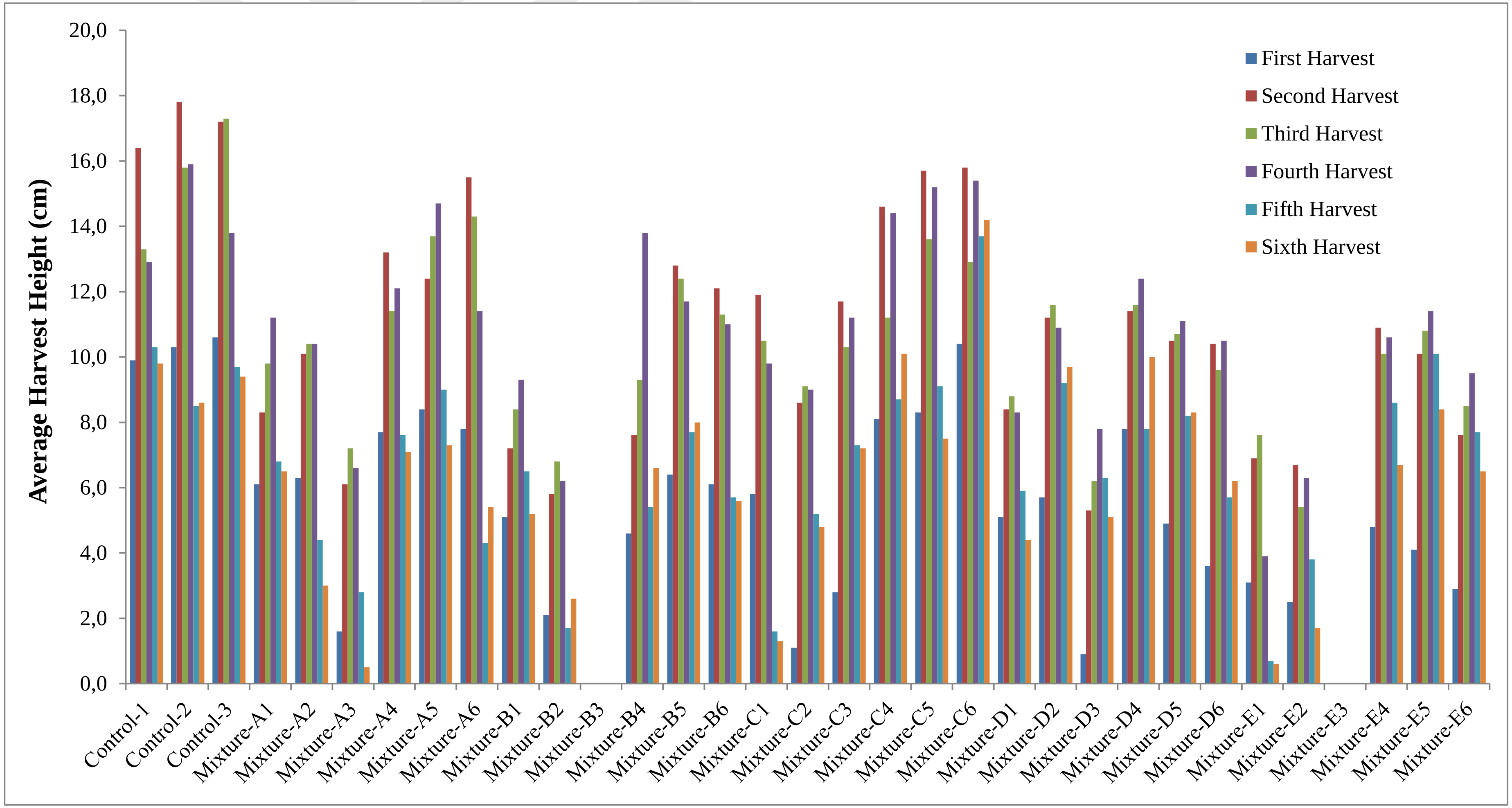


Figure 4.8. Graphical representation of average harvest heights of MT samples

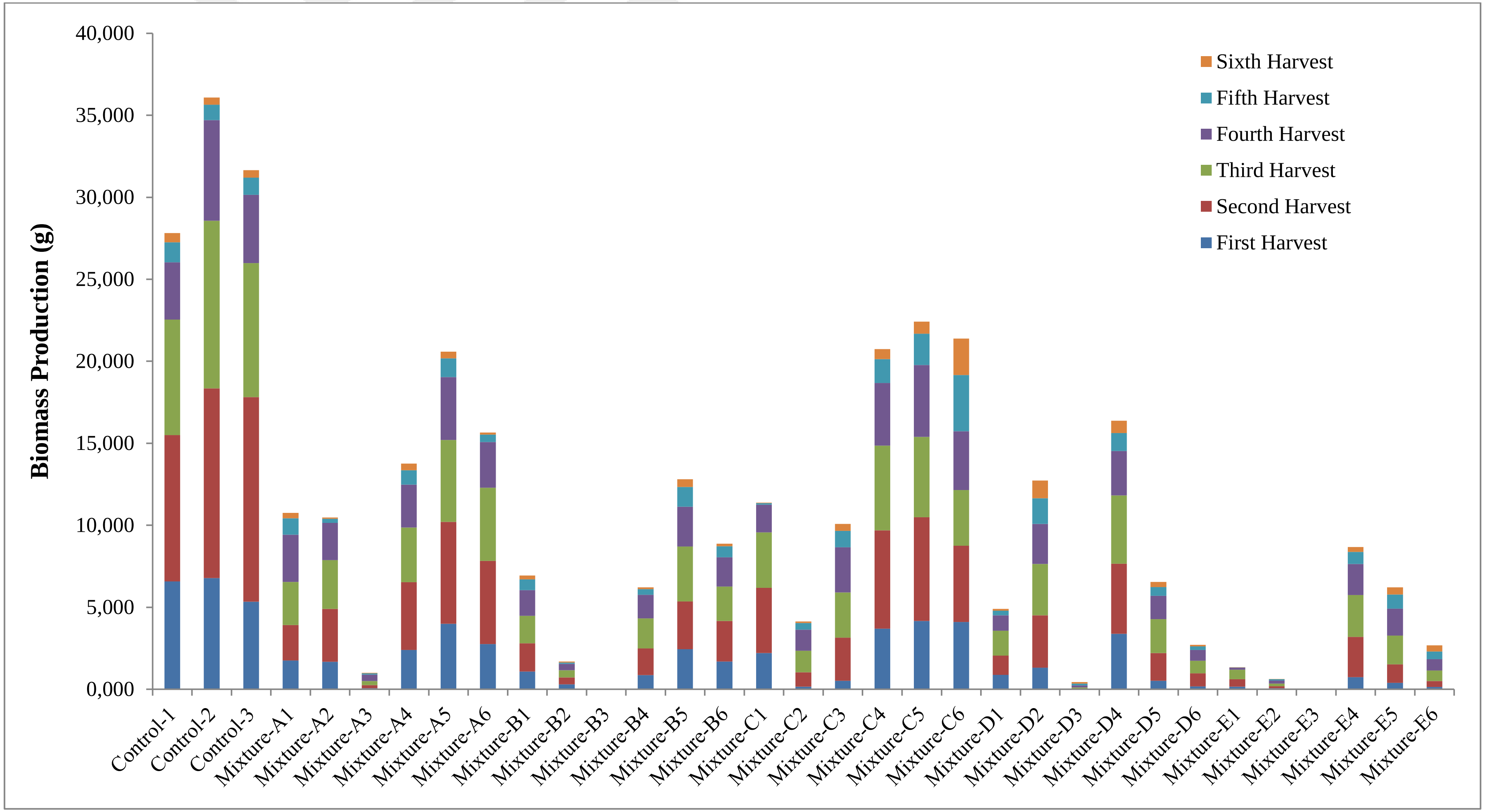


Figure 4.9. Graphical representation of biomass production quantities of MT samples

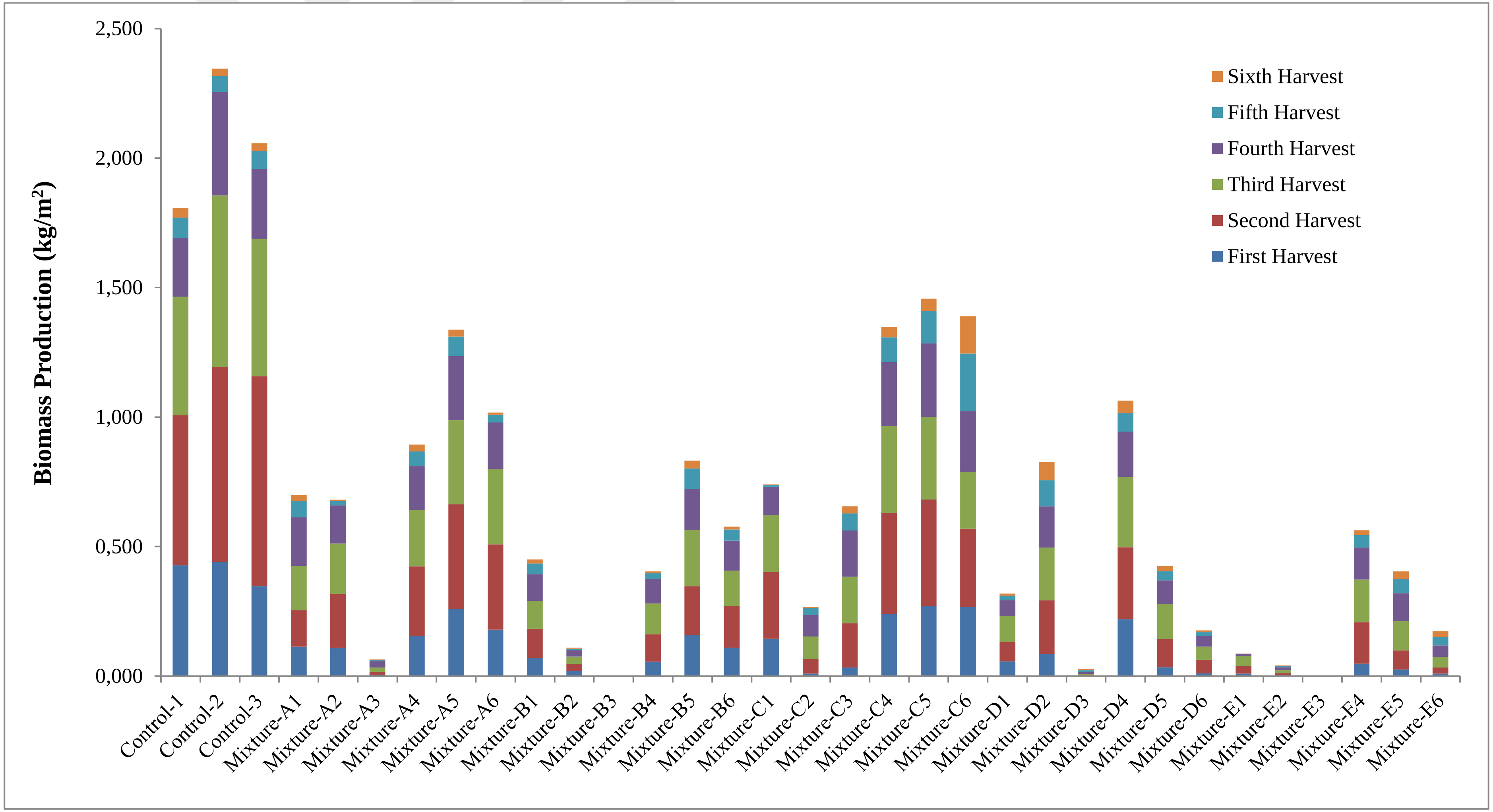


Figure 4.10. Graphical representation of biomass production quantities of MT samples

Considering the grass growth performances during six-months period, efficiency ranking was made among the entire MT samples by giving equal scores for each performance indicator of interest. The ranking scores for all MT samples are summarized in Table 4.32 with respect to germination success rate (%), total and average growth height (cm) and biomass production (g), respectively.

Table 4.32. Ranking scores of plant growth performances of MT samples

Sample codes	Germination success rate (%)	Total growth height (cm)	Average growth height (cm)	Biomass production (g)	Overall ranking
Control-1	3	3	4	5	4
Control-2	2	2	3	2	2
Control-3	1	1	2	1	1
Mixture-A1	9	12	17	14	12
Mixture-A2	11	14	19	15	15
Mixture-A3	24	27	28	29	28
Mixture-A4	7	6	9	12	9
Mixture-A5	4	5	6	6	5
Mixture-A6	6	8	11	10	10
Mixture-B1	16	17	23	20	20
Mixture-B2	21	24	29	27	26
Mixture-B3	33	33	33	33	33
Mixture-B4	17	18	18	22	19
Mixture-B5	12	11	9	11	11
Mixture-B6	14	13	14	16	14
Mixture-C1	15	19	21	18	18
Mixture-C2	25	25	25	26	25
Mixture-C3	20	20	16	13	17
Mixture-C4	10	7	7	7	6
Mixture-C5	13	10	5	3	7
Mixture-C6	5	4	1	4	3
Mixture-D1	22	22	24	23	23
Mixture-D2	18	15	10	9	13
Mixture-D3	31	31	26	31	30
Mixture-D4	8	9	8	8	8
Mixture-D5	23	21	13	21	21
Mixture-D6	29	29	20	25	27
Mixture-E1	26	28	31	28	29
Mixture-E2	30	30	30	30	31
Mixture-E3	32	32	32	32	32
Mixture-E4	19	16	15	17	16
Mixture-E5	27	23	12	19	22
Mixture-E6	28	26	4	24	24

When six harvests were taken into consideration so far, the results obtained to the overall ranking with regard to grass growth performances can be listed as follows:

- Ranking of control samples according to the grass growth performances were;

- Control-3 > Control-2 > Control-1

- Mixture prescription showed the best grass growth performance was;
  - 6th numbered MT samples for each series
  - (2/3 $DM_{Mixture}$ (washed) + 1/6 peat + 1/6 sheep manure)
- The best MT samples according to the grass growth were;
  - Having high ‘’sand’’ content
  - Containing washed DM
  - C6 > A5 > C4 > C5 > D4 > A4 > A6
- The worst MT samples according to the grass growth were;
  - Having high ‘’silt-clay’’ content
  - Containing unwashed DM
  - B3 > E3> E2 > D3 > E1 > A3
- MT samples of no plant growth or germination of grass seeds were;
  - Having high ‘’silt-clay’’ content
  - Containing unwashed DM
  - B3, E3
- It is observed that as the amount of unwashed DM in MT samples increases, grass growth performances decrease. Furthermore, as the quantity of washed DM in MT samples increases, grass growth performances increase.

4.2.5.1 The Suggestions about the Usage of Marine DM as Topsoil

The suggestions are listed as follows for the usage of marine DM as MT in urban landscaping applications:

- Before the utilization of DM as MT in urban landscaping applications, *characterization* (AYY-App.3B analysis) should be done and it may be required *some pre-treatments* such as sieving, desalination (washing), organic amelioration and pH adjustment, respectively.
- Salinity level should be minimized to a level of *not preventing the cultivation of plants.* DM can always be used if precaut*ions are taken in order to prevent the increase of salinity.*
- The most important issue to prevent the formation of salini*ty is the formation of drainage infrastructure* in areas using MT produced with marine DMs.

- The ideal irrigation method is "*drip irrigation*" method among pressurized irrigation methods in the irrigation of this type of soil.
- In this irrigation method, plant growth becomes more feasible *even in salty soil* compared to other irrigation.
- Drainage system is required in drip irrigation method and it will require less investment than other irrigation methods.
- Another issue, which increases the salinity is *the fertilization* to be used in application area. The addition of fertilizer in appropriate time and dose will *minimize the salinity problem*.
- *A fertilization program to be selected pursuant to the type of plants of interest* will provide healthier plant development in this type of MTs.
- In the application, the salt deposition risk is a problem that may arise in case of *an uncontrolled fertilization program* or *not establishing any proper drainage system*.
- There is almost no salt accumulation risk with drip irrigation method.
- MTs under investigation produced by DMs can be used in the rehabilitation of uncontrolled dumping areas, the reclamation of abandoned quarries/mineries, the rehabilitation of areas exposed to wind and water and the cultivation of ornamental plants and forest products, respectively.

4.2.6 The Assessment of Irrigation Water (TÜBİTAK MAM Gebze Campus Tap Water) Analysis Results

The analysis results of TÜBİTAK MAM campus tap water in accordance with "Notification of Wastewater Plant Technical Methods Appendix-7: (E7.1, E7.2 and E7.7)" limit values are reported in between Table 4.33 and Table 4.35, respectively. According to the analysis results, the tap water was found to be suitable for utilization as an irrigation water.

Table 4.33. TÜBİTAK MAM campus tap water sample analysis results and "Notification of Wastewater Plant Technical Methods Appendix-7.1"; Classification limit values of purified wastewater to be used for irrigation

Parameters	Result	Table E7.1 limit values (Class A)
pH	7.58	6 - 9
BOD (mg/L)	< 5	< 20
Turbidity (NTU)	0.19	< 2
Fecal coliform (kob/100 ml)	0	0
Free chlorine (S. Cl_2 mg/L)	< 0.05	> 1

Table 4.34. TÜBİTAK MAM campus tap water sample analysis results and "Notification of Wastewater Plant Technical Methods Appendix-7.2"; The chemical quality assessment values of irrigation water

Parameters	Result	Hazard Degree in Use		
		None	Little - Medium	Hazardous
		Class I Water	Class II Water	Class III Water
Salinity;				
EC (µS/cm)	294	< 700	700 - 3000	> 3000
TDS (mg/L)	146	< 500	500 - 2000	> 2000
Permeability;				
SAR_{Tad} 0-3	1.13	EC ≥ 0.7	0.7 - 0.2	< 0.2
Specific Ion Toxicity;				
Na (mg/L)	42.5			
Surface Irrigation		< 3	3 - 9	>9
Drip Irrigation		< 70	>70	
Chloride (Cl^-)(mg/L)	3.22			
Surface Irrigation		< 140	140 - 350	>350
Drip Irrigation		< 100	> 100	
B (mg/L)	0.018	< 0.7	07 – 3.0	>3.0

Table 4.35. TÜBİTAK MAM campus tap water sample analysis results and "Notification of Wastewater Plant Technical Methods Appendix-7.7"; Maximum permissible heavy metals and toxic elements limit values in irrigation waters

Parameters	Result	Maximum permissible concentrations: The limit values on all kinds of ground when continuously irrigated	Maximum permissible concentrations: Clayey soils having a pH 6.0-8.5 when irrigation <20 years
Al (mg/L)	0.03	5.00	20.00
As (mg/L)	< 0.0005	0.1	2.0
Be (mg/L)	< 0.0001	0.1	0.5
B (mg/L)	0.018	1.0	> 3.75
Cd (mg/L)	0.00005	0.01	0.05
T.Cr (mg/L)	< 0.0005	0.1	1.0
Co (mg/L)	0.00035	0.05	5.0
Cu (mg/L)	0.0016	0.2	0.5
F^- (mg/L)	0.05	1.0	15.0
Fe (mg/L)	0.012	5.0	20.0
Pb (mg/L)	0.00026	5.0	10.0
Li (mg/L)	0.00101	2.5	2.5
Mn (mg/L)	0.0014	0.2	10.0
Mo (mg/L)	< 0.005	0.01	0.05
Ni (mg/L)	0.0006	0.2	2.0
Se (mg/L)	0.0011	0.02	0.02
V (mg/L)	< 0.0005	0.1	1.0
Zn (mg/L)	0.19	2.0	10.0

4.2.7 The Evaluation of Analysis Results of Plant Nutrients in Harvested Grasses

The analysis results of the available plant nutrients obtained for entire MT samples at each harvest are given in between Table 4.36 and Table 4.41 together with the sufficiency ranges of relevant macro- and micronutrients.

Sufficiency range of a plant is the range of nutrient amount to maximize growth and to satisfy the nutritional requirements of the plant (McCauley et al., 2011). As it can be seen from Table 4.36 through Table 4.41, the concentrations of macro- and micronutrients of the harvested grasses have been found between plant's sufficiency ranges in most cases. However, there are also some exceptions observed for the quantities of nutrients. For instance, the concentrations of Mg and Ca were above the limit (toxicity range) at some harvests, especially in the control samples, Mixture-A4, Mixture-C4, Mixture-C5 and Mixture-C6 samples. The concentration of

Ca in grasses harvested in MT samples comprising washed $DM_{Mixture}$ samples is often higher than those of including unwashed $DM_{Mixture}$ samples. It is clear that the excess of macro-elements such as Ca inhibits the uptake of micro-elements (i.e. deficiency of Mn) required for the plant growth. It is a well-known fact that nitrogen, phosphorus and potassium are primary macronutrients and play a structural role in the plant growth (Pagani et al., 2014). It is found that all harvested grasses contain sufficient amounts of these elements which are in agreement with the green (4^{th} numbered colour) colour of harvested grasses. Moreover, harvested grasses of MT samples including washed $DM_{Mixture}$ samples are generally richer than those of unwashed in terms of macronutrients. Although sulfur contents of grasses have been found between the sufficiency range, N/S ratio, which is greater than 18 (Mills and Jones, 1996), indicates the sulfur deficiency of the grasses grown in MT samples containing unwashed $DM_{Mixture}$ samples. It is seen that the entire harvested grasses possess high contents of micronutrients.

Table 4.36. Plant nutrient concentrations in MT samples (first harvest)

Samples/ Parameters/ Sufficiency Range	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Cu (ppm)	Mn (ppm)	Zn (ppm)	N/S Ratio	N/K Ratio
	1-5 %	**0.1-0.5 %**	**2-4 %**	**0.4-0.8 %**	**0.1-0.4 %**	**0.1-0.4 %**	**50-250 ppm**	**5-20 ppm**	**25-300 ppm**	**25-150 ppm**	**10-15**	**1.2-2.2**
Control-1	3.92	0.37	4.19	1.08	0.71	0.27	145	12	148	46	14.51	0.94
Control-2	3.48	0.28	3.94	0.85	0.60	0.28	149	13	189	50	12.43	0.88
Control-3	2.57	0.27	3.31	0.82	0.69	0.20	155	17	231	54	12.85	0.78
Mixture-A1	2.93	0.21	1.95	0.43	0.29	0.13	14	12	95	59	22.54	1.50
Mixture-A2	2.24	0.20	1.55	0.36	0.27	0.11	143	17	106	44	20.36	1.45
Mixture-A3	Content could not be determined.											
Mixture-A4	2.94	0.26	2.70	0.52	0.49	0.22	157	19	84	88	13.36	1.09
Mixture-A5	3.74	0.19	2.79	0.45	0.40	0.27	147	18	62	62	13.85	1.34
Mixture-A6	2.53	0.16	2.12	0.37	0.42	0.22	162	16	75	74	11.50	1.19
Mixture-B1	2.48	0.18	1.87	0.35	0.24	0.14	137	14	91	69	17.71	1.33
Mixture-B2	Content could not be determined.											
Mixture-B3	Harvest could not be made.											
Mixture-B4	1.98	0.17	1.85	0.29	0.26	0.15	143	20	81	48	13.21	1.07
Mixture-B5	2.65	0.20	1.98	0.38	0.31	0.20	160	22	94	68	13.40	1.34
Mixture-B6	2.87	0.13	2.24	0.43	0.28	0.21	168	22	97	76	13.67	1.28
Mixture-C1	2.87	0.19	2.10	0.38	0.32	0.19	139	13	59	64	15.11	1.37
Mixture-C2	Content could not be determined.											
Mixture-C3	Content could not be determined.											
Mixture-C4	3.14	0.21	2.69	0.58	0.58	0.26	156	18	123	83	12.08	1.17
Mixture-C5	3.87	0.27	3.55	0.54	0.57	0.28	169	20	114	79	13.82	1.09
Mixture-C6	3.32	0.33	3.16	0.43	0.55	0.26	182	26	155	95	12.80	1.05
Mixture-D1	2.42	0.03	1.73	0.33	0.17	0.14	151	14	99	38	17.29	1.40
Mixture-D2	2.38	0.08	1.27	0.37	0.20	0.15	142	16	77	36	15.87	1.87
Mixture-D3	Content could not be determined.											
Mixture-D4	2.66	0.30	3.48	0.44	0.33	0.18	164	23	77	74	14.78	0.76
Mixture-D5	Content could not be determined.											
Mixture-D6	Content could not be determined.											
Mixture-E1	Content could not be determined.											
Mixture-E2	Content could not be determined.											
Mixture-E3	Harvest could not be made.											
Mixture-E4	Content could not be determined.											
Mixture-E5	Content could not be determined.											
Mixture-E6	Content could not be determined.											

Table 4.37. Plant nutrient concentrations in MT samples (second harvest)

Samples/ Parameters/ Sufficiency Range	N (%) 1-5 %	P (%) 0.1-0.5 %	K (%) 2-4 %	Ca (%) 0.4-0.8 %	Mg (%) 0.1-0.4 %	S (%) 0.1-0.4 %	Fe (ppm) 50-250 ppm	Cu (ppm) 5-20 ppm	Mn (ppm) 25-300 ppm	Zn (ppm) 25-150 ppm	N/S Ratio 10-15	N/K Ratio 1.2-2.2
Control-1	4.29	0.43	4.59	1.58	0.78	0.34	201	19	187	65	12.62	0.93
Control-2	4.64	0.35	5.26	1.06	0.59	0.35	165	23	263	63	13.26	0.88
Control-3	3.35	0.47	3.87	1.09	0.54	0.29	188	17	299	82	11.55	0.87
Mixture-A1	3.47	0.24	2.77	0.50	0.30	0.21	154	12	95	87	16.52	1.25
Mixture-A2	4.03	0.38	2.92	0.47	0.36	0.26	186	18	174	93	15.50	1.38
Mixture-A3							Content could not be determined.					
Mixture-A4	4.75	0.41	4.75	0.90	0.52	0.38	213	21	125	112	12.50	1.00
Mixture-A5	4.42	0.28	4.15	0.70	0.48	0.36	186	25	88	64	12.28	1.07
Mixture-A6	4.06	0.27	3.67	0.65	0.43	0.36	165	20	139	70	11.27	1.11
Mixture-B1	3.98	0.30	3.29	0.49	0.36	0.28	172	19	98	76	14.21	1.21
Mixture-B2							Content could not be determined.					
Mixture-B3							Harvest could not be made.					
Mixture-B4	3.10	0.28	2.90	0.35	0.23	0.28	162	11	88	68	10.69	1.07
Mixture-B5	3.37	0.24	2.69	0.44	0.24	0.30	156	15	72	57	11.23	1.25
Mixture-B6	3.47	0.19	3.12	0.58	0.33	0.31	207	19	108	91	11.19	1.11
Mixture-C1	4.33	0.35	3.58	0.60	0.40	0.29	173	17	70	83	14.93	1.21
Mixture-C2							Content could not be determined.					
Mixture-C3	3.57	0.21	2.75	0.33	0.29	0.23	119	15	65	80	15.52	1.30
Mixture-C4	4.57	0.31	3.54	0.67	0.57	0.34	203	20	68	107	13.44	1.29
Mixture-C5	4.34	0.34	3.38	0.69	0.67	0.35	156	15	72	74	12.40	1.28
Mixture-C6	3.06	0.31	3.67	0.77	0.65	0.28	16	18	151	55	10.93	0.83
Mixture-D1	3.98	0.07	3.11	0.42	0.24	0.26	166	12	117	40	15.31	1.28
Mixture-D2	3.14	0.23	2.84	0.48	0.21	0.22	142	12	103	41	14.27	1.11
Mixture-D3							Content could not be determined.					
Mixture-D4	3.15	0.27	3.62	0.59	0.28	0.26	160	13	81	68	12.12	0.87
Mixture-D5	2.65	0.13	2.26	0.58	0.25	0.22	144	11	78	57	12.05	1.17
Mixture-D6							Content could not be determined.					
Mixture-E1							Content could not be determined.					
Mixture-E2							Content could not be determined.					
Mixture-E3							Harvest could not be made.					
Mixture-E4	3.25	0.19	2.66	0.50	0.26	0.28	141	11	104	30	11.61	1.22
Mixture-E5	2.67	0.14	1.70	0.52	0.21	0.26	124	9	92	27	10.27	1.57
Mixture-E6							Content could not be determined.					

Table 4.38. Plant nutrient concentrations in MT samples (third harvest)

Samples/ Parameters/	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Cu (ppm)	Mn (ppm)	Zn (ppm)	N/S Ratio	N/K Ratio
Sufficiency Range	**1-5 %**	**0.1-0.5 %**	**2-4 %**	**0.4-0.8 %**	**0.1-0.4 %**	**0.1-0.4 %**	**50-250 ppm**	**5-20 ppm**	**25-300 ppm**	**25-150 ppm**	**10-15**	**1.2-2.2**
Control-1	3.89	0.38	3.74	1.12	0.67	0.34	157	11	145	51	11.44	1.04
Control-2	4.36	0.29	4.23	0.88	0.51	0.38	136	18	215	51	11.47	1.03
Control-3	2.47	0.35	2.56	0.65	0.31	0.24	125	11	266	53	10.29	0.96
Mixture-A1	4.33	0.31	2.94	0.52	0.33	0.28	182	14	108	98	15.46	1.47
Mixture-A2	4.13	0.38	2.57	0.43	0.33	0.26	183	16	161	81	15.88	1.61
Mixture-A3	Content could not be determined.											
Mixture-A4	4.05	0.34	3.37	0.65	0.41	0.34	164	24	89	81	11.91	1.20
Mixture-A5	4.07	0.22	3.20	0.55	0.38	0.36	149	18	70	50	11.31	1.27
Mixture-A6	4.06	0.28	3.31	0.49	0.41	0.35	152	16	124	67	11.60	1.23
Mixture-B1	4.04	0.29	2.84	0.46	0.32	0.27	163	17	89	86	14.96	1.42
Mixture-B2	Content could not be determined.											
Mixture-B3	Harvest could not be made.											
Mixture-B4	3.94	0.33	2.91	0.36	0.29	0.30	183	14	106	59	13.13	1.35
Mixture-B5	3.62	0.26	2.61	0.41	0.29	0.31	175	18	79	66	11.68	1.39
Mixture-B6	3.62	0.16	2.69	0.45	0.30	0.34	181	16	80	80	10.65	1.35
Mixture-C1	4.20	0.32	3.25	0.56	0.35	0.27	144	15	66	74	15.56	1.29
Mixture-C2	4.30	0.19	2.98	0.54	0.36	0.25	163	17	76	89	17.20	1.44
Mixture-C3	4.21	0.24	3.28	0.42	0.32	0.27	124	16	71	92	15.59	1.28
Mixture-C4	4.44	0.30	2.69	0.60	0.34	0.33	173	15	49	93	13.45	1.65
Mixture-C5	4.20	0.28	3.08	0.48	0.33	0.34	128	11	54	66	12.35	1.36
Mixture-C6	2.91	0.30	2.31	0.39	0.23	0.28	152	13	124	43	10.39	1.26
Mixture-D1	4.06	0.05	2.93	0.45	0.25	0.26	167	12	107	40	15.62	1.39
Mixture-D2	3.39	0.23	2.54	0.49	0.24	0.20	144	13	102	42	16.95	1.33
Mixture-D3	Content could not be determined.											
Mixture-D4	3.51	0.29	3.35	0.46	0.30	0.26	149	13	82	65	13.50	1.05
Mixture-D5	3.26	0.14	2.39	0.47	0.26	0.26	168	13	103	71	12.54	1.36
Mixture-D6	3.42	0.08	2.88	0.31	0.24	0.23	122	10	74	56	14.87	1.19
Mixture-E1	Content could not be determined.											
Mixture-E2	Content could not be determined.											
Mixture-E3	Harvest could not be made.											
Mixture-E4	3.68	0.19	3.05	0.33	0.28	0.25	142	11	108	35	14.72	1.21
Mixture-E5	3.43	0.18	2.27	0.46	0.27	0.28	162	12	126	39	12.25	1.51
Mixture-E6	Content could not be determined.											

Table 4.39. Plant nutrient concentrations in MT samples (fourth harvest)

Samples/ Parameters/ Sufficiency Range	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Cu (ppm)	Mn (ppm)	Zn (ppm)	N/S Ratio	N/K Ratio
	1-5 %	**0.1-0.5 %**	**2-4 %**	**0.4-0.8 %**	**0.1-0.4 %**	**0.1-0.4 %**	**50-250 ppm**	**5-20 ppm**	**25-300 ppm**	**25-150 ppm**	**10-15**	**1.2-2.2**
Control-1	2.73	0.24	3.36	1.00	0.45	0.23	117	9	98	43	11.87	0.81
Control-2	3.17	0.21	3.66	0.79	0.38	0.29	108	14	162	47	10.93	0.87
Control-3	1.96	0.28	3.23	0.77	0.34	0.19	97	11	190	46	10.32	0.61
Mixture-A1	4.67	0.43	3.19	0.60	0.34	0.27	187	17	120	94	17.30	1.46
Mixture-A2	3.66	0.38	2.65	0.39	0.30	0.24	173	15	121	74	15.25	1.38
Mixture-A3	Content could not be determined.											
Mixture-A4	3.74	0.34	3.14	0.74	0.40	0.26	169	22	98	89	14.38	1.19
Mixture-A5	3.49	0.21	2.83	0.68	0.35	0.24	130	16	65	54	14.54	1.23
Mixture-A6	3.05	0.21	3.28	0.55	0.29	0.28	133	11	95	55	10.89	0.93
Mixture-B1	3.96	0.36	2.35	0.48	0.36	0.25	173	14	95	84	15.84	1.69
Mixture-B2	Content could not be determined.											
Mixture-B3	Harvest could not be made.											
Mixture-B4	3.35	0.28	2.81	0.48	0.29	0.24	169	15	97	74	13.96	1.19
Mixture-B5	2.40	0.23	2.47	0.45	0.26	0.21	148	15	66	79	11.43	0.97
Mixture-B6	3.67	0.18	2.74	0.48	0.30	0.25	194	18	78	87	14.68	1.34
Mixture-C1	2.34	0.21	2.36	0.40	0.24	0.16	95	9	40	69	14.63	0.99
Mixture-C2	4.36	0.24	.301	0.60	0.39	0.24	179	11	86	97	18.17	1.45
Mixture-C3	4.01	0.27	.317	0.42	0.34	0.23	156	14	79	103	17.43	1.26
Mixture-C4	3.28	0.34	3.53	0.68	0.39	0.29	171	15	49	95	11.31	0.93
Mixture-C5	4.32	0.28	3.81	0.64	0.47	0.30	149	18	90	91	14.40	1.13
Mixture-C6	3.74	0.30	4.47	0.71	0.54	0.27	208	18	139	100	13.85	0.84
Mixture-D1	2.97	0.04	2.24	0.38	0.18	0.20	155	10	65	34	14.85	1.33
Mixture-D2	2.79	0.15	2.39	0.38	0.21	0.17	126	11	78	39	16.41	1.17
Mixture-D3	Content could not be determined.											
Mixture-D4	2.79	0.20	2.77	0.51	0.24	0.27	112	12	64	55	10.33	1.01
Mixture-D5	2.70	0.14	2.26	0.49	0.21	0.24	145	12	85	64	11.25	1.19
Mixture-D6	Content could not be determined.											
Mixture-E1	Content could not be determined.											
Mixture-E2	Content could not be determined.											
Mixture-E3	Harvest could not be made.											
Mixture-E4	3.17	0.17	2.52	0.32	0.23	0.30	132	10	88	32	10.57	1.26
Mixture-E5	3.68	0.21	2.48	0.50	0.27	0.28	186	11	119	43	13.54	1.48
Mixture-E6	Content could not be determined.											

Table 4.40. Plant nutrient concentrations in MT samples (fifth harvest)

Samples/ Parameters/	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	S (%)	Fe (ppm)	Cu (ppm)	Mn (ppm)	Zn (ppm)	N/S Ratio	N/K Ratio
Sufficiency Range	**1-5 %**	**0.1-0.5 %**	**2-4 %**	**0.4-0.8 %**	**0.1-0.4 %**	**0.1-0.4 %**	**50-250 ppm**	**5-20 ppm**	**25-300 ppm**	**25-150 ppm**	**10-15**	**1.2-2.2**
Control-1	3.20	0.20	3.56	1.08	0.38	0.27	90	7	132	48	11.85	0.90
Control-2	2.79	0.29	3.17	0.96	0.30	0.25	75	8	140	44	11.16	0.88
Control-3	3.59	0.27	3.28	1.17	0.28	0.31	80	8	163	48	11.58	1.09
Mixture-A1	2.87	0.15	2.35	0.67	0.35	0.20	136	12	91	74	14.35	1.22
Mixture-A2							Content could not be determined.					
Mixture-A3							Content could not be determined.					
Mixture-A4	3.58	0.20	2.70	0.65	0.46	0.30	112	17	95	70	11.93	1.33
Mixture-A5	3.10	0.19	2.41	0.58	0.44	0.25	104	14	76	62	12.40	1.29
Mixture-A6							Content could not be determined.					
Mixture-B1							Content could not be determined.					
Mixture-B2							Content could not be determined.					
Mixture-B3							Harvest could not be made.					
Mixture-B4							Content could not be determined.					
Mixture-B5	3.65	0.25	2.92	0.51	0.45	0.26	148	18	83	71	14.04	1.25
Mixture-B6	2.71	0.09	2.37	0.48	0.41	0.22	133	12	78	73	12.32	1.14
Mixture-C1							Content could not be determined.					
Mixture-C2							Content could not be determined.					
Mixture-C3	2.95	0.20	2.48	0.40	0.35	0.18	106	13	79	74	16.39	1.19
Mixture-C4	2.72	0.19	3.04	0.64	0.44	0.19	118	10	64	64	14.32	0.89
Mixture-C5	3.23	0.30	3.60	0.56	0.48	0.24	101	11	49	67	13.46	0.89
Mixture-C6	4.24	0.18	4.18	0.68	0.54	0.33	175	20	158	85	12.85	1.01
Mixture-D1							Content could not be determined.					
Mixture-D2	3.12	0.34	2.56	0.48	0.36	0.17	140	11	58	46	18.35	1.22
Mixture-D3							Content could not be determined.					
Mixture-D4	2.42	0.19	2.99	0.48	0.30	0.25	99	9	58	48	9.68	0.81
Mixture-D5							Content could not be determined.					
Mixture-D6							Content could not be determined.					
Mixture-E1							Content could not be determined.					
Mixture-E2							Content could not be determined.					
Mixture-E3							Harvest could not be made.					
Mixture-E4	2.69	0.18	2.34	0.43	0.21	0.26	104	9	72	45	10.35	1.15
Mixture-E5	3.12	0.13	2.55	0.49	0.24	0.24	143	13	111	41	13.00	1.22
Mixture-E6							Content could not be determined.					

Table 4.41. Plant nutrient concentrations in MT samples (sixth harvest)

Samples/ Parameters/	**N (%)**	**P (%)**	**K (%)**	**Ca (%)**	**Mg (%)**	**S (%)**	**Fe (ppm)**	**Cu (ppm)**	**Mn (ppm)**	**Zn (ppm)**	**N/S Ratio**	**N/K Ratio**
Sufficiency Range	**1-5 %**	**0.1-0.5 %**	**2-4 %**	**0.4-0.8 %**	**0.1-0.4 %**	**0.1-0.4 %**	**50-250 ppm**	**5-20 ppm**	**25-300 ppm**	**25-150 ppm**	**10-15**	**1.2-2.2**
Control-1	2.54	0.26	2.59	0.90	0.48	0.24	143	13	179	57	10.58	0.98
Control-2	2.45	0.22	2.58	0.80	0.54	0.22	132	16	219	55	11.14	0.95
Control-3	2.30	0.24	2.47	0.86	0.64	0.22	129	15	303	63	10.45	0.93
Mixture-A1						Content could not be determined.						
Mixture-A2						Content could not be determined.						
Mixture-A3						Content could not be determined.						
Mixture-A4						Content could not be determined.						
Mixture-A5	2.69	0.13	1.99	0.48	0.61	0.26	138	17	83	48	10.35	1.35
Mixture-A6						Content could not be determined.						
Mixture-B1						Content could not be determined.						
Mixture-B2						Content could not be determined.						
Mixture-B3						Harvest could not be made.						
Mixture-B4						Content could not be determined.						
Mixture-B5	2.79	0.27	1.74	0.42	0.55	0.24	167	15	87	73	11.63	1.60
Mixture-B6						Content could not be determined.						
Mixture-C1						Content could not be determined.						
Mixture-C2						Content could not be determined.						
Mixture-C3						Content could not be determined.						
Mixture-C4	2.70	0.33	2.41	0.62	0.61	0.21	181	11	81	69	12.86	1.12
Mixture-C5	3.17	0.35	2.67	0.52	0.63	0.24	177	12	98	84	13.21	1.19
Mixture-C6	4.48	0.43	3.62	0.57	0.69	0.29	188	13	159	93	15.45	1.24
Mixture-D1						Content could not be determined.						
Mixture-D2	3.53	0.29	2.47	0.47	0.58	0.26	135	15	86	46	13.58	1.43
Mixture-D3						Content could not be determined.						
Mixture-D4	1.86	0.07	2.19	0.42	0.52	0.18	144	12	85	69	10.33	0.85
Mixture-D5						Content could not be determined.						
Mixture-D6						Content could not be determined.						
Mixture-E1						Content could not be determined.						
Mixture-E2						Content could not be determined.						
Mixture-E3						Harvest could not be made.						
Mixture-E4						Content could not be determined.						
Mixture-E5	1.96	0.11	2.29	0.40	0.49	0.16	159	10	113	34	12.25	0.86
Mixture-E6						Content could not be determined.						

4.2.8 The Assessment of Soil Quality Analysis Results of MT Samples at the End of Grass Growth Period

At the end of grass growth period, the physical and chemical analyses of MT samples taken from 1-5 cm depth of each pot were performed and the analysis results given in Table 4.42-Table 4.44 were evaluated with respect to soil quality limit values (Table A.1-Table A.3). The assessment of control and MT samples in terms of soil quality at the end of grass growth period is as follows:

- Control samples have slightly acidic pH nature while MT samples are found in neutral pH range.
- It is observed that the salt contents of the entire MT were reduced because of the regular irrigation for plant growth when compared with measurements made before grass planting. 1^{st},2^{nd},3^{rd} numbered MT samples have some salt content ("slightly salty" EC: 2-4 mS/cm) whereas 4^{th},5^{th},6^{th} numbered MT samples possess quite low salt contents (“saltless” EC: 0-2 mS/cm).
- When compared with measurements made before grass planting, there is some decrease in the quantities of total nitrogen and phosphorus of both control and MT samples. Nevertheless, their contents are found in the "too high" level due to the contribution of sheep manure. Moreover, it is seen that there is “very high” level of organic carbon content because of peat and sheep manure contributions.
- The contents of available macronutrients are still quite high compared with measurements made before grass planting.
- The porosities of MT samples prepared with marine DMs are ranged between 48-60%. Their pore volumes vary from 0.66 g/cm^3 to 0.78 g/cm^3.
- Specific gravities were determined between 1.67 g/cm^3 to 2.26 g/cm^3 and bulk densities were specified from 0.77 g/cm^3 to 1.02 g/cm^3, respectively.

Table 4.42. The "soil quality" analysis results of MT samples at the end of grass growth period (Control and Mixture-A topsoil samples)

Parameters/Samples		Control -1-	Control -2-	Control -3-	Mix. A1	Mix. A2	Mix. A3	Mix. A4	Mix. A5	Mix. A6
pH (Aq. Sol.)		6.32	6.36	6.54	7.13	7.21	7.27	7.25	7.32	7.38
EC (at sat.) (mS/cm)		1.54	1.71	1.83	3.48	3.59	3.67	1.87	1.94	1.98
TC (mg/kg)		120,20	87,56	56,68	130,74	89,72	72,69	117,87	87,81	71,43
TOC (mg/kg)		117,81	80,09	51,49	126,31	83,74	66,42	113,88	82,79	65,09
IC (mg/kg)		2,39	7,47	5,20	4,43	5,98	6,28	3,99	5,02	6,33
Total nitrogen (mg/kg)		5,185	3,073	1,862	3,950	3,327	1,584	3,895	3,222	1,458
Total phosphorus (mg/kg)		1,228	586	405	807	748	655	929	875	802
Available macronutrients; (mg/kg)	Ca	4,378	6,912	4,541	6,172	5,254	4,814	7,145	4,937	5,896
	Mg	327	505	210	673	636	522	506	476	410
	Na	51.86	110.3	64.17	1294	1586	1973	738.9	721.6	844.1
	K	442	578	302	618	496	307	478	291	277
C/N ratio		20.67	28.49	30.45	33.10	26.97	45.83	30.26	27.26	48.98
N/P ratio		4.22	5.24	4.60	4.90	4.45	2.42	4.19	3.68	1.82
Pore volume (m^3/m^3)		0.88	0.93	0.94	0.83	0.83	0.88	0.85	0.89	0.92
Specific gravity (g/cm^3)		1.90	2.01	1.15	1.88	2.09	2.21	1.87	2.05	2.26
Bulk density (g/cm^3)		0.81	1.01	2.16	0.97	1.01	1.03	0.94	0.97	1.02
Porosity (%)		57.4	49.8	46.8	48.4	51.7	53.4	49.7	52.7	54.9

Table 4.43. The "soil quality" analysis results of MT samples at the end of grass growth period (Mixture-B and Mixture-C topsoil samples)

Parameters/Samples		Mix. B1	Mix. B2	Mix. B3	Mix. B4	Mix. B5	Mix. B6	Mix. C1	Mix. C2	Mix. C3	Mix. C4	Mix. C5	Mix. C6
pH (Aq. Sol.)		7.34	7.38	7.37	7.33	7.24	7.42	7.37	7.41	7.29	7.24	7.21	7.14
EC (at sat.) (mS/cm)		3.57	3.71	4.86	2.05	1.84	1.96	3.81	3.68	4.21	1.57	1.69	1.61
TC (mg/kg)		130,05	115,99	87,04	128,55	110,64	73,13	135,89	110,82	89,56	124,76	101,08	75,39
TOC (mg/kg)		123,86	108,77	77,94	122,88	103,45	65,38	126,04	100,87	76,89	117,74	91,37	63,49
IC (mg/kg)		6,19	7,22	9,09	5,67	7,19	7,74	9,86	9,95	12,67	7,02	9,72	11,90
Total nitrogen (mg/kg)		4,581	3,242	1,804	6,106	3,287	1,748	4,562	3,076	1,971	3,485	3,143	1,431
Total phosphorus (mg/kg)		1,277	984	706	1,235	979	761	1,578	1,159	947	1,709	1,291	1,049
Available macronutrients; (mg/kg)	Ca	8,916	6,908	7,248	8,422	7,670	6,931	5,078	6,287	6,094	4,577	4,339	4,280
	Mg	589	641	1,096	772	851	720	610	778	476	489	502	336
	Na	1,544	1,938	2,847	678.1	706.9	754.3	1184	2486	1875	697.2	524.7	472.2
	K	894	720	678	772	519	342	707	694	519	620	471	267
C/N ratio		28.39	35.78	43.23	21.05	33.66	41.85	29.79	36.03	45.44	35.80	32.16	52.69
N/P ratio		3.59	3.29	2.56	4.94	3.36	2.30	2.89	1.95	2.08	2.04	2.43	1.36
Pore volume (m^3/m^3)		0.97	0.97	0.98	0.92	0.95	0.98	0.89	0.90	0.923	0.88	0.90	0.93
Specific gravity (g/cm^3)		1.83	2.05	2.18	1.82	2.07	2.22	1.82	1.85	1.90	1.78	1.83	1.91
Bulk density (g/cm^3)		0.91	0.95	0.99	0.90	0.96	1.02	0.83	0.88	0.94	0.80	0.85	0.93
Porosity (%)		50.3	53.7	54.6	50.5	53.6	54.1	54.4	52.4	50.5	55.1	53.6	51.3

Table 4.44. The "soil quality" analysis results of MT samples at the end of grass growth period (Mixture-D and Mixture-E topsoil samples)

Parameters/Samples		**Mix. D1**	**Mix. D2**	**Mix. D3**	**Mix. D4**	**Mix. D5**	**Mix. D6**	**Mix. E1**	**Mix. E2**	**Mix. E3**	**Mix. E4**	**Mix. E5**	**Mix. E6**
pH (Aq. Sol.)		7.40	7.21	7.41	7.28	7.29	7.36	7.40	7.43	7.47	7.39	7.33	7.35
EC (at sat.) (mS/cm)		3.77	3.19	3.84	1.86	2.07	2.01	4.02	4.09	5.49	1.94	1.98	1.91
TC (mg/kg)		137,08	96,17	89,64	123,69	105,05	84,47	135,41	108,99	81,89	128,00	103,20	74,03
TOC (mg/kg)		129,61	86,43	77,20	116,28	95,933	73,28	130,14	101,51	72,41	122,91	96,42	65,34
IC (mg/kg)		7,48	9,74	12,44	7,40	8,13	11,20	5,26	7,48	9,48	5,09	6,78	8,69
Total nitrogen (mg/kg)		3,502	3,284	1,564	5,228	3,418	1,410	4,738	3,332	2,195	5,153	3,164	1,407
Total phosphorus (mg/kg)		1,114	1,204	627	1036	896	764	1053	969	897	1199	916	845
Available macronutrients; (mg/kg)	Ca	9,226	8,864	7,865	9,118	8,216	7,744	9,219	9,086	8,694	7,914	7,749	5,997
	Mg	681	508	741	650	632	528	792	786	749	609	551	484
	Na	1,007	1,126	2,489	537.1	569.9	683.3	1,512	1,694	2,472	786.8	814.2	941.7
	K	686	527	578	682	564	296	803	741	627	773	687	432
C/N ratio		39.14	29.28	57.31	23.66	30.74	59.91	28.58	32.71	37.31	24.84	41.15	52.62
N/P ratio		3.14	2.73	2.49	5.05	3.81	1.85	4.50	3.44	2.45	4.30	3.45	1.67
Pore volume (m^3/m^3)		0.67	0.69	0.72	0.68	0.71	0.82	0.86	0.88	0.90	0.81	0.85	0.89
Specific gravity (g/cm^3)		2.13	2.19	2.21	2.10	2.14	2.17	1.85	1.88	1.67	1.84	1.90	1.70
Bulk density (g/cm^3)		0.85	0.90	0.96	0.88	0.94	0.97	0.84	0.81	0.79	0.80	0.87	0.77
Porosity (%)		60.1	58.9	56.6	58.1	56.1	55.3	54.6	54.5	53.3	56.5	55.3	54.7

4.2.9 The Assessment of Seasonal Outdoor Ornamental Plant Growing Studies in the MT Samples

When considering the previous grass growth performances (germination success rate (%), total harvest height (cm), average harvest height (cm) and biomass production (kg/m^2)), it was determined that the best mixture prescription is numbered 6^{th} MT series such as Mixture-A6 and Mixture-C6. Thus, the growing of two summer season ornamental plants (marigold and geranium) and one winter season ornamental plant was tested in Mixture-A6 and Mixture-C6 as the best MT samples and Mixture-D6 as the worst MT sample and Control-3 as a control sample. These outdoor ornamental plants are preferred because the development can be monitored more easily in terms of climatic conditions at the time of work.

The summary of soil quality analysis results of MT samples used to examine the growth performances of seasonal ornamental plants are illustrated in Table 4.45.

Table 4.45. The summary of soil quality analysis results of MT samples (Control-3, Mixture-A6, Mixture-C6 and Mixture-D6) used for investigating the growth performances of seasonal ornamental plants

Parameters/Samples		Control-3	Mix. A6	Mix. C6	Mix. D6
Water content (%)		16.93	26.07	25.18	42.11
Solid content (%)		83.07	73.93	74.82	57.89
pH (aq. sol.)		6.67	7.47	7.43	7.43
EC (at sat. (mS/cm)		2.16	2.17	2.03	2.21
Soil texture;		(Loamy sand)	(Loamy sand)	(Loamy sand)	(Sandy loam)
Sand (%):		73.3	86.8	84.7	66.2
Silt (%):		23.5	6.1	8.8	24.9
Clay (%):		3.2	7.1	6.5	8.9
Organic matter (%)		11.82	5.93	8.31	4.34
TC (mg/kg)		72,58	76,22	105,65	92,62
TOC (mg/kg)		65,35	69,10	89,14	79,73
IC (mg/kg)		7,23	7,12	16,51	12,89
Available micronutrients; (mg/kg)	Fe	306.8	125.9	184.6	94.66
	Cu	0.16	1.14	2.13	4.20
	Zn	1.19	4.10	12.01	4.35
	Mn	115.4	26.2	94.8	31.2
	Al	0.02	0.09	0.01	0.07
Available macronutrients; (mg/kg)	Ca	5,395	7,576	8,541	8,387
	Mg	455	575	568	650
	Na	71	1,037	1,379	1,347
	K	361	360	412	397
Total nitrogen (mg/kg)		2,409	1,559	2,256	1,683
Total phoshorus (mg/kg)		643	841	722	812

As previously denoted, the soil texture classes are identified as "loamy sand" for Control-3, Mixture-A6 and Mixture-C6 samples while "sandy loam" for Mixture-D6 sample. They have solid content of 58-83% and are found in neutral pH range (pH=6.50-7.50). MTs prepared with washed DMs have low salt content ("saltless" EC: 0-2 mS/cm) and their organic matter contents are found in "High" level (4.34-11.82%) due to the presence of sheep manure. All MT samples are rich in terms of available macronutrients and available micronutrients (enough-(very) high). The contents of total nitrogen and total phosphorus are also "very high" because of the addition of sheep manure.

4.2.9.1 The Summer Season Ornamental Plant Growing

Within the scope of the study, two outdoor ornamental plants (marigold and geranium) (Figure 4.11) for summer season have been studied to be grown in the selected MT samples.

a)

b)

Figure 4.11. Summer season ornamental plants; a) marigold b) geranium

4.2.9.1.1 Growing of Summer Season Ornamental Plants with "Transplanting Seedling" Method

First of all, marigold and geranium seeds were put into the tiny seed pots in order to develop and ensure the realization of transplanting process. **Transplanting** is a process for the transfer of growing seed from its growing medium to another medium with soil or without soil. Control-3 topsoil sample was used as growth media of the relevant ornamental plants (Figure 4.12).

Figure 4.12. Seeds of summer season ornamental plants and overview of planted seeds in the tiny seed pots

The planted marigold and geranium seeds were irrigated twice during the day by giving both 3-4 drops of water in the morning and 8-10 drops of water in the afternoon, respectively. All the tiny pots involving ornamental plant seeds were positioned in order to benefit from equal amounts of sunlight.

Marigold and geranium seeds sown into the tiny pots were started to germinate and grow after 3th and 6th day of the planting process. The growing performances of marigold and geranium seeds in a month in the tiny seed pots are illustrated visually in Figure 4.13 and Figure 4.14, respectively.

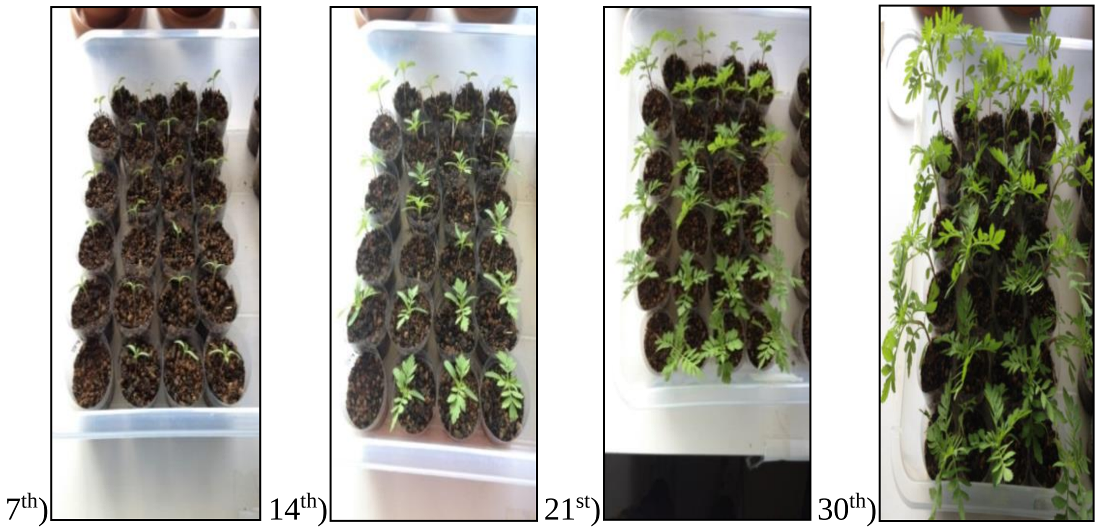


Figure 4.13. Pictures showing the growing of marigold seeds in the tiny seed pots (7th, 14th, 21st and 30th days)

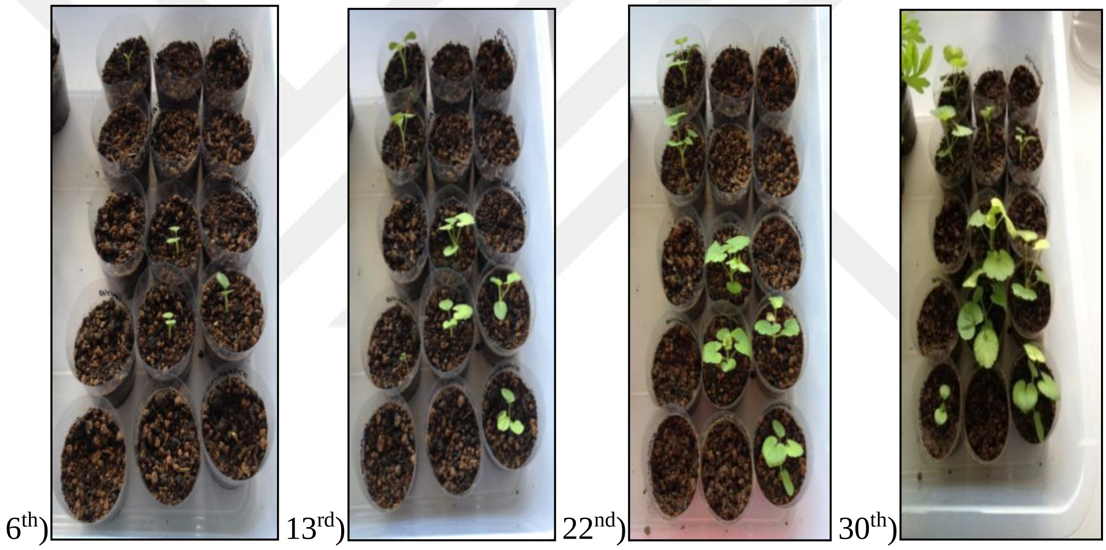


Figure 4.14. Pictures showing the growing of geranium seeds in the tiny seed pots (6th, 13rd, 22nd and 30th days)

At the end of one month follow-up period, hairy roots of growing seeds of marigold and geranium with the help of water were removed from Control-3 topsoil medium (growing medium of seed) and planted into predetermined Mixture-A6, Mixture-C6 and Mixture-D6 topsoil samples (main pots) (transplanting). Six grown marigold seeds and three grown geranium seeds were sown into each pot including MT samples. The transplanting processes of these grown ornamental plants are demonstrated in Figure 4.15 and Figure 4.16.

Figure 4.15. Transplanting of marigold seeds from tiny seed pot into the main pots

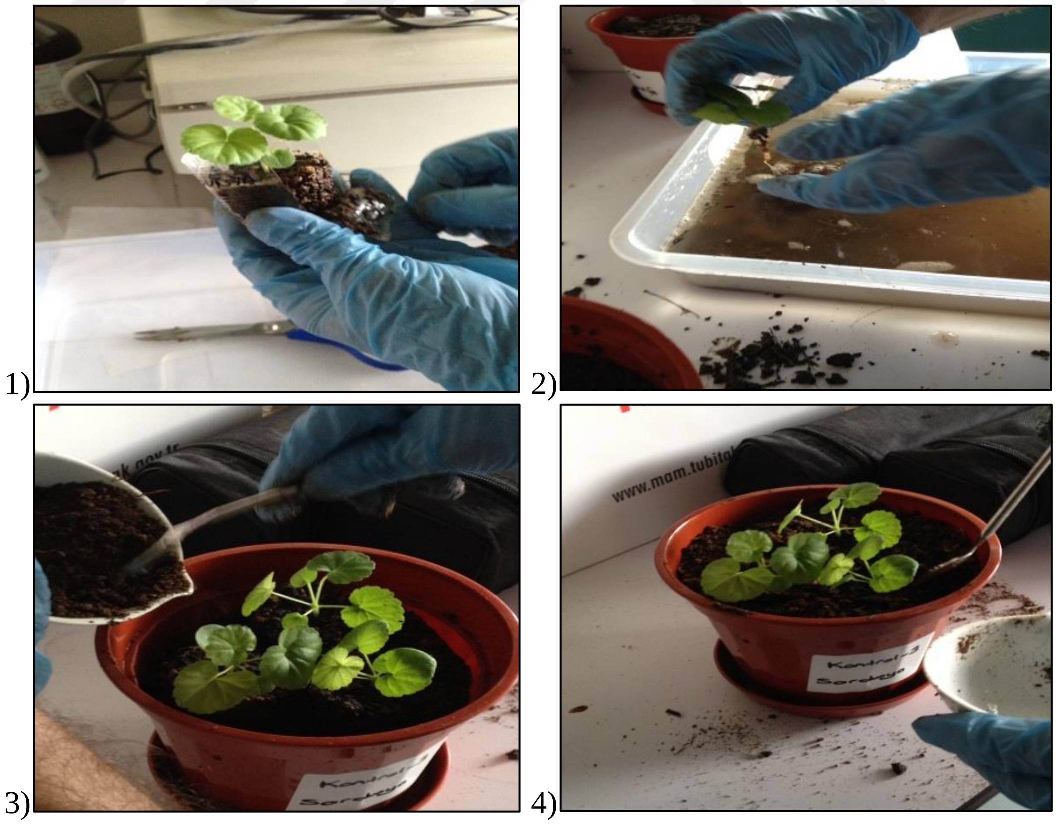


Figure 4.16. Transplanting of geranium seeds from tiny seed pot into the main pots

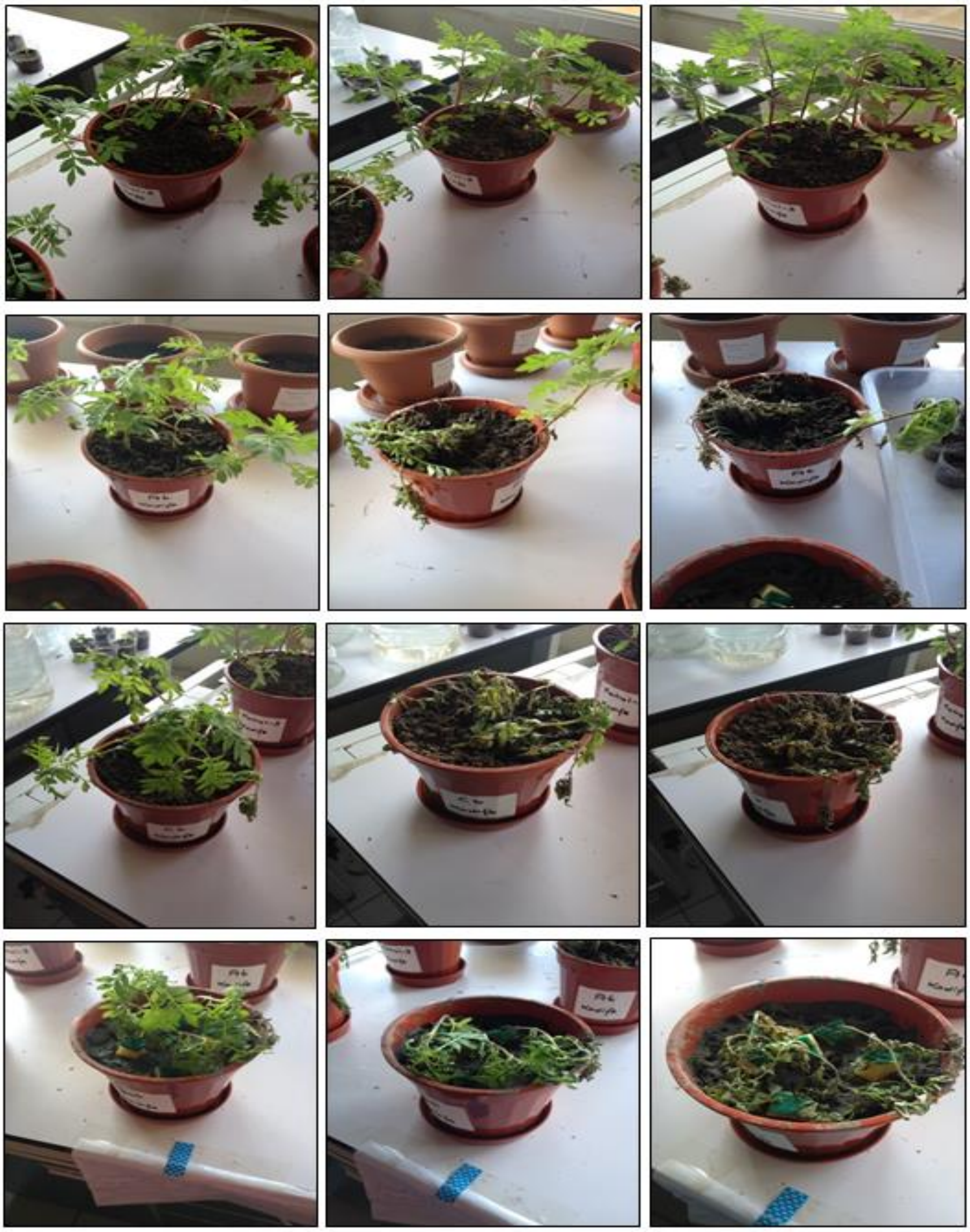
After the transplanting process, the seeds of interest were tried to adapt to their environment; however, it is observed that they showed a little weak and bent posture unlike healthy upright posture in the tiny pots at the end of the first six hours of transplanting. The images related to the grown marigold and geranium ornamental plants' seeds at the end of first day in their main pots after transplanting process are illustrated in Figure 4.17.

Figure 4.17. The images related to the first day of grown marigold and geranium seeds in their main pots after transplanting

The performances of grown marigold seeds in the main pots were followed every day for three months period (Figure 4.18). At the end of 15th day, it is observed that the entire marigold ornamental plants were died in Mixture-A6, Mixture-C6 and Mixture-D6 samples. On the other hand, throughout three-months follow-up period, marigold ornamental plants in Control-3 topsoil have continued to their normal growth and development, and the leaf colours of these plants were determined to be dark green (healthy leaves). The results indicated that geranium ornamental plants can be grown in control sample easily. Information about the periodic performance of the relevant plants after transplanting is summarized in Table 4.46.

Table 4.46. The periodic performance of marigold ornamental plants

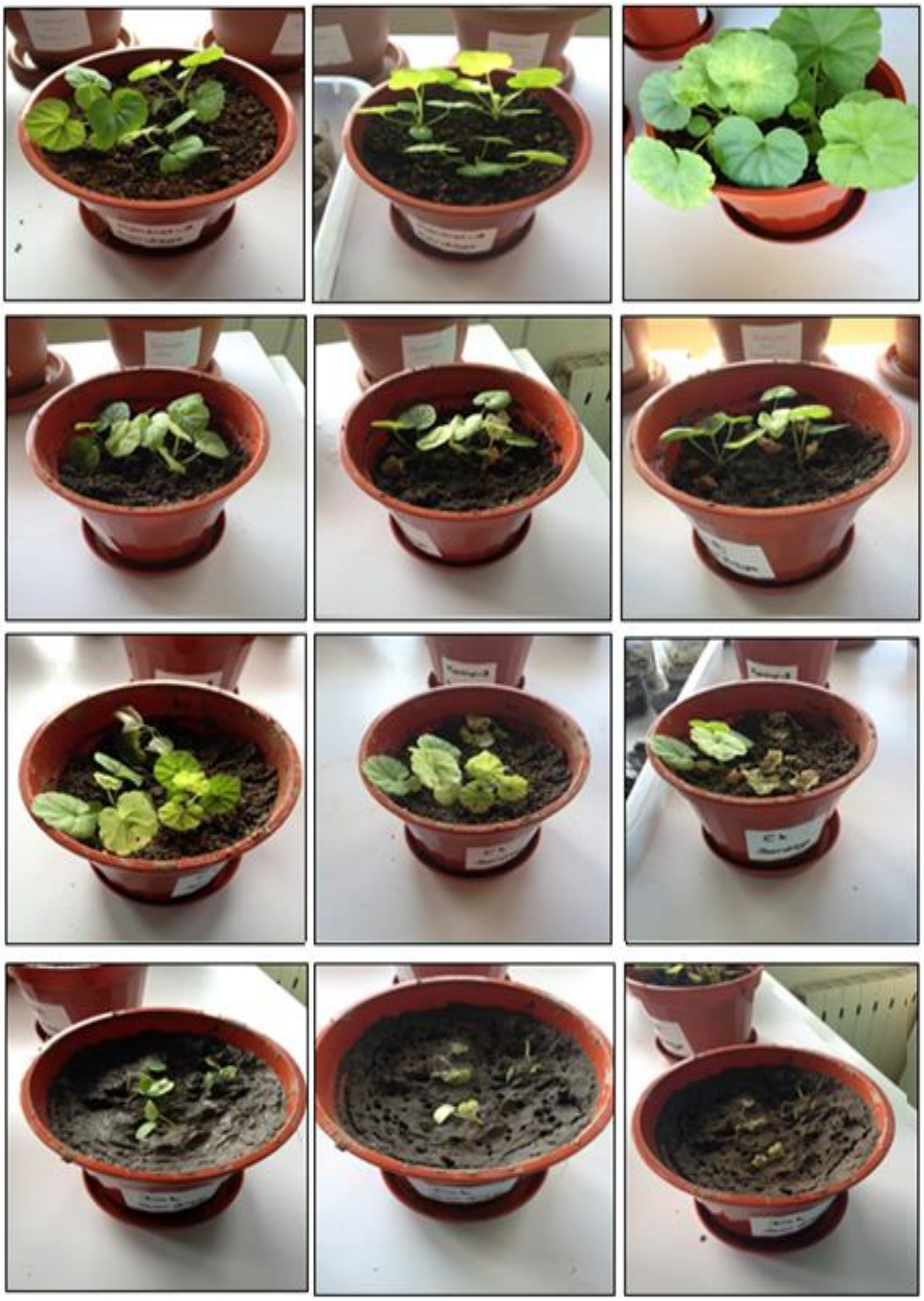
Sample Code	At the end of 2 weeks		At the end of 1.5 months		At the end of 3 months	
	Average number of leaf	**Average stem length (cm)**	**Average number of leaf**	**Average stem length (cm)**	**Average number of leaf**	**Average stem length (cm)**
Control-3	3	5.4	7	8.7	14	11.2
Mixture-A6	The plants did not survive.		-	-	-	-
Mixture-C6	The plants did not survive.		-	-	-	-
Mixture-D6	The plants did not survive.		-	-	-	-



(12nd) (55th) (90th)

Figure 4.18. The situation of grown marigold seeds in the main pots containing Control-3, Mixture-A6, Mixture-C6 and Mixture-D6 topsoils, at the end of 12nd, 55th and 90th days, respectively.

All of geranium ornamental plants in Mixture-D6 withered and died in the end of 17th day. During this period, one of three geranium ornamental plants in Mixture-A6 and two of three geranium ornamental plants in Mixture-C6 died. Along three-months monitoring period, leaves of these plants in these manufactured topsoils have started yellowing and weakening (Figure 4.19).



(5th)　　(30th)　　(90th)

Figure 4.19. The situation of grown geranium seeds in the main pots containing Control-3, Mixture-A6, Mixture-C6 and Mixture-D6 topsoils, at the end of 5th, 30th and 90th days, respectively.

The performances of grown geranium seeds in the main pots were also followed every day for three months period (Figure 4.19). Appreciable growth and development in the stem length of geranium ornamental plants in main pots including Mixture-A6, Mixture-C6 and Mixture-D6 were not observed. On the other hand, throughout three-months follow-up period, geranium ornamental plants in Control-3 topsoil have continued to their normal growth and development, and the leaf colours of these plants were determined to be dark green (healthy leaves). The results indicated that geranium ornamental plants can be grown in control sample easily. Information about the periodic performance of the relevant plants after transplanting is also summarized in Table 4.47.

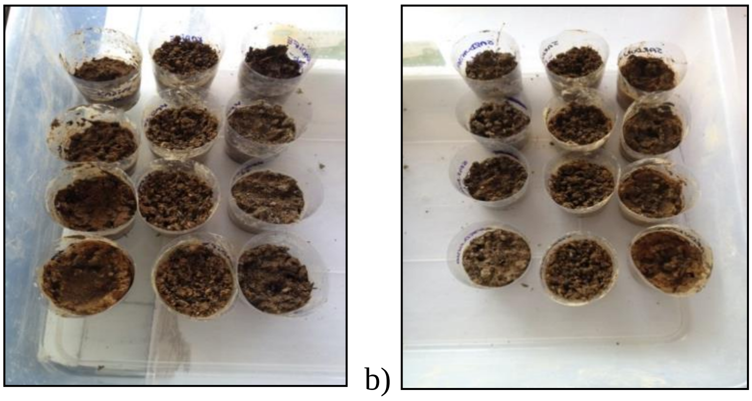
Table 4.47. The periodic performance of geranium ornamental plant

Sample Code	At the end of 2 weeks		At the end of 1.5 months		At the end of 3 months	
	Average number of leaf	Average stem length (cm)	Average number of leaf	Average stem length (cm)	Average number of leaf	Average stem length (cm)
Control-3	3	6.4	7	9.6	14	12.4
Mixture-A6	3	2.8	3	2.9	3	3.1
Mixture-C6	4	4.8	4	5.1	5	5.4
Mixture-D6	The plants did not survive.		-	-	-	-

4.2.9.1.2 Growing of Summer Season Ornamental Plants with "Displacement" Method

Displacement process is the placement of plant with existing soil from growing medium to new soil place without damaging the roots of the plant (DIPTAR, 2016).

In this process, Mixture-A6, Mixture-C6 and Mixture-D6 samples were used as growing medium in order to germinate and grow the marigold and geranium ornamental plants instead of Control-3 topsoil. At the end of one month seed germination and growing process, the seeds under investigation were placed into main pots containing the same MT environments with the aim of preventing the adaptation problem as emerged previously in transplanting process. Figure 4.20 displays marigold and geranium ornamental plants' seeds planted in the tiny seed pots containing the MTs prepared with washed DMs.

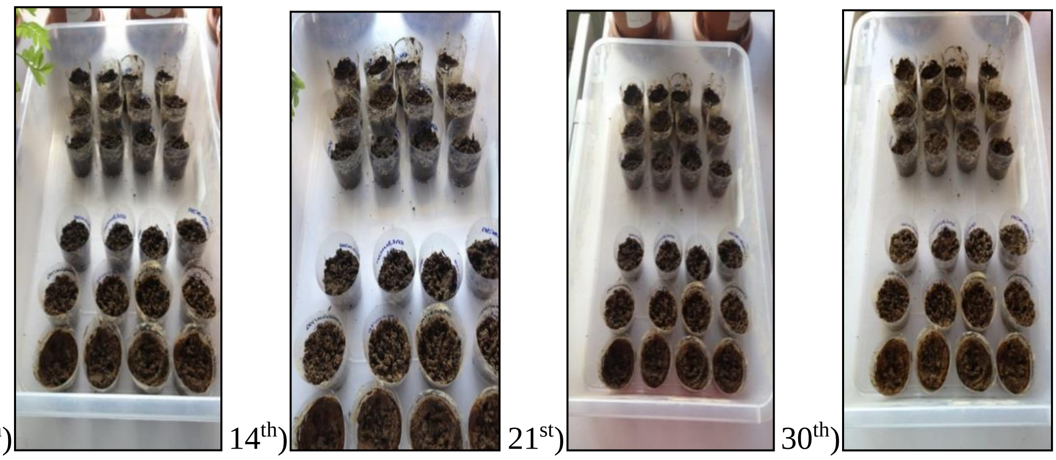


a) b)

Figure 4.20. General view of summer season ornamental plants' seeds in the tiny seed pots containing MTs prepared with washed DMs a) marigold seed b) geranium seed.

The planted marigold and geranium seeds into the tiny pots containing Mixture-A6, Mixture-C6 and Mixture-D6 topsoils were irrigated twice during the day by giving both 3-4 drops of water in the morning and 8-10 drops of water in the afternoon during a month, respectively. All the tiny pots involving ornamental plant seeds were placed in order to benefit from equal amounts of sunlight.

After the planting of marigold and geranium ornamental plants were completed, the seed growth and development was followed regularly. At the end of one month period, it had been seen that there was no seed growth and germination in the tiny pots. The images related to the growing and germination performances of marigold and geranium seeds in a month in the tiny seed pots containing MT prepared with washed DMs are given in Figure 4.21.



7^{th}) 14^{th}) 21^{st}) 30^{th})

Figure 4.21. Growing performances of planted marigold and geranium seeds in the tiny seed pots containing MTs prepared with washed DMs (7^{th}, 14^{th}, 21^{st} and 30^{th} days)

4.2.9.2 The Winter Season Ornamental Plant Growing

In the scope of this work, one winter season ornamental plant (carnation) (Figure 4.22) has been studied to be raised in the selected MT samples.

Figure 4.22. General view of carnation (winter season) ornamental plant

4.2.9.2.1. Growing of Winter Season Ornamental Plant with "Transplanting Seedling" Method

Carnation ornamental plant seeds were placed firstly into the tiny seed pots in order to develop and ensure the realization of transplanting process. The Control-3 topsoil sample was used as growing media of the relevant ornamental plant (Figure 4.23).

Figure 4.23. Seeds of carnation ornamental plant and overview of planted seeds in the tiny seed pots

The planted seeds of carnation into the tiny pots were irrigated for twice during the day by both giving 3-4 drops of water in the morning and 4-6 drops of water in the afternoon, respectively. All the tiny pots containing carnation ornamental plant were placed in order to utilize from equal amounts of sunlight.

Carnation seeds sown into the tiny pots were started to germinate and grow after 6th day of the planting process. The images related to the growing and germinating performances of carnation seeds during a month in the tiny pots are illustrated in Figure 4.24.

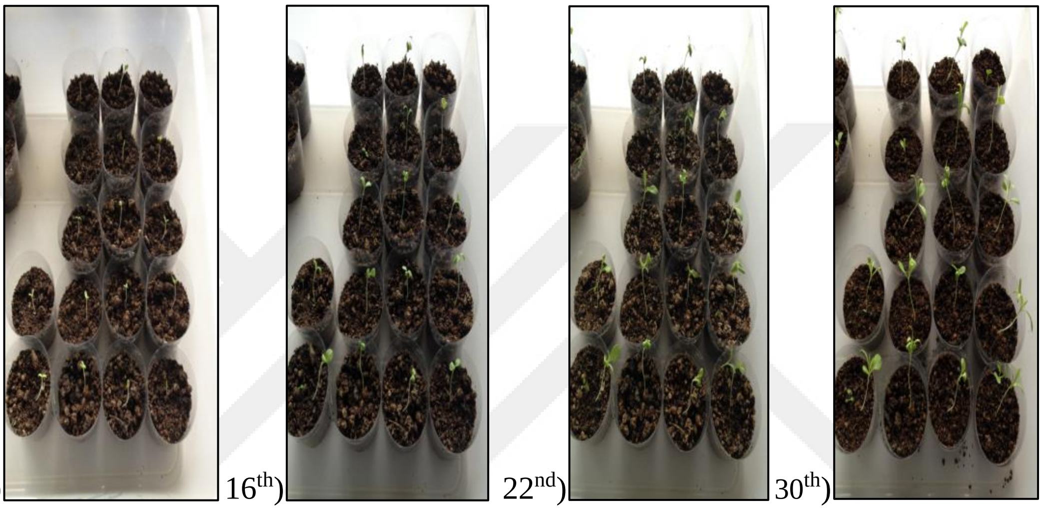
9th)


Figure 4.24. Pictures showing the growing of carnation seeds in the tiny seed pots (9th, 16th, 22nd and 30th days)

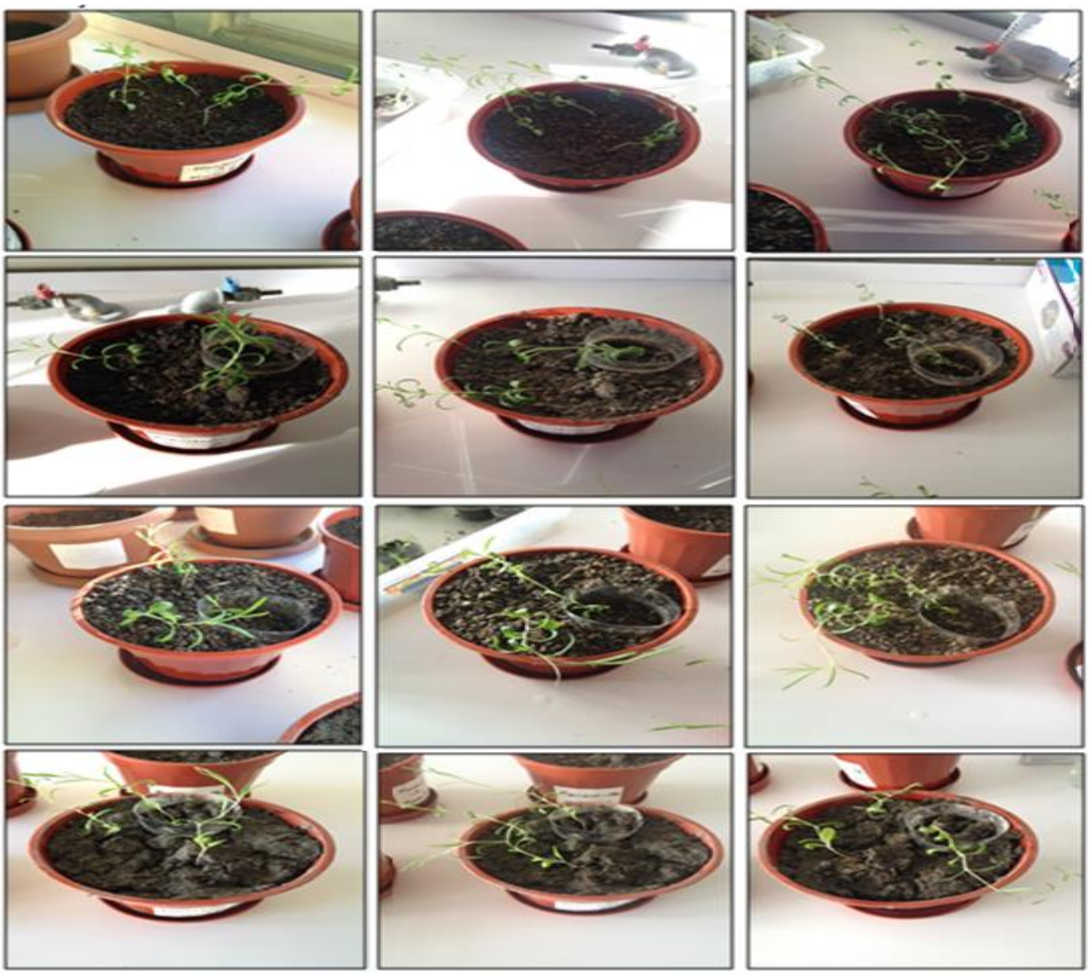
Throughout one month, carnation seeds were grown in the tiny pots like marigold and geranium ornamental plants and their growth performances were followed up visually. At the end of one month monitoring period, growing seeds of carnation ornamental plant were removed from the Control-3 topsoil medium and planted into predetermined the Mixture-A6, Mixture-C6 and Mixture-D6 topsoil samples (main pots) (transplanting). Three grown carnation seeds were sown into each pot including MT samples. The transplanting process of the grown carnation ornamental plant is demonstrated in Figure 4.25.

Figure 4.25. Transplanting of grown carnation seeds from tiny seed pot into the main pots of including MT samples

After the transplanting process of carnation ornamental plants was performed, the seeds were tried to adapt to their environment; however, it was observed that they showed a little weak and bent posture unhealthy upright posture in the tiny pots at the end of the first four hours of transplanting. The images related to the grown carnation ornamental plant's seeds at the end of first day in their main pots after transplanting process are illustrated in Figure 4.26.

Figure 4.26. The images related to the first day of grown carnation seeds in their main pots after transplanting

The performances of grown carnation seeds in the main pots were followed every day for three months period (Figure 4.27).



(12nd)　　(55th)　　(90th)

Figure 4.27. At the end of 12nd, 55th and 90th days, the current situation of grown carnation seeds in the main pots

At the end of 17th day, it was observed that the developments of carnation ornamental plants were quite weak in main pots involving the Mixture-A6, Mixture-C6 and Mixture-D6 topsoils (weaknesses in the leaves and stems of grown carnations plants in Mixture-A6). In Mixture-A6's pot, the carnation plants were started to die at the end of 85th day. On the other hand, some empurpling in the stem and weakening in the leaves of grown carnation plants were observed in the Mixture-C6's pot. In the Mixture-D6, it is seen that there was no any elongation in the stem of carnation plants and yellowing in the leaves. After three-months follow-up period, carnation ornamental plants in the Control-3 topsoil have continued to their normal growth and development, and the leaf colours of this plant were found to be dark green (healthy leaves). Unfortunately, it was observed that the growth and development of carnation ornamental plants in the Mixture-A6, Mixture-C6 and Mixture-D6 samples produced with washed DMs were very low and their leaf colours were found to be light green.

Information about the periodic performance of the relevant grown carnation plants in the main pots after transplanting is summarized in Table 4.48.

Table 4.48. The periodic performance of carnation ornamental plant

Sample Code	At the end of 2 weeks		At the end of 1.5 months		At the end of 3 months	
	Average number of leaf	Average stem length (cm)	Average number of leaf	Average stem length (cm)	Average number of leaf	Average stem length (cm)
Control-3	16	8.1	22	11.9	26	17.3
Mixture-A6	12	6.4	14	6.7	14	6.8
Mixture-C6	12	7.3	14	7.5	14	7.8
Mixture-D6	12	6.1	12	6.3	12	6.7

4.2.9.2.2. Growing of Winter Season Ornamental Plant with "Displacement" Method

Like summer season ornamental plants, the carnation ornamental plants were germinated and grown in the Mixture-A6, Mixture-C6 and Mixture-D6 topsoils produced with washed DMs instead of the Control-3 topsoil. At the end of one month seed germination and the growing process, the seeds were placed into the main pots containing the same MT environments with the aim of preventing the adaptation problem as emerged previously in the transplanting process. Figure 4.28 displays the general view of seeds of carnation ornamental plants in the tiny seed pots containing MTs prepared with washed DMs.

Figure 4.28. General view of carnation ornamental plant seeds in the tiny seed pots containing MTs prepared with washed DMs

The sown carnation seeds into the tiny pots containing MTs prepared with washed DMs were irrigated twice during the day by both giving 4-6 drops of water in the morning and in the afternoon. All the tiny pots involving carnation ornamental plant seeds were placed in order to benefit from equal amounts of sunlight.

After the planting of carnation ornamental plants were actualized, the seed growth and the development was followed regularly. At the end of one month period, it was seen that there was no seed growth and germination for carnation ornamental plant in the tiny pots. The images related to the growing and germination performances of carnation seeds in a month in the tiny seed pots containing MTs prepared with washed DMs are shown in Figure 4.29.

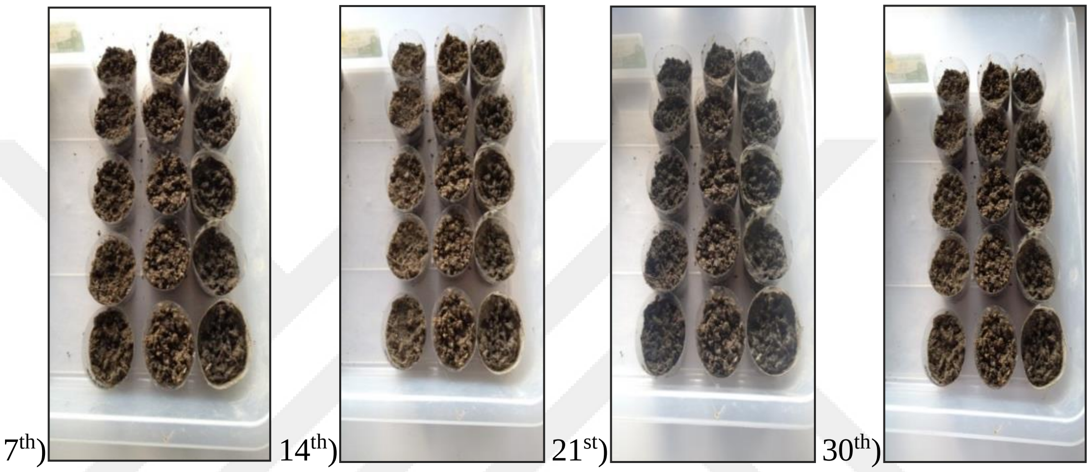


Figure 4.29. Growing performances of planted carnation seeds in the tiny seed pots containing MTs prepared with washed DMs (7th, 14th, 21st and 30th days)

4.2.9.3 The General Review about Growing of Seasonal Ornamental Plants

The Mixture-A6 and the Mixture-C6 coded MT samples prepared with washed DMs have **low silt-clay content** and **water absorption capacity**. Thus, it was observed that the root of outdoor of ornamental plants were failed in order to take nutrients from the soil and develop adequately. Mixture-D6 has a **very tight soil structure** because of the **high silt-clay content**. Hence, it could not uptake sufficient air for the growth of seasonal ornamental plants. As a result, it was seen that MTs prepared by $DM_{Mixtures}$ (Mixture-A6, Mixture-C6 and Mixture-D6) are *technically not feasible* for growing seasonal ornamental plants with the transplanting and the displacement methods due to their physico-chemical structures.

4.3 Design and Operating Principle of Industrial-Scale DM Pre-Treatment Plant

The designs of both the sand pre-treatment plants existed in our country and the DM pre-treatment plants in abroad were taken into consideration in the theoretical design of industrial-scale DM pre-treatment plant. The establishment of DM pre-treatment plant as a stationary plant in the same field with the urban wastewater treatment plant (WWTP) having the secondary treatment system, the use of the relevant urban WWTP effluent as process water in the DM pre-treatment plant and; thus, the reduction of water consumption costs were considered. However, before the utilization of urban WWTP effluent as process water, it is required to be passed through sand filtration and UV disinfection processes. Also, in this plant, coarse sieve system was designed as three-storey for the beneficial use of DM as an aggregate in the concrete applications. For the beneficial use of DM as MT in landscaping applications, only 5 mm coarse sieve will be required.

DM coming from feeding bunker to the two-storey coarse sieve system with the conveyor belt will be treated with the washing (nozzle)-sieving method in order to remove rubbish and coarse material (>100 mm and 50-100 mm) in the content of DM. Then, lumps in the structure of DM will be distributed by addition of water into the mixer named blademill. DM resulting from mixer (blademill) will be passed through triple wash vibrational sieve system (>22 mm, 12-22 mm, 5-12 mm) where 5 mm sieve is necessary for MT applications. Then, DM sludge will be taken to the 250 ton/hour capacity hydrocyclone in order to classify the finer and coarser fractions of DM according to the density differences with the help of centrifugal forces within a vortex. Accordingly; the sandy material (5 mm-63 μm) will be taken from the bottom output of hydrocyclone and dewatering of this material will be achieved by passing through dewatering sieve. Watery clay-silt mixture (<63 μm) received from the top output of hydrocyclone will be firstly sent to the octagonal intermediate tank having 180 m^3 mixer, then, transfer to the settling basin (thickener) where chemical polymer dosage will be applied. Clay-silt fraction emerged from the bottom output of thickener will be transferred to the 200 ton/hour capacity filter-press. It will be used to collect these very fine particles in water. Because of high salt content of and high cost salt removal of wastewater taken from the upper of thickener, the recovery of wastewater were not considered within this design. The discharge of process wastewater by passing through the micro sieve/sand filtration to the sea/canalization has been contemplated. On the other hand, such a DM pre-treatment plant has been expected to be efficient in pre-treatment of DM having a maximum of 40% clay-silt content. The theoretical design of industrial-scale DM pre-treatment plant is demonstrated in Figure 4.30. Kim et al (2016) designed the same type of schematic diagram for the separation of pore water generated from raw dredged sediments collected from Shingal Lake.

4.3.1 The Characterization and Management of DM Washing-Sieving Wastewater

The laboratory-scale DM washing-sieving experiments were carried out in order to characterize and manage the washing wastewater of DM samples to be beneficially used in landscaping applications. As previously denoted, the amount of tap water used for washing of DMs for landscaping applications was selected as 1:1 (w/v) ratio.

The washing water volumes, initial and final EC values of DMs during laboratory-scale washing-sieving trials are summarized in Table 4.49.

Table 4.49. Washing water volumes, initial and final EC values of DMs during laboratory-scale washing-sieving trials

Sample Code	Raw DM						Washed DM		
	pH	EC (mS/cm)	Particle Size Distribution (%)				Washing Water Volume (ml)	pH	EC (mS/cm)
			>2mm	2mm-200 µm	200-63 µm	<63µm			
DM-1	8.20	5.1	6.3	7.3	**81.3**	5.1	500	9.11	1.95
DM-2	9.38	1.0	**26.8**	**34.9**	**37.3**	1.0	500	9.51	1.10
DM-3	8.91	10.6	11.9	**45.9**	**31.6**	10.6	500	8.69	1.23
DM-4	8.77	0.6	13.0	**61.2**	**25.2**	0.6	500	9.09	1.05
DM-5	8.87	**21.6**	**22.9**	**40.6**	14.9	**21.6**	500	9.21	1.16
DM-6	8.56	**23.4**	**20.8**	**29.2**	**26.6**	**23.4**	500	8.82	1.65
DM-7	8.16	1.0	**36.8**	**60.1**	2.1	1.0	500	8.78	1.37
DM-8	8.35	16.0	**24.2**	**20.6**	**39.2**	16.0	500	9.09	1.97
DM-9	8.92	**40.4**	**36.9**	10.1	12.7	**40.4**	500	8.94	1.58
DM-10	8.76	11.1	**25.3**	13.3	**50.3**	11.1	500	9.09	1.97
DM-12	8.62	19.7	17.7	**37.2**	**25.4**	19.7	500	9.58	1.08
DM-13	7.90	**38.4**	**36.5**	10.3	14.8	**38.4**	500	9.47	1.29
DM-14	8.49	0.3	6.0	**47.3**	**46.4**	0.3	500	8.56	1.73
DM-15	8.89	0.7	**39.6**	**58.2**	1.5	0.7	500	9.62	1.37
DM-16	9.11	**31.9**	**28.2**	**27.4**	12.5	**31.9**	500	9.47	1.37

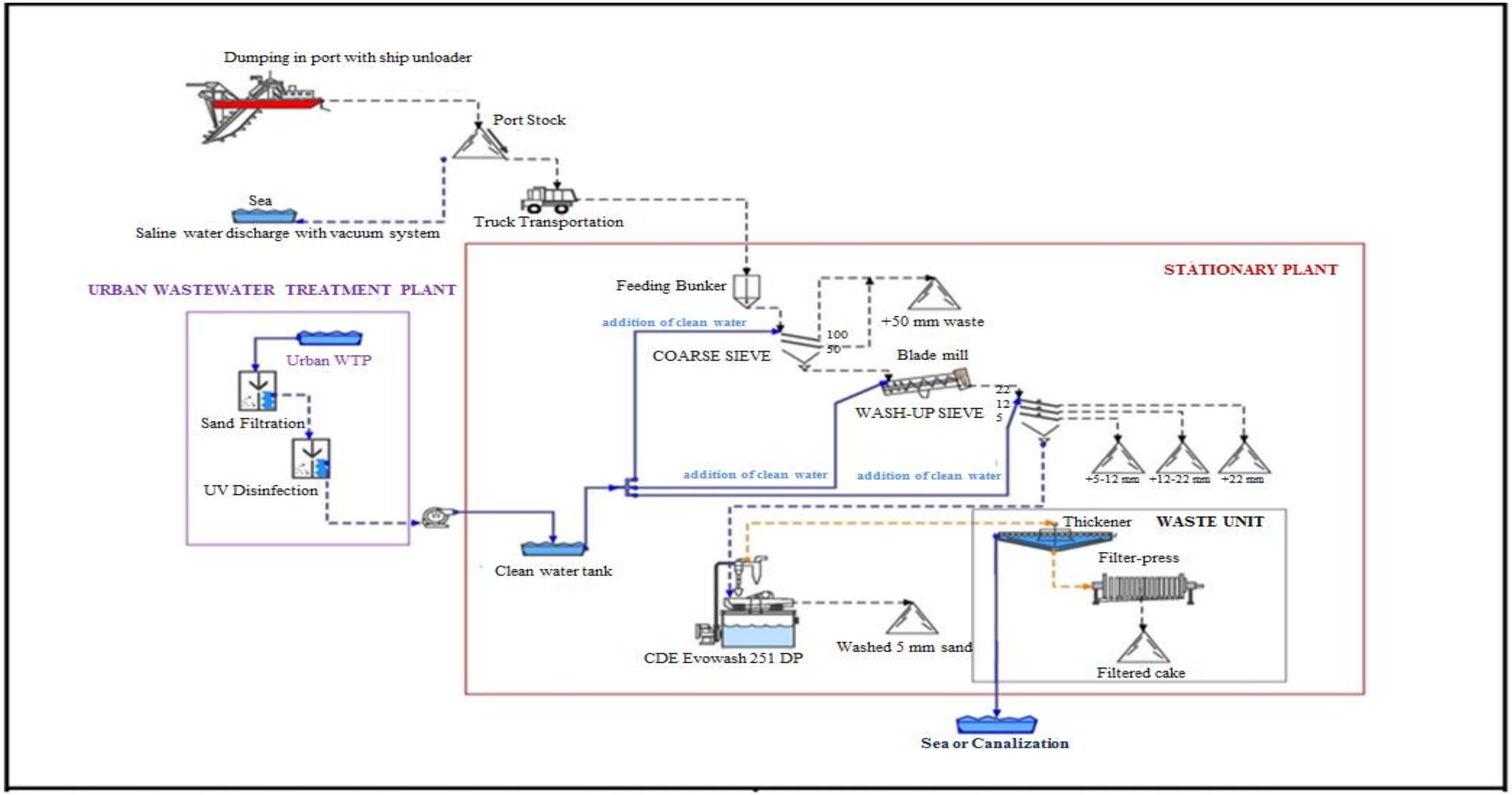


Figure 4.30. The theoretical design of industrial-scale DM pre-treatment plant

4.3.1.1 The Assessment of Characterization of Wastewater Resulting From Washing Process

As it is known, there is no available industrial discharge criterion regarding the DM pre-treatment plant wastewater in "SKKY Regulation". Thus, sand washing plant criteria (SKKY-Table 7.5), deep sea discharge criteria (SKKY-Table 22) and general quality criteria for seawater (SKKY-Table 4) situated in SKKY were taken into consideration in terms of parameter selection in order to characterize wastewater resulting from the laboratory-scale DM washing-sieving procedure. The characterization results of raw DM were also taken into account. The selected parameters for DM washing-sieving wastewater characterization are as follows;

- pH,
- EC (mS/cm),
- Total salt (%),
- Chloride (mg/L),
- Sulfate (mg/L),
- Total suspended solid (TSS) (mg/L),
- TOC (mg/L),
- Nutrients (TKN and total phosphorus) (mg/L),
- Heavy metals (Pb, Cd, Cr, Cu, Ni, Hg, Zn, As, Ag) (mg/L).

The results regarding to the characterization of laboratory-scale DM washing-sieving wastewaters are pointed out in Table 4.50 and Table 4.51. Accordingly, after the separation of coarse and fine material, it is observed that TSS is the most important pollution parameter remaining in the water phase. It is well-known fact that TSS is the sum of the settleable and non-settleable solids in the water sample. It leads to the turbidity in the receiving environment and it prevents the light transmittance. Therefore, it is an important parameter with respect to the receiving environment (DIPTAR, 2016).

Table 4.50. Characterization results of wastewaters resulting from laboratory-scale DM washing-sieving process with respect to conventional parameters

Sample Code	pH		EC (mS/cm)	Salt Content (%)	TSS (mg/L)		Chloride (mg/L)	Sulfate (mg/L)	TKN (mg/L)		TP (mg/L)		TOC (mg/L)
	Result	SKKY Limit Value			Result	SKKY Limit Value			Result	SKKY Limit Value	Result	SKKY Limit Value	
DM-1	8.34	6-9 (Table 22); (Table 4)	8.46	2.71	69	100 mg/L (Table 7.5); 350 mg/L (Table 22); 30 mg/L (Table 4)	2,515	53	2.40	40 mg/L (Table 22)	0.10	10 mg/L (Table 22)	< 0.5
DM-2	8.07		8.38	4.76	78		2,125	672	< 0.50		0.09		< 0.5
DM-3	7.94		5.02	1.41	202		1,244	332	1.23		0.10		1.3
DM-4	8.04		6.14	3.27	250		1,681	257	0.62		0.14		< 0.5
DM-5	8.06		8.05	2.69	102		2,409	137	1.36		0.20		< 0.5
DM-6	8.04		14.40	2.91	96		7,004	1,390	0.98		0.08		< 0.5
DM-7	7.66		15.03	8.79	174		4,756	1,078	0.82		0.05		< 0.5
DM-8	7.84		21.90	4.41	< 5		7,276	1,342	0.66		0.10		< 0.5
DM-9	8.22		8.44	2.59	56		246	584	< 0.50		0.09		< 0.5
DM-10	8.38		8.51	2.64	53		2,603	35	2.13		0.12		< 0.5
DM-12	7.91		8.30	4.98	128		2,363	670	1.80		0.12		2.5
DM-13	8.27		7.97	4.82	274		2,462	284	3.77		0.08		< 0.5
DM-14	7.93		5.46	1.14	64		389	241	0.60		0.09		< 0.5
DM-15	7.81		10.06	2.83	75		2,783	771	< 0.50		0.11		< 0.5
DM-16	8.03		11.81	6.94	34		3,536	497	2.13		0.14		< 0.5

Table 4.51. The characterization results of wastewaters resulting from laboratory-scale DMs washing-sieving process with respect to dissolved heavy metals

Parameter (mg/L)	SKKY limit (mg/L)	DM-1 –DM-16
Pb	0.1 (Table 4)	< 0.01
Cd	0.01 (Table 4)	< 0.004
Cr	0.1 (Table 4); 0.3 (Table 7.5)	< 0.006
Cu	0.01 (Table 4)	< 0.02
Ni	0.1 (Table 4)	< 0.004
Hg	0.004 (Table 4)	< 0.00013
Zn	0.1 (Table 4)	< 0.007
As	0.1 (Table 4)	< 0.014
Ag	-	< 0.004

As it is seen from Table 4.51, pH values of wastewaters were within the range (pH: 6-9) as specified in SKKY. Furthermore, TSS contents of wastewaters resulting from laboratory-scale DM washing-sieving procedure were highly variable where TSS contents of wastewaters were between the range of 5-274 mg/L and the average TSS value is approximately 110 mg/L. It is observed that the main reasons of the fluctuations in TSS contents are probably the physico-chemical structures of DMs. Besides, the water quantities used in the laboratory-scale DM washing-sieving process seems to have an impact on the precipitation efficiency.

When the nutrient analysis results of the relevant wastewaters were investigated, it is seen that the concentrations of TKN and TP were determined as <0.5-3.77 mg/L and 0.08-0.20 mg/L, respectively. On the other hand, it is found that heavy metal concentrations obtained in dissolved form of wastewaters of interest are below SKKY limits. This result is also consistent with the alkaline pH of the wastewaters. Therefore, it is clear that wastewaters are not foreseen a risk in terms of heavy metal parameters.

4.3.1.2 The Optimization Study of Precipitation Time

It is clear that the most important parameter of laboratory-scale DM washing-sieving process's wastewater characteristics among others seems to be TSS. Therefore, considering the presence of nutrients in particulate form in wastewater, it is necessary to optimize the removal of TSS; thus, the removal of nutrients for further investigations against TSS-related nutrient contaminations. Imhoff funnel trial was just conducted for DM-13 sample having the highest TSS as representative. The volumetric quantities of time dependent-settleable solids of laboratory-scale washing wastewater taken from upper phase of Imhoff funnel relating to DM-13 sample are illustrated in Figure 4.31.

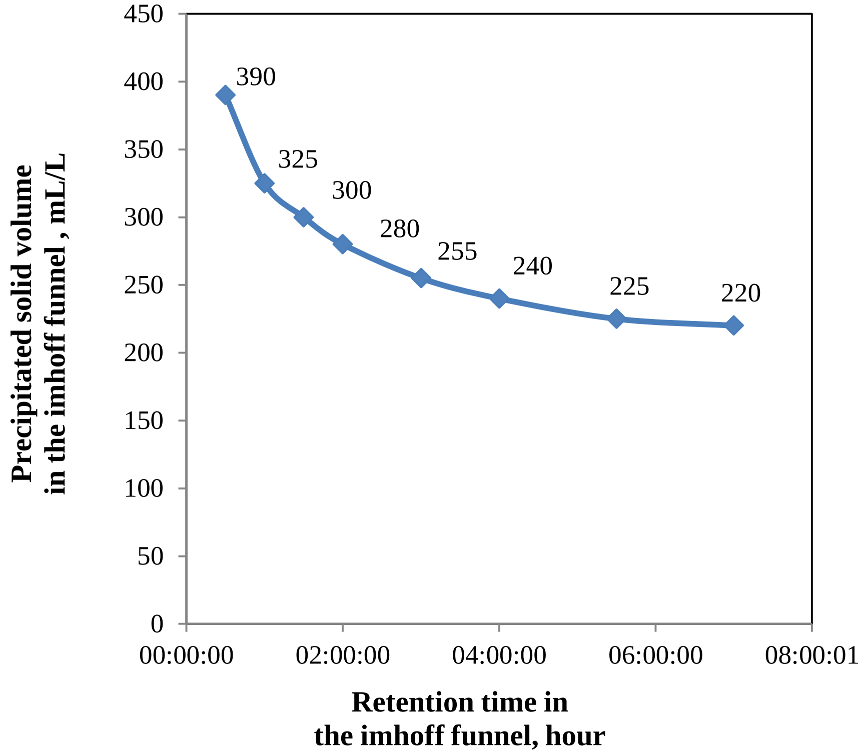


Figure 4.31. The volumetric quantities of time-dependent settleable solids of laboratory-scale washing wastewater taken from Imhoff funnel relating to DM-13 sample

The analysis results of laboratory-scale washing wastewaters relating to DM-13 sample taken from Imhoff funnel are reported in Table 4.52 together with the results of raw and filtered wastewater.

Table 4.52. The analysis results of laboratory-scale washing wastewaters relating to DM-13 sample in the Imhoff funnel

The procedure	Amount of Sample (g)	Washing Water Volume (ml)	Analysis Parameters				
			TSS (mg/L)	VSS (mg/L)	TKN (mg/L)	TP (mg/L)	TOC (mg/L)
Raw Wastewater (t=0; No retention in the Imhoff funnel)	500	500	28,350	2,200	823	2.71	506.0
1 hours retention in the Imhoff funnel			110	10	0.82	0.27	5.3
2 hours retention in the Imhoff funnel			75	5	0.82	0.19	6.5
7 hours retention in the Imhoff funnel			30	15	0.82	0.14	5.1
Filtered Wastewater			<2	<2	<0.50	0.07	4.5

It can be clearly seen from Table 4.56 that the increment in retention time and TSS removal also increases the removal of VSS, TKN, TP and TOC. Besides, it is observed that the filtered wastewater has no "DM-13 sample"-dependent contamination. This tendency is also in agreement with the idea of the existence of relevant pollutants in particulate form in wastewaters of concern.

4.3.1.3 Daily Water Utilization and Wastewater Discharge Load in the 1,500 m^3 Capacity Industrial-Scale DM Pre-Treatment Plant

The water utilization and the management of wastewater resulting from DM pre-treatment plant are the important issues due to excess amounts of water. Considering the 1,500 m^3/day DM washing capacity of the relevant plant, it is clear that 1,500 m^3 washing water will be used for the desalination of DMs and approximately 1,500 m^3/day wastewater will be generated in the real scale application (1:1 (w/v)).

In case of wastewater discharge at the end of DM washing-sieving procedure per day to the receiving environment, the possible wastewater pollution load reached to the receiving environment was calculated and is presented in Table 4.53.

Table 4.53. Wastewater pollution load for 1,500 m^3 DM washing capacity plant

The procedure	Amount of washing water (m^3/day)	Wastewater pollution load				
		TSS (ton/day)	**VSS (ton/day)**	**TKN (ton/day)**	**TP (ton/day)**	**TOC (ton/day)**
Raw wastewater	1,500 m^3	42,525	3,300	124.00	4.1	759.0
1 hour gravitational precipitation		165	15	1.23	0.4	8.0
Filtered Wastewater		-	-	-	0.1	6.8

It is observed that the discharge of wastewater generated without silt-clay separation into the receiving environment will be 42,525 ton/day. Considering ~7-8% of TSS is organic origin, a significant amount of organic matter and nutrients will also be discharged to the environment. After 1 hour of gravitational precipitation trial, the amount of TSS to be discharged daily will only be 165 ton. Besides, the load of nutrients (TKN, TP) to be reached to the receiving environment will be reduced significantly with the removal of TSS. For instance, pollution load of wastewater discharged to the environment without precipitation will be 124 ton/day, 4.1 ton/day and 759 ton/day in terms of TKN, TP and TOC while relevant discharge will be 1.23 ton/day, 0.4 ton/day and 8.0 ton/day after performing 1 hour precipitation, respectively.

4.3.1.4 Water Utilization in Industrial-Scale DM Pre-Treatment Plant and Suggestions for the Management of Wastewater

The optimization of DM washing process in terms of water utilization: When some factors such as the high capacity (1,500 m^3/day) of possible industrial-scale DM pre-treatment plant, limited water resources and unit cost of water are taken into account, the requirement for the reduction of water utilization and the optimization of washing process can be clearly seen. Therefore, some recommendations for reducing the use of water are presented below for DM washing-sieving process:

- Before DM is subjected to the washing process, the removal of saline water within DM (the use of settlement ponds having drainage pipes underlain),
- Gradual washing of DM, the utilization of water having low salinity for the utilization of DM having high salinity at the beginning with the internal back cycles.

Alternative water resource use: The establishment of possible stationary industrial-scale DM pre-treatment plant close to the urban WWTPs having advanced or secondary treatment process; thus, the possible reduction of water consumption by using the relevant WWTPs' effluents as process water should be taken into consideration. It is thought that the effluent of the urban WWTP will be purified by pre-subjecting to sand filtration and UV disinfection; then, residual chlorination, if necessary.

Wastewater management: Due to the high ratio of TSS content, possible industrial-scale DM pre-treatment plant's wastewater must be absolutely subjected to at least gravitational precipitation process prior to discharge. The use of micro sieves having suitable pore sizes and/or chemical precipitation using coagulant and flocculant material can also be taken into account for the increment for precipitation process. However, it should not be forgotten that DM can be affected by chemical precipitation. Thus, the selection of the appropriate chemicals to be used in precipitation process should be done by considering the assessment way of silt-clay residues of DMs.

Possible regions/ports for the establishment of stationary industrial-scale DM pre-treatment plant across Turkey are presented in Table 4.54 and in Figure 4.33, respectively. The relevant regions/ports are well-known for their intensive dredging operations. Urban WWTPs including advanced or secondary treatment process situated close to these regions/ports were also taken into account for the possible reduction of water consumption by using the relevant WWTPs' effluents as process water, as previously denoted. The requirement of mobile DM pre-treatment plant for small-scale dredging activities such as fishery harbours should also be evaluated. Suggestions about the matching of stationary industrial-scale DM pre-treatment plants with urban WWTPs are reported in Table 4.55 according to the possible dredging scenarios to be performed in the sampling points.

Table 4.54. Possible regions/ports for the establishment of stationary industrial-scale DM pre-treatment plant (suggestions)

Name of sea	Possible Regions
Marmara Sea	İstanbul Ambarlı Port Yalova Altınova (Shipyards Area)
Black Sea	İstanbul Sile Samsun Port Rize Port
Aegean Sea	İzmir Aliağa Gulf İzmir Çiğli WWTP area
Mediterranean Sea	İskenderun Port Mersin Port Antalya Port

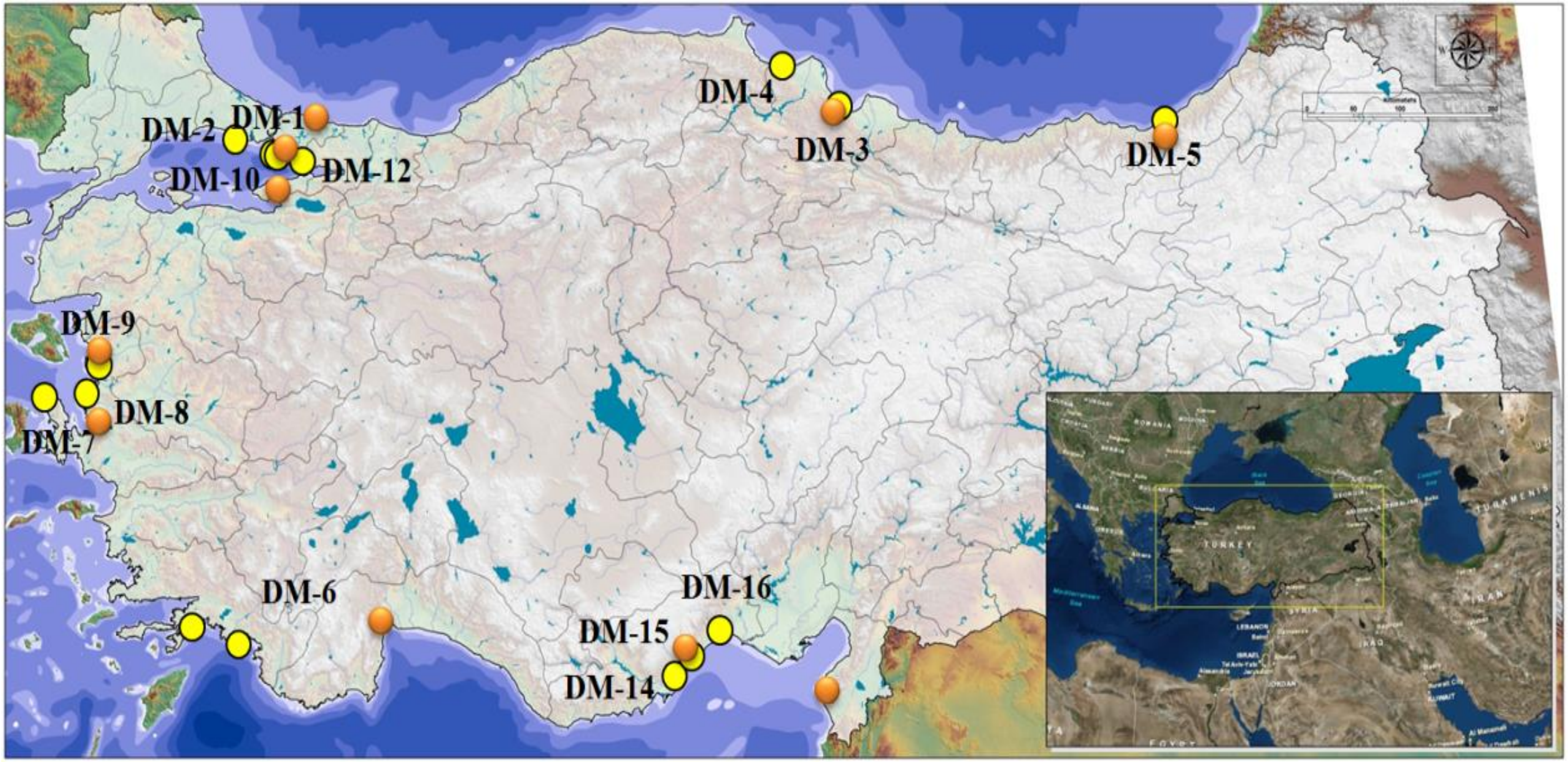


Figure 4.32. Sampling points (yellow) and possible regions/ports planned for the establishment of stationary industrial-scale DM pre-treatment plant (orange)

Table 4.55. Matching of possible stationary industrial-scale DM pre-treatment plants with urban WWTPs

Name of Sampling Points	Estimated DM (m^3)	Possible DM Pre-Treatment Plant Region	Existence of WWTP	WWTP Level/Technology	WWTP Average Capacity (m^3/day)
İstanbul Tuzla Marina	300,000	Yalova Altınova	• Altınova Tavşanlı Kaytazdere Subaşı WWTP	• Secondary Treatment Classic Activated Sludge	12,200
İstanbul Ambarlı Port	50,000	Istanbul Ambarlı Port	• Ambarlı Advanced Biological WWTP • Küçükçekmece WWTP	• Advanced Treatment and Disinfection • Sieve-Sand Holder	240,000 354,000
Samsun Port	400,000	Samsun Port	• Ondokuz Mayıs WWTP	• Secondary Treatment Classic Activated Sludge	10,000
Samsun Alaçam Yakakent Fishery Harbour	50,000	Samsun Port	• Ondokuz Mayıs WWTP	• Secondary Treatment Classic Activated Sludge	10,000
Rize Port	300,000	Rize Port	• No WWTP. (Deep Sea Discharge)	-	-
Muğla Göcek Marina	50,000	Antalya Port	• Hurma WWTP	• Extended Aeration Activated Sludge	-
İzmir Karaburun Tepeboz Village Fishery Harbour	50,000	İzmir Çiğli	• Çiğli WWTP	• Extended Aeration Activated Sludge	-
İzmir Nemrut Gulf Batıçim Harbour	100,000	Izmir Aliağa Gulf	• Aliağa WWTP	• Secondary Treatment Artificial Wetland	-
İzmir PETKIM Container Port	100,000	Izmir Çiğli	• Çiğli WWTP	• Extended Aeration Activated Sludge	-
İstanbul Tuzla Shipyards Area	100,000	Yalova Altınova	• Altınova Tavşanlı Kaytazdere Subaşı WWTP	• Secondary Treatment Classic Activated Sludge	12,200
Eskihisar Fishery Harbour	75,000	Yalova Altınova	• Altınova Tavşanlı Kaytazdere Subaşı WWTP	• Secondary Treatment Classic Activated Sludge	12,200
TÜPRAŞ Yarımca Port	100,000	Yalova Altınova	• Altınova Tavşanlı Kaytazdere Subaşı WWTP	• Secondary Treatment Classic Activated Sludge	12,200
Erdemli METU Campus Port	100,000	Mersin International Port	• Atakent WWTP • Erdemli WWTP • Karaduvar WWTP • Tarsus WWTP • Iskenderun WWTP	• Classic Activated Sludge • Extended Aeration Activated Sludge • - • Extended Aeration Activated Sludge • Classic Activated Sludge	8,000 20,000 190,000 61,000 57,000
Erdemli Fishery Harbour	50,000	Mersin International Port	• Atakent WWTP • Erdemli WWTP • Karaduvar WWTP • Tarsus WWTP • Iskenderun WWTP	• Classic Activated Sludge • Extended Aeration Activated Sludge • - • Extended Aeration Activated Sludge • Classic Activated Sludge	8,000 20,000 190,000 6,.000 57,000
Mersin International Port	2,000,000	Mersin Port	• Atakent WWTP • Erdemli WWTP • Karaduvar WWTP • Tarsus WWTP • Iskenderun WWTP	• Classic Activated Sludge • Extended Aeration Activated Sludge • - • Extended Aeration Activated Sludge • Classic Activated Sludge	8,000 20,000 190,000 61,000 57,000

4.3.1.5 Dredging, Unloading and Transfer of DMs to the Possible Stationary Industrial-Scale DM Pre-Treatment Plant

Several assumptions for the management of DM. Approximately 1,500 m^3 DM (specific gravity ~ 2,500 kg/m^3) will be dredged with a backhoe dredger in the commercial harbour/marina per day, as discussed previously; then, transferred to the shore through 250 and/or 500 m^3 barges. DM will be unloaded from barge to the 2,000 m^3 (25 m x 40 m x 2 m) capacity settling basin constructed at the harbour. The required costs for dredging, transfer of DM to the settling basin and then to the relevant industrial-scale DM pre-treatment plant will be belonged to the harbour company performing dredging. The construction of impermeable layer, drainage layer and drainage pipes with the vacuum system for initial dewatering/desalination of DM within the settling basin should be taken into account.

5. COST ANALYSIS

One of the important elements on decision-making is the determination of the costs for open dumping/upland disposal/beneficial use alternatives. Therefore, the costs of all DM management options should be calculated and the net unit cost of DM's dredging/open dumping/upland disposal/beneficial use must be known.

In the cost analysis, all costs relating to final dumping/disposal of DM and the financial returns to be occurred in case of beneficial use of DM as manufactured topsoil in landscaping applications will be computed. In the calculation of expenses, all the costs associated with dredging of DM, unloading to the harbour area, temporary storage at the harbour, transportation to the DM pre-treatment plant, physical improvement in the plant (washing (desalination)), sieving by separating into different fractions, dewatering) and the conversion to the final product will be reckoned. In addition to these costs, if there are some repeated different costs in time, these costs in the future will also be considered. If there is some income in the reuse of DM, a net expense will be reached by deducting of this income from the expenses and unit cost will be obtained with dividing of this expense to the amount of DM for the beneficial use. Unit costs will be used to make comparisons between different alternatives in terms of finance and the most effective cost (the lowest unit cost) alternative will be determined.

Certainly, environmental costs of each alternative are also considered as well as financial costs. An alternative can be financially low cost; however, it can be costly in terms of environment. The development of a method including environmental costs to be taken into consideration is targeted in decision-making mechanism.

In the scope of second thesis progress report, dredging cost, dumping cost at sea, landfilling disposal cost, beneficial use cost as manufactured topsoil in landscaping applications and the initial investment and operating costs of DM pre-treatment plant were given.

5.1 Cost Analysis Methodology

This section describes the methodology for the financial evaluation of alternative use methods of DMs.

The method used in this study is the “Dynamic Unit Cost (DUC) Method” similar to Cost Analysis. Primarily, "what is the meaning of cost analysis" should be explained in order to understand this method (European Commission, 2014).

Cost analysis is an analysis method used to compare alternative investment projects. Both private enterprises and various public corporations have been used this method to make a selection and ranking among the investment projects. It includes the comparison of required expenditures of the project with the expected incomes during the economic life of the investment. In other words, expected net income (the annual difference between revenues and expenses) with a certain "discount rate" is reduced to the beginning period of investment value (present value) and this value is compared with the investment expenditure. Net Present Value (NPV) is calculated with equation (16) which represents Y_0; the first investment, NB; net benefit (annual income and expense difference), d; discount rate, n; year (European Commission, 2014).

$$NPV = -\mathrm{Yo} + \sum_{n=1}^{n} \frac{\mathrm{NBn}}{(1+d)^n} \tag{16}$$

While making a selection among the alternative projects, the project having the highest benefit-cost ratio (or the highest NPV) is selected (European Commission, 2014).

In the cost analysis, the identification of income and cost and the determination of the scope in a quantitative manner are usually difficult topics. These difficulties are mainly due to the following reasons:

a) Difficulties encountered in the financial expression of some type of costs also cause difficulties in the accurate calculation of costs. For instance, the benefit (clean environment, clean air) to be gained from an investment project aimed at preventing environmental pollution is extremely difficult to be expressed in financial term (European Commission, 2014).

b) Similarly, a lot of positive/negative external affects are concerned in real life. In these cases, prices based on the company will not reflect the real (social) costs; it will be placed above or below the costs. For example, manufacturing process causing air pollution will increase the real cost to be met by the private company because of unexpected precautions. Similarly, a project defined with insufficient profitability by private company in terms of trading may become a high social benefit (profitability) project. (European Commission, 2014).

In DUC method, primarily NPV is calculated by taking into account all the costs of each alternative. This value is then divided by the NPV of the amount of DM to be processed in the years with that alternative. The alternative having the lowest unit cost is preferred. DUC can be calculated via empirical formula as presented in equation (17) below (European Commission, 2014).

$$DUC = \frac{\mathrm{NPV}}{\sum_{\mathrm{n}=1}^{\mathrm{n}} \frac{\mathrm{PDMn}}{(1+\mathrm{d})^{\mathrm{n}}}} \tag{17}$$

In equation (2), DUC is the dynamic unit cost; NPV is the net present value; PDM is the amount of processed DM (m^3); d is the discount rate and n indicates the year (European Commission, 2014).

5.1.1 Cost Items related to the Alternative Management Options of DMs

The costs are detailed below for different DM management options:

Processing Costs;

In case of beneficial use applications, “DM pre-treatment plant” should be needed due to the physico-chemical characteristics of DMs. For such a pre-treatment plant, capacity should be selected; investment and operating costs should be calculated. A unit cost should be calculated by considering the costs such as land allocation, machinery/equipment purchasing, construction activities, personnel and energy expenses. Sales revenue of the final product should also be considered. Stationary DM pre-treatment plant generally consists of the following units:

- Raw DM storage area (temporary storage pools),
- Coarse sieve system,
- Washing-sieving (classification) system,
- Hydrocyclone,
- The filter-press dewatering system,
- WWTP (the purification and reuse of the washing water),
- Stock areas for classified DMs in accordance with the different particle sizes,
- Storage area for the stocking of residuals (glass, metal, plastic waste, etc.),
- The conveyor system for the transfer of DM between pre-treatment units.

Loading and Unloading Costs;

Individual loading and unloading costs for different transportation methods should be mentioned. For example, transportation of DM through the pipeline, due to the pumping directly to the dewatering unit, will eliminate the cost of loading and unloading. Transportation with truck will only bring loading cost; that's why unloading of DM directly to the designated areas with truck is possible. In the transportation via train, both loading and unloading costs will arise. Because, the possibility of having railway next to the dredging area or dewatering plant is low. In the transportation with sea vehicles, only dumping cost will be involved due to the direct loading to the barge. Loading and unloading costs should be calculated for different transportation alternatives.

Dredging/Dumping at Sea Costs;

The cost account with respect to dredging operations performed with the bucket ladder and cutter suction dredger and the related dumping costs should be considered.

Transportation Costs;

The transportation of DM from dredging area to the final usage area is an important cost factor. This cost can vary depending on the transport type and the distance.

Landfill Disposal Costs;

If the usage/disposal of DM on land, soil or landfill is concerned, different costs can be occurred. If DM is land-filled, disposal costs per ton should be included. All transportation costs required for the transfer of DMs to the disposal sites and landfilling costs of DMs should be considered. The cost calculation related to the transportation of DM to appropriate disposal sites (landfills, wild landfill sites, abandoned mine sites, etc.) determined on land and to be disposed in these areas was made.

Beneficial Use Costs;

DM is a valuable resource and the costs related to the use of DM as manufactured topsoil in the landscaping instead of natural topsoil should be considered.

5.2 Cost Calculation related to Dredging and Dumping at Sea

In the scope of this thesis study, the usage of "*dredging unit costs and CER prices for 2016*" presented on the own website of MTMAC (Ministry of Transportation, Maritime Affairs and Communication) has been found appropriate for the calculation of the dredging costs performed in the sampling points.

Bucket-Ladder Dredger, C**utter Suction Dredger** and **Excavator** are generally used as dredgers in the dredging operations. Due to the lack of mobility of these dredgers, towboats are preferred in order to transport these marine vehicles to the related dredging area. **Barges** are also used for dumping of DM excavated from the ports/harbours.

In the scope of this thesis work, the costs of dredging and dumping at sea were determined by the following factors:

- The amount of DM
- Dredging unit price. It is 2 TL/m^3 for fishery harbours and 15 TL/m^3 for other ports/harbours/marinas.
- CER distance (Distance between the dredging area and first departure

point of dredger). (CER Price calculation is presented in equation (18) below).

CER Price = CER distance x Total of average fuel consumption per mile of all the dredgers during CER x Fuel unit price (18)

- The fuel unit cost was accepted as 4 TL for the fuel consumption of vehicles used in dredging operation.

The following assumptions were made while calculating the costs of dredging and dumping at sea:

- Dredging operation was made with dredgers attached to MTMAC.
- Dredging operation was generally carried out with "Backhoe Dredger" having 250 m^3/h dredging capacity.
- An average of 1500 m^3 DM per day dredged via backhoe dredger was accepted. There may be some differences depending on the sampling points.
- The volume of barge used for dumping of DM at sea is 500 m^3 for dredging operations in the Aegean Sea and the Mediterranean; 250 m^3 for dredging operations in the Black Sea and both 250 m^3 and 500 m^3 for dredging operations in the Marmara Sea.
- There are not any long-distance movement ability of backhoe dredger and cutter-suction dredger. They can move 2-3 m back and forth from their own locations during dredging operation. They should be pulled by towboat to the dredging area.
- There is long-distance movement ability of barges.

Components determining the costs of dredging at each sampling points are shown in Table 5.1.

Table 5.1. Components determining the costs of dredging in the sampling points

Sample Code	Sampling Points	Estimated Dredging Amount (m^3)	Towboat Name	Towboat Fuel Consumption (L/mile)	Dredger Name	Towboat CER Distance (mile)
DM-1	Istanbul Tuzla Marina	300,000	Yekta Inceören	26.5	Kazar VI	1
DM-2	Istanbul Ambarlı Port	50,000	Yekta Inceören	26.5	Kazar VI	31
DM-3	Samsun Port	400,000	Ahmet Atahan	26.5	Kazar IV Kazar X	1
DM-4	Samsun Alaçam Yakakent Fishery Harbour	50,000	Ahmet Atahan	26.5	Kazar IV Kazar X	1
DM-5	Rize Port	300,000	Ahmet Atahan	26.5	Kazar IV	200
DM-6	Muğla Göcek Marina	50,000	Rıza Berke	45	Kazar VIII	285
DM-7	Izmir Karaburun Tepeboz Village Fishery Harbour	50,000	Rıza Berke	45	Kazar VIII	32
DM-8	Izmir Nemrut Gulf Batıçim Harbour	100,000	Rıza Berke	45	Kazar VIII	50
DM-9	Izmir PETKİM Container Port	100,000	Rıza Berke	45	Kazar VIII	50
DM-10	Istanbul Tuzla Shipyards Area	100,000	Yekta Inceören	26.5	Kazar VI	1
DM-12	Kocaeli Eskihisar Fishery Harbour	75,000	Yekta Inceören	26.5	Kazar VI	9
DM-13	Kocaeli TUPRAS Yarımca Port	100,000	Yekta Inceören	26.5	Kazar VI	25
DM-14	Mersin Erdemli METU Campus Port	100,000	Rıza Berke	45	Kazar VIII	500
DM-15	Mersin Erdemli Fishery Harbour	50,000	Rıza Berke	45	Kazar VIII	505
DM-16	Mersin International Port (MIP)	2,000,000	Rıza Berke	45	Kazar VIII	520

In accordance with information provided in Table 5.1, for example, the dredging costs for Istanbul Tuzla Marina were determined as follows:

- Dredging cost = Dredging unit price X The amount of DM
  = 15 X 300,000 = 4,500,000 TL
- CER Price = Fuel consumption of towboat X 1 mile X 4 TL
  = 26.5 X 1 X 4 = 106 TL
- Unit dredging cost = (Dredging cost + CER Price) / The total amount of DM
  (4,500,000 + 106) / 300,000 = 15 TL/m^3

Due to the fact that CER price is not high, the unit cost has not changed much.

Table 5.2 shows the unit dredging costs calculated for all sampling points in the scope of the thesis study.

Table 5.2. Unit dredging costs calculated for all sampling points

Sample Code	Sampling Points	Dredging Cost (TL)	CER Price (TL)	Total Dredging Cost (TL)	Total Unit Dredging Cost (TL/m^3)
DM-1	Istanbul Tuzla Marina	4,500,000	106	4,500,106	15.00
DM-2	Istanbul Ambarlı Port	750,000	3286	753,286	15.07
DM-3	Samsun Port	6,000,000	106	6,000,106	15.00
DM-4	Samsun Alaçam Yakakent Fishery Harbour	100,000	106	100,106	2.00
DM-5	Rize Port	4,500,000	21200	4,521,200	15.07
DM-6	Muğla Göcek Marina	750,000	51300	801,300	16.03
DM-7	Izmir Karaburun Tepeboz Village Fishery Harbour	100,000	5760	105,760	2.12
DM-8	Izmir Nemrut Gulf Batıçim Harbour	1,500,000	9000	1,509,000	15.09
DM-9	Izmir PETKİM Container Port	1,500,000	9000	1,509,000	15.09
DM-10	Istanbul Tuzla Shipyards Area	1,500,000	106	1,500,106	15.00
DM-12	Kocaeli Eskihisar Fishery Harbour	150,000	954	150,954	2.01
DM-13	Kocaeli TUPRAS Yarımca Port	1,500,000	2650	1,502,650	15.03
DM-14	Mersin Erdemli METU Campus Port	1,500,000	90000	1,590,000	15.90
DM-15	Mersin Erdemli Fishery Harbour	100,000	90900	190,900	3.82
DM-16	Mersin International Port (MIP)	30,000,000	93600	30,093,600	15.05

After dredging, dumping cost was determined by the following factors:

- CER distance
- Fuel consumption of barge. Fuel unit cost was accepted as 4 TL.
- In addition, if dumping area are found in 3 miles distance, dumping cost is situated within the dredging cost. If the transportation for dumping is made a greater distance from 3 miles, an additional transportation fee is determined by a formula. This formula as presented in equation (19) below is:

DT = Additional transportation cost in the transportation exceeding the 3 nautical miles with barge (TL/m³)

$$L = (\text{Total Transportation Distance} - 3)$$
$$DT = (0.74 + (0.28 \times L)) \times 1.6 \qquad (19)$$

Components determining the costs of dumping at sea at each sampling points are shown in Table 5.3.

Also, information about the ship rental prices is found in this table. These costs are not taken into account in case of dumping at sea. However, in the event of transportation of material to the land, it is supposed to be paid by ship rent for transportation up to the land and while the cost of transportation from the sea is determined, these values are added to the account.

Table 5.3. Components determining the costs of dumping at sea in the sampling points

Sample Code	Sampling Points	Barge Name	Barge CER Distance (mile)	Daily Dumping Capacity (m^3)	Estimated Dredging-Dumping Time (day)	Barge Monthly Rent (25 day/month) (Vat, except of oil and fuel, include personal)	Barge Monthly Rent (25 day/month) (Vat, except of oil and fuel, include personal)	Barge Average Fuel Consumption (liter/mile)	Distance Between Dumping Area and Sampling Point (mile)
DM-1	Istanbul Tuzla Marina	Dökü IV DLH-Kum I	1	1500	200	120,000	165,000	11 21	4.72
DM-2	Istanbul Ambarlı Port	DLH-Kum I	31	1500	34	0	165,000	21	13.60
DM-3	Samsun Port	Dökü I Dökü V	1	1000	400	120,000	120,000	11 11	10.46
DM-4	Samsun Alaçam Yakakent Fishery Harbour	Dökü I Dökü V	1	750	67	120,000	120,000	11 11	18.00
DM-5	Rize Port	Dökü I	200	1500	200	0	120,000	11	4.20
DM-6	Muğla Göcek Marina	Çamur IV	285	1500	34	0	165,000	21	12.48
DM-7	Izmir Karaburun Tepeboz Village Fishery Harbour	Çamur IV	32	1000	50	0	165,000	21	16.42
DM-8	Izmir Nemrut Gulf Batıçim Harbour	Çamur IV	50	1500	67	0	165,000	21	4.92
DM-9	Izmir PETKİM Container Port	Çamur IV	50	1500	67	0	165,000	21	4.49
DM-10	Istanbul Tuzla Shipyards Area	Dökü IV DLH-Kum I	1	1500	67	120,000	165,000	11 21	4.39
DM-12	Kocaeli Eskihisar Fishery Harbour	DLH-Kum I	9	1000	75	0	165,000	21	18.33
DM-13	Kocaeli TUPRAS Yarımca Port	DLH-Kum I DLH-Kum II	25	1500	67	165,000	165,000	21 21	31.75
DM-14	Mersin Erdemli METU Campus Port	Çamur V	500	1500	67	0	165,000	21	1.27
DM-15	Mersin Erdemli Fishery Harbour	Çamur V	505	1500	34	0	165,000	21	1.37
DM-16	Mersin International Port (MIP)	Çamur V	520	1500	1334	0	165,000	21	9.21

In accordance with the information provided in Table 5.3, for instance, the dumping cost at sea for Istanbul Tuzla Marina was determined as follows:

Assuming the dumping to be made with DÖKÜ IV barge,

$$\text{CER Price} = \text{Fuel consumption of barge X 1 mile X 4 TL}$$
$$= 11 \text{ X } 1 \text{ X } 4 = 44 \text{ TL}$$

There is an additional fee because dumping area is far from 3 miles.

$$\text{An additional transportation fee} = (0.74 + (0.28 \text{ x } (4.72\text{-}3)) \text{ x } 1.6$$
$$= 1.95456 \text{ TL/m}^3$$

An additional transportation fee = 1.95456 X 300,000 = 586,368 TL

Unit dumping cost = (CER price + an additional transportation fee) / the total amount of DM

$$= (44 + 586{,}368) / 300{,}000 = 1.95 \text{ TL/m}^3$$

Unit dumping costs calculated for all sampling points are given in Table 5.4, unit dredging and dumping costs are shown in Table 5.5, respectively.

Table 5.4. Unit dumping costs (and transportation costs at sea for the disposal alternative) calculated for all sampling points

Sample Code	Sampling Points	Barge CER Price 1 (TL)	Barge CER Price 2 (TL)	Barge Rent 1 (TL) (in case of transport to land)	Barge Rent 2 (TL) (in case of transport to land)	Additional Dumping Cost (TL)	Total Dumping Cost 1 (TL)	Total Dumping Cost 2 (TL)	Minimum Unit Dumping Cost (TL/m^3)	Minimum Unit Transportation Cost (TL/m^3)
DM-1	Istanbul Tuzla Marina	44	84	960,000	1,320,000	586,368	586,412	586,452	1.95	5.15
DM-2	Istanbul Ambarlı Port	2,604	0	224,400	0	296,640	299,244	0	5.98	10.47
DM-3	Samsun Port	88	0	3,840,000	0	1,810,432	1,810,520	0	4.53	14.13
DM-4	Samsun Alaçam Yakakent Fishery Harbour	88	0	643,200	0	395,200	395,288	0	7.91	20.77
DM-5	Rize Port	17,600	0	960,000	0	516,480	534,080	0	1.78	4.98
DM-6	Muğla Göcek Marina	47,880	0	224,400	0	271,552	319,432	0	6.39	10.88
DM-7	Izmir Karaburun Tepeboz Village Fishery Harbour	5,376	0	330,000	0	359,808	365,184	0	7.30	13.90
DM-8	Izmir Nemrut Gulf Batıçim Harbour	8,400	0	442,200	0	204,416	212,816	0	2.13	6.55
DM-9	Izmir PETKİM Container Port	8,400	0	442,200	0	185,152	193,552	0	1.94	6.36
DM-10	Istanbul Tuzla Shipyards Area	44	84	321,600	442,200	180,672	180,716	328,998	1.81	5.02
DM-12	Kocaeli Eskihisar Fishery Harbour	1,512	0	495,000	0	603,888	605,400	0	8.07	14.67
DM-13	Kocaeli TUPRAS Yarımca Port	4,200	0	884,400	0	1,406,400	1,410,600	0	14.11	22.95
DM-14	Mersin Erdemli METU Campus Port	84,000	0	442,200	0	118,400	202,400	0	2.02	6.45
DM-15	Mersin Erdemli Fishery Harbour	84,840	0	224,400	0	59,200	144,040	0	2.88	7.37
DM-16	Mersin International Port (MIP)	87,360	0	8,804,400	0	7,932,160	8,019,520	0	4.01	8.41

Barge CER Price 1 and CER Price 2 have been determined optionally due to the different average fuel consumption of the different barges in MTMAC MDCE infrastructure

Table 5.5. Unit costs calculated for the dredging and dumping at sea

Sample Code	Sampling Points	Estimated Dredging Amount (m^3/year)	Unit Dredging Cost (TL/m^3)	The Dumping Cost at Sea (TL/m^3)	The Lowest Unit Cost for Dredging + Dumping at Sea (TL/m^3)
DM-1	Istanbul Tuzla Marina	300,000	15.00	1.95	16.95
DM-2	Istanbul Ambarlı Port	50,000	15.07	5.98	21.05
DM-3	Samsun Port	400,000	15.00	4.53	19.53
DM-4	Samsun Alaçam Yakakent Fishery Harbour	50,000	2.00	7.91	9.91
DM-5	Rize Port	300,000	15.07	1.78	16.85
DM-6	Muğla Göcek Marina	50,000	16.03	6.39	22.41
DM-7	Izmir Karaburun Tepeboz Village Fishery Harbour	50,000	2.12	7.30	9.42
DM-8	Izmir Nemrut Gulf Batıçim Harbour	100,000	15.09	2.13	17.22
DM-9	Izmir PETKİM Container Port	100,000	15.09	1.94	17.03
DM-10	Istanbul Tuzla Shipyards Area	100,000	15.00	1.81	16.81
DM-12	Kocaeli Eskihisar Fishery Harbour	75,000	2.01	8.07	10.08
DM-13	Kocaeli TUPRAS Yarımca Port	100,000	15.03	14.11	29.13
DM-14	Mersin Erdemli METU Campus Port	100,000	15.90	2.02	17.92
DM-15	Mersin Erdemli Fishery Harbour	50,000	3.82	2.88	6.70
DM-16	Mersin International Port (MIP)	2,000,000	15.05	4.01	19.06

5.3 Landfill Disposal Cost Calculation

In this subchapter, the costs related to the disposal of DM at Class II (non-hazardous waste) landfill have been examined.

For the upland disposal alternative, several landfill and dumping sites are determined close to sampling points according to the geological and hydrogeological site studies which are given in Table 5.6 and Table 5.7 with distances to the sampling points.

Information on the storage of DM for each sampling point in the nearest landfill or former quarry and similar area is situated in Table 5.6 and Table 5.7. The assumptions used in the calculations are as follows:

- The transportation capacity of truck was admitted as **25 ton**. The average specific gravity of DM was adopted as **2.50 ton/m^3**. That is, 1 ton of DM is **0.4 m^3**. Therefore, transportation volume of truck was assumed to be **10 m^3**.
- According to the total material amount, the number of required voyage of truck was calculated.
- Storage cost in Class II (non-hazardous waste) landfill site was accepted as **180 TL/ton (450 TL/m^3)**.
- The storage cost in uncontrolled disposal site was adopted as 60% of storage cost in Class II landfill site (due to the rehabilitation cost of uncontrolled disposal site). Thus, it is admitted as **108 TL/ton (270 TL/m^3)**.
- Approximate transportation cost range (round trip up to 100 km) within the city was adopted as **5 TL/km**.
- Transportation cost for far distance (round trip more than 100 km) was taken as **3.5 TL/km**.

In the light of data on storage, total unit costs (Transportation + Storage) are given for each pilot area in Table 5.8 and Table 5.9, respectively. In case of alternative transportation routes, two different transportation cost will occur, unit costs as the minimum and maximum are given in Table 5.8 and Table 5.9, respectively. Accordingly, unit costs are changed between 280 and 506 TL/m^3.

Table 5.6. Information about controlled/uncontrolled upland disposal alternatives in the sampling points

Sample Code	Sampling Points	Number of Voyage required for Transportation	Unit Transportation Cost (TL/km)	Name of Controlled/Uncontrolled Upland Disposal Sites of DM	Distance (km) of Controlled/Uncontrolled Upland Disposal Site to the Sampling Point (one way)
DM-1	Istanbul Tuzla Marina	30,000	5	Gebze IZAYDAŞ Landfill Site	D100 - 31 km/Motorway - 38 km
			5	Dilovası IZAYDAŞ Landfill Site	D100 - 21 km/Motorway - 28 km
			3.5	ISTAC Landfill Site (Kömürcüoda Solid Waste Landfill Site)	65 km
DM-2	Istanbul Ambarlı Port	5,000	3.5	Abandoned Coal Fields (2 ads) in European side of the north along the Black Sea coast around Ciftalan village	61 km - 69 km
			3.5	ISTAC Odayeri Solid Waste Landfill Site	60 km
			3.5	Eyüp Solid Waste Landfill Site	62 km
DM-3	Samsun Port	40,000	5	Yılanlar Old Solid Waste Uncontrolled Disposal Site	D100 - 11 km/Motorway - 21 km
			5	Samsun Solid Waste Landfill Site	D100 - 16 km/Motorway - 20 km
DM-4	Samsun Alaçam Yakakent Fishery Harbour	5,000	5	Alaçam Solid Waste Uncontrolled Disposal Site	13 km
			5	Area described as suitable in geographical information system (GIS) questioning in Yakakent	10 km
DM-5	Rize Port	30,000	5	Trabzon-Rize Solid Waste Landfill Site	36 km
			3.5	Abandoned Basalt Quarry (between Fındıklı-Arhavi)	76 km
DM-6	Muğla Göcek Marina	5,000	5	Abandoned Serpentinite Quarry in Marmaris	16 km
			5	Marmaris Waste Landfill Site	8.5 km
DM-7	Izmir Karaburun Tepeboz Village Fishery Harbour	5,000	5	Active Karaburun Uncontrolled Disposal Site	11 km
			5	Active Mordoğan Uncontrolled Disposal Site	32 km
			5	Sarpıncık Village Exit	7 km
DM-8	Izmir Nemrut Gulf Batıçim Harbour	10,000	5	Unrehabilitated Excavation Disposal Site in Aliağa	D100 - 16 km/Motorway - 21 km
			5	Lotus Inc. Excavation Disposal Site in Aliağa	13.5 km
			5	Active Aliağa Wild Landfill Site	13 km
			5	Landfill Site operated by Som Waste Inc. in Aliağa	21 km
			5	Abandoned Limestone Quarry in Aliağa	30 km
			5	Abandoned Limestone Quarry in Aliağaa	31 km

Table 5.7. Information about controlled/uncontrolled upland disposal alternatives in the sampling points (Table 5.6 continued)

Sample Code	Sampling Points	Number of Voyage required for Transportation	Unit Transportation Cost (TL/km)	Name of Controlled/Uncontrolled Upland Disposal Sites of DM	Distance (km) of Controlled/Uncontrolled Upland Disposal Site to the Sampling Point (one way)
DM-9	Izmir PETKIM Container Port	10,000	5	Unrehabilitated Excavation Disposal Site in Aliağa	13 km
			5	Lotus Inc. Excavation Disposal Site in Aliağa	10 km
			5	Active Aliağa Wild Landfill Site	10 km
			5	Landfill Site operated by Som Waste Inc.	17 km
			5	Abandoned Limestone Quarry in Aliağa	26 km
			5	Abandoned Limestone Quarry in Aliağa	27 km
DM-10	Istanbul Tuzla Shipyards Area	10,000	5	Gebze IZAYDAS Landfill Site	D100 - 31 km/Motorway - 38 km
			5	Dilovası IZAYDAS Landfill Site	D100 - 21 km/Motorway - 28 km
			3.5	ISTAC Landfill Site (Kömürcüoda Solid Waste Landfill Site)	65 km
DM-12	Kocaeli Eskihisar Fishery Harbour	7,500	5	Gebze IZAYDAS Landfill Site	11 km
			5	Dilovası IZAYDAS Landfill Site	21 km
			5	Active Excavation Area	12 km
			5	Izmit IZAYDAS Integrated Waste Disposal Facility	D100 27 km / E80 28 km
DM-13	Kocaeli TUPRAS Yarımca Port	10,000	5	Gebze IZAYDAS Landfill Site	D100 30 km/Anatolia Motorway + DE80 38 km
			5	Dilovası IZAYDAS Landfill Site	D100 20 km/Anatolia Motorway + DE80 28 km
DM-14	Mersin Erdemli METU Campus Port	10,000	3.5	Mersin Camili-Esenli Abandoned Limestone Quarry	67 km
			3.5	Mersin Solid Waste Landfill Site	80 km
			3.5	Mersin Kromsan Waste Landfill Site	80 km
			5	Silifke Solid Waste Landfill Site	15 km
DM-15	Mersin Erdemli Fishery Harbour	5,000	3.5	Mersin Camili-Esenli Abandoned Limestone Quarry	60 km
			3.5	Mersin Solid Waste Landfill Site	77 km
			3.5	Mersin Kromsan Waste Landfill Site	73 km
			5	Silifke Solid Waste Landfill Site	44 km
DM-16	Mersin International Port (MIP)	200,000	5	Mersin Camili-Esenli Abandoned Limestone Quarry	20 km
			5	Mersin Solid Waste Landfill Site	20 km
			5	Mersin Kromsan Waste Landfill Site	17 km

Table 5.8. Controlled/uncontrolled upland disposal unit costs in the sampling points

Sample Code	Sampling Points	Name of Controlled/Uncontrolled Upland Disposal Sites of DM	The Transportation Cost to the Disposal Sites (Total) (TL)		Total Upland Disposal Cost (Only Storage) (TL)	Total Unit Cost (Transportation+Storage) (TL/m^3)	
DM-1	Istanbul Tuzla Marina	Gebze IZAYDAŞ Landfill Site	9,300,000	11,400,000	135,000,000	481	488
		Dilovası IZAYDAŞ Landfill Site	6,300,000	8,400,000		471	478
		ISTAC Landfill Site (Kömürcüoda Solid Waste Landfill Site)	13,650,000			496	
DM-2	Istanbul Ambarlı Port	Abandoned Coal Fields (2 ads) in European side of the north along the Black Sea coast around Ciftalan village	2,135,000	2,415,000	13,500,000	313	318
		ISTAC Odayeri Solid Waste Landfill Site	2,100,000		22,500,000	492	
		Eyüp Solid Waste Landfill Site	2,170,000		22,500,000	493	
DM-3	Samsun Port	Yılanlar Old Solid Waste Uncontrolled Disposal Site	4,400,000	8,400,000	108,000,000	281	291
		Samsun Solid Waste Landfill Site	6,400,000	8,000,000	180,000,000	466	470
DM-4	Samsun Alaçam Yakakent Fishery Harbour	Alaçam Solid Waste Uncontrolled Disposal Site	650,000		13,500,000	283	
		Area described as suitable in geographical information system (GIS) questioning in Yakakent	500,000		13,500,000	280	
DM-5	Rize Port	Trabzon-Rize Solid Waste Landfill Site	10,800,000		135,000,000	486	
		Abandoned Basalt Quarry (between Fındıklı-Arhavi)	15,960,000		81,000,000	323	
DM-6	Muğla Göcek Marina	Abandoned Serpentinite Quarry in Marmaris	560,000		13,500,000	281	
		Marmaris Waste Landfill Site	297,500		22,500,000	456	
DM-7	Izmir Karaburun Tepeboz Village Fishery Harbour	Active Karaburun Uncontrolled Disposal Site	550,000		13,500,000	281	
		Active Mordoğan Uncontrolled Disposal Site	1,600,000		13,500,000	302	
		Sarpıncık Village Exit	350,000		13,500,000	277	
DM-8	Izmir Nemrut Gulf Batıçim Harbour	Unrehabilitated Excavation Disposal Site in Aliağa	1,600,000	2,100,000	27,000,000	286	291
		Lotus Inc. Excavation Disposal Site in Aliağa	1,350,000		27,000,000	284	
		Active Aliağa Wild Landfill Site	1,300,000		27,000,000	283	
		Landfill Site operated by Som Waste Inc. in Aliağa	2,100,000		45,000,000	471	
		Abandoned Limestone Quarry in Aliağa	3,000,000		27,000,000	300	
		Abandoned Limestone Quarry in Aliağa	3,100,000		27,000,000	301	

Table 5.9. Controlled/uncontrolled upland disposal unit costs in the sampling points (Table 5.8 continued)

Sample Code	Sampling Points	Name of Controlled/Uncontrolled Upland Disposal Sites of DM	The Transportation Cost to the Disposal Sites (Total) (TL)		Total Upland Disposal Cost (Only Storage) (TL)	Total Unit Cost (Transportation+Storage) (TL/m^3)	
DM-9	Izmir PETKIM Container Port	Unrehabilitated Excavation Disposal Site in Aliağa	1,300,000		27,000,000	283	
		Lotus Inc. Excavation Disposal Site in Aliağa	1,000,000		27,000,000	280	
		Active Aliağa Wild Landfill Site	1,000,000		27,000,000	280	
		Landfill Site operated by Som Waste Inc.	1,700,000		45,000,000	467	
		Abandoned Limestone Quarry in Aliağa	2,600,000		27,000,000	296	
		Abandoned Limestone Quarry in Aliağa	2,700,000		27,000,000	297	
DM-10	Istanbul Tuzla Shipyards Area	Gebze IZAYDAS Landfill Site	3,100,000	3,800,000	45,000,000	481	488
		Dilovası IZAYDAS Landfill Site	2,100,000	2,800,000	45,000,000	471	478
		ISTAC Landfill Site (Kömürcüoda Solid Waste Landfill Site)	4,550,000		45,000,000	496	
DM-12	Kocaeli Eskihisar Fishery Harbour	Gebze IZAYDAS Landfill Site	825,000		33,750,000	461	
		Dilovası IZAYDAS Landfill Site	1,575,000		33,750,000	471	
		Active Excavation Area	900,000		20,250,000	282	
		Izmit IZAYDAS Integrated Waste Disposal Facility	2,025,000	2,100,000	33,750,000	477	478
DM-13	Kocaeli TUPRAS Yarımca Port	Gebze IZAYDAS Landfill Site	3,000,000	3,800,000	45,000,000	480	488
		Dilovası IZAYDAS Landfill Site	2,000,000	2,800,000	45,000,000	470	478
DM-14	Mersin Erdemli METU Campus Port	Mersin Camili-Esenli Abandoned Limestone Quarry	4,690,000		27,000,000	317	
		Mersin Solid Waste Landfill Site	5,600,000		45,000,000	506	
		Mersin Kromsan Waste Landfill Site	5,600,000		45,000,000	506	
		Silifke Solid Waste Landfill Site	1,500,000		45,000,000	465	
DM-15	Mersin Erdemli Fishery Harbour	Mersin Camili-Esenli Abandoned Limestone Quarry	2,100,000		13,500,000	312	
		Mersin Solid Waste Landfill Site	2,695,000		22,500,000	504	
		Mersin Kromsan Waste Landfill Site	2,555,000		22,500,000	501	
		Silifke Solid Waste Landfill Site	2,200,000		22,500,000	494	
DM-16	Mersin International Port (MIP)	Mersin Camili-Esenli Abandoned Limestone Quarry	40,000,000		540,000,000	290	
		Mersin Solid Waste Landfill Site	40,000,000		900,000,000	470	
		Mersin Kromsan Waste Landfill Site	34,000,000		900,000,000	467	

The information given in Table 5.8 and Table 5.9, for instance, the disposal costs of DM to the nearest controlled/uncontrolled upland disposal sites for Istanbul Tuzla Marina will be determined. Assuming that DM will be disposed in Gebze IZAYDAŞ Landfill Site, 300,000 m^3 of material can be transported in 30,000 times with 10 m^3 trucks. Given that the shortest route is 31 kilometers, the lowest unit cost is calculated as follows:

30,000 times X 2 X 31 X 5 TL/km= 9,300,000 TL transportation cost

Total upland disposal cost = 300,000 m^3 X 450 TL/m^3 = 135,000,000 TL

Total disposal unit cost = (135,000,000 + 9,300,000) / 300,000 = 481 TL/m^3

Other unit costs are calculated in a similar way.

5.4 Beneficial Use of DM as Manufactured Topsoil in Landscaping Applications

It becomes more of an issue that high salt content of DM in accordance with the relevant standards should be reduced to an acceptable level for the use of DM as manufactured topsoil in urban landscaping applications. Therefore, the reduction of high salt content of DM by washing-sieving process is required. The first investment and operating cost of DM pre-treatment plant are the most important costs in related beneficial use alternative.

5.4.1 DM Pre-Treatment Plant's First Investment and Operating Costs

It is necessary to make some assumptions to calculate the first investment and operating costs of DM pre-treatment plant designed prior to beneficial use of DM as MT in landscaping applications. Assumptions and the costs of concern are given as follows:

5.4.1.1 The First Investment Cost Calculation

The installation of DM pre-treatment plant has been considered by private sector institutions/organizations with their own resources. The size of land required for the construction of this plant has been foreseen as 3,000 m^2 (50 m x 60 m) and it is assumed that the land will be allocated freely. The washing-sieving of 1,500 m^3 raw DM per day has been envisaged in the DM pre-treatment plant. The solid matter amount of DM excavated by bucket ladder dredger has been accepted as 65%. 200 ton/h net washed dry product (5 mm-63 μm) (528,000 ton/year washed product) will be obtained at the end of DM washing-sieving process. Quality gravel (+5 mm) to be emerged from process is not included in this tonnage. The effluent of WWTP given freely (without pay) to DM pre-treatment plant and pumping of the related effluent water by pipeline to the plant have been planned. 30 cm thick (900 m^3) (C25/30 strength class) floor concrete has been assumed to be poured for 3,000 m^2 plant floor area. Ready-mixed concrete cost is 130 TL/m^3 and total concrete cost with concrete paving labor and reinforcement has been adopted as 260 TL/m^3. The construction cost of 2,000 m^3 (25 x 40 m x 2 m) settlement pool with impermeable layer, drainage pipes, drainage layer, and C25/30 strength class concrete has been considered as 100,000 TL. The renewal cost has been foreseen every five years and 10% of the first investment cost of the related equipment for feeding bunker, conveyor belts, vibratory sieves, mixer (blademill), hydrocyclone system, thickener and filter-press in DM pre-treatment plant. Water pump to be used in the transfer of process water to the plant will be completely renewed every five years. 3 trucks having 25 ton capacity, 1 dozer and 1 excavator will be found in DM pre-treatment plant, administration building will be constructed in the plant area for staff and one weighbridge will also take place. The cost of unexpected expenses in DM pre-treatment plant has been accepted as 10% of the first investment cost of the total mechanical equipment.

5.4.1.2 Operating Cost Calculation

DM pre-treatment plant will work for 10 hours a day, 22 days a month and 12 months a year, respectively. A total of 10 staff including 5 drivers, 4 workers and 1 plant supervisor will be responsible in the plant. Average staff expense was adopted as 60,000 TL/staff/year. Electricity consumption was foreseen as 1.6 kW/ton net washed products (5 mm - 63 μm) and electricity unit price was taken as 0.29 TL/kW. Process water consumption in the plant was predicted as 200 tons/hour (same with DM tonnage) by considering DM laboratory scale washing-sieving experiments and washing efficiency in industrial scale. Polymer consumption was assumed to be 100 g for 1 ton of net washed product and polymer cost was estimated as 10 TL/kg. Fuel consumption for machines used in the plant was envisaged as 0.2 L/ton finished product. The maintenance and repair cost of DM pre-treatment plant were accepted as an annual fee of 2.5% of the total mechanical equipment first investment cost. The required operating expense for the purification of inlet and outlet water of plant was considered as 225,000 TL per year. General administration expenses were accepted as 10% of operating costs (staff, electricity, water, polymers, fuel, maintenance and repair costs). The economic analysis was conducted for 15 years for the account of operating cost.

5.4.1.3 General Assessment of DM Pre-Treatment Plant Cost Analysis

While incomes and expenses of DM pre-treatment plant were calculated, constant price was accepted and inflation was not taken into account. The first investment cost for 1,500 m^3/day capacity DM pre-treatment plant was calculated as 6,753,600 TL and operating cost (staff, electricity, water, polymer, fuel, maintenance and repair, wastewater treatment plant operating costs and administrative expenses) was computed as 2,403,981 TL/year (200.332 TL/month or 4.55 TL/ton), respectively. The first investment and operating cost for DM pre-treatment plant are given in Table 5.10 and Table 5.11, respectively.

Table 5.10. DM pre-treatment plant first investment cost

Activity	First Investment Cost Component	Cost (TL)
Construction Affairs	Plant Establishment Area	Allocation
	Plant Floor Concrete	234,000
	Water Leakage/Precipitation Pool	100,000
	Plant Inlet Water Treatment (Sand Filtration and UV Disinfection)	600,000
	Plant Effluent Treatment (Micro Sieves and Sand Filter)	750,000
Machine-Equipment	Plant Establishment with Feeding Bunker and Conveyor Belt	500,000
	Vibratory Coarse Sieve System	160,000
	Mixer (blademill)	240,000
	Vibratory Fine Sieve System	160,000
	Hydrocyclone System	1,100,000
	Intermediate Tank, Thickener, Filter-Press	1,400,000
	Water Pump	6,000
	Administration Building	50,000
	Weighbridge	100,000
	Dozer	160,000
	Trucks (3)	450,000
	Loader	160,000
	Unexpected Expenses	583,600
	TOTAL	**6,753,600**

Table 5.11. DM pre-treatment plant operating cost

Operating Cost Component	Cost (TL) (Annual)
Staff (10 people)	600,000
Electricity Expenses	244,992
Water Utilization	free
Polymer Addition	528,000
Fuel Used	462,000
Maintenance – Repair Expenses	145,900
Treatment Plants Operating Expenses	225,000
General Administration Expenses	198,089
TOTAL	**2,403,981**

The sale price of washed final product was determined as 10 TL/ton (25 TL/m^3). Annual income of DM pre-treatment plant will be 5,280,000 TL if 528,000 tons of products are totally sold. Furthermore, as the annual operating cost is deducted from this charge, the annual net income of the plant will become 2,876,019 TL. The repayment period is the necessary time to pay back the total first investment cost completely from project's net cash inflows. While the NPV of the income was 36,509,182 TL; the NPV of expenditure was calculated as 23,172,248 TL. When the NPV of the product was 3,650,918 tons, the unit cost (NPV expenditure/NPV product) for the washing-sieving of DM was determined as 15.75 TL/m^3 (6.3

TL/ton). If 1.1 TL/ton (2.77 TL/m^3) as the cost of transportation from sea to the land and 25% profit are added to this value, 9.33 TL/ton + vat sale price is determined and the product sales price is estimated as 10 TL/ton.

5.5 Comparison of Dumping at Sea, Landfill Disposal and Beneficial Use Alternatives

The comparison of costs calculated for dumping at sea, landfill disposal and beneficial use of DM as manufactured topsoil in landscaping applications was presented in Table 5.14. The costs include transportation from sea to land (removing of DM from sea to land), transportation to DM pre-treatment plant (Table 5.12 and Table 5.13) and DM pre-treatment costs as well. Daily crane rent is accepted for 3.54 TL for the transportation work from sea to land and a unit cost is included in the estimate calculations in accordance with the amount of material.

As it can be seen, dumping at sea is the most convenient management option, the disposal of DM at the controlled/uncontrolled landfills is a quite costly alternative. The beneficial use, which is another management option, of DM is essential. For example; dumping cost at sea as 21.05 TL/m^3, landfill disposal cost as 330.2-510.9 TL/m^3 and beneficial use cost as 48.88-53.88 TL/m^3 were determined in the management of DM removed from sampling point in Ambarlı Port. When the cost required for the pre-treatment of DM, first investment and operating costs are taken into consideration, the product sales price is estimated as 9.33 TL/ton (~10 TL/ton). Nowadays, considering the danger of extinction of natural resources, it is necessary to optimize the usage amount of soil supply for plant growth and find alternative sources as soil. Also, 1 m^3 of natural soil is about 75 TL in the current situation in Turkey. When DM was economically evaluated, the usage of DM as manufactured topsoil in landscaping applications instead of natural soil can be thought. Furthermore, when the cost analysis of DM as MT in urban landscaping applications is compared to the use of the same material in concrete systems, the high salt content of DM for the usage of DMs in concrete systems should be reduced to lower level (400 μS/cm) than the use of DM as MT in urban landscaping applications. Thus, the water consumption required for washing the DM will be higher and this consumption will be increased the beneficial use cost of DM in concrete system.

Although dumping of DM at sea seems to be more preferable management option than beneficial use of DM as topsoil in landscaping with regard to cost analysis, the beneficial use of this material should be evaluated to provide high value-added product as topsoil, to conserve natural resources (natural soil), to ensure "economical input" for our country.

Table 5.12. Calculation of transportation cost to DM pre-treatment plant

Name of Sampling Points	Estimated DM (m^3)	Possible DM Pre-Treatment Region	Existence of WWTP	Transport Distance (mile) from Sea to DM Pre-Treatment Plant	Land Transport Distance (km) to DM Pre-Treatment Plant	Dredging Unit Cost (TL/m^3)	Transport Unit Cost at Sea (TL/m^3)	Number of Dredging Day	Transport Unit Cost from Sea to Land (TL/m^3)	Transport Unit Cost in the Land (TL/m^3)	From Sea (TL/m^3)	From Land (TL/m^3)
Istanbul Tuzla Marina	300,000	Yalova Altınova	Altınova Tavşanlı Kaytazdere	18	34 km (with Topçular ferryboat)	15.00	5.15	200	2.36	17	22.52	34.36
			Subaşı WWTP		117	15.00	5.15	200	2.36	40.95	22.52	58.31
İstanbul Ambarlı Port	50,000	İstanbul Ambarlı Port	Ambarlı Advanced Biological WWTP	-	8	15.07		34	2.41	4		21.47
			Küçükçekmece WWTP		18	15.07		34	2.41	9		26.47
Samsun Port	400,000	Samsun Port	Ondokuz Mayıs WWTP	-	60	15.00		400	3.54	30	18.54	48.54
Samsun Alaçam Yakakent Fishery Harbour	50,000	Samsun Port	Ondokuz Mayıs WWTP	60	60	2.00	20.77	67	4.74	30	27.52	36.75
Rize Port	300,000	Rize Port	No WWTP. (Deep Sea Discharge)	-	-					-		
Muğla Göcek Marina	50,000	Antalya Port	Hurma WWTP	185	231	16.03	10.88	34	2.41	80.85	29.31	99.28
Izmir Karaburun Tepeboz Village Fishery Harbour	50,000	İzmir Çiğli	Çiğli WWTP	35	163	2.12	13.90	50	3.54	57.05	19.56	62.71
Izmir Nemrut Gulf Batıçim Harbour	100,000	İzmir Aliağa Gulf	Aliağa WWTP	13	13	15.09	6.55	67	2.37	6.5	24.01	23.96

Table 5.13. Calculation of transportation cost to DM pre-treatment plant (Table 5.12 continued)

Name of Sampling Point	Estimated DM (m^3)	Possible DM Pre-Treatment Region	Existence of WWTP	Transport Distance (mile) from Sea to DM Pre-Treatment Plant	Land Transport Distance (km) to DM Pre-Treatment Plant	Dredging Unit Cost (TL/m^3)	Transport Unit Cost at Sea (TL/m^3)	Number of Dredging Day	Transport Unit Cost from Sea to Land (TL/m^3)	Transport Unit Cost in the Land (TL/m^3)	From Sea (TL/m^3)	From Land (TL/m^3)
Izmir PETKIM Container Port	100,000	İzmir Çiğli	Çiğli WWTP	13	56	15.09	6.36	67	2.37	28	23.82	45.46
Istanbul Tuzla Shipyards Area	100,000	Yalova Altınova	Altınova Tavşanlı Kaytazdere Subaşı WWTP	18	34 km (with Topçular ferryboat)	15.00	5.02	67	2.37	17	22.40	34.37
					117	15.00	5.02	67	2.37	40.95	22.40	58.32
Eskihisar Fishery Harbour	75,000	Yalova Altınova	Altınova Tavşanlı Kaytazdere Subaşı WWTP	7	26 km (with Topçular ferryboat)	2.01	14.67	75	3.54	13	20.22	18.55
					101	2.01	14.67	75	3.54	35.35	20.22	40.90
TÜPRAS Yarımca Port	100,000	Yalova Altınova	Altınova Tavşanlı Kaytazdere Subaşı WWTP	12	65	15.03	22.95	67	2.37	32.5	40.35	49.90
					61 km (with Topçular ferryboat)	15.03	22.95	67	2.37	30.5	40.35	47.90
Erdemli METU Campus Port	100,000	Mersin Port	Atakent WWTP	25	92	15.90	6.45	67	2.37	46	24.72	64.27
			Erdemli WWTP		62	15.90	6.45	67	2.37	31	24.72	49.27
			Karaduvar WWTP		10	15.90	6.45	67	2.37	5	24.72	23.27
			Tarsus WWTP		26	15.90	6.45	67	2.37	13	24.72	31.27
			Iskenderun WWTP		213	15.90	6.45	67	2.37	74.55	24.72	92.82
Erdemli Fishery Harbour	50,000	Mersin Port	Atakent WWTP	25	92	3.82	7.37	34	2.41	46	13.59	52.23
			Erdemli WWTP		62	3.82	7.37	34	2.41	31	13.59	37.23
			Karaduvar WWTP		10	3.82	7.37	34	2.41	5	13.59	11.23
			Tarsus WWTP		26	3.82	7.37	34	2.41	13	13.59	19.23
			Iskenderun WWTP		213	3.82	7.37	34	2.41	74.55	13.59	80.78
Mersin International Port (MIP)	2,000,000	Mersin Port	Atakent WWTP	25	92	15.05	8.41	1334	2.36	46	25.82	63.41
			Erdemli WWTP		62	15.05	8.41	1334	2.36	31	25.82	48.41
			Karaduvar WWTP		10	15.05	8.41	1334	2.36	5	25.82	22.41
			Tarsus WWTP		26	15.05	8.41	1334	2.36	13	25.82	30.41
			Iskenderun WWTP		213	15.05	8.41	1334	2.36	74.55	25.82	91.96

Table 5.14. Comparison of costs calculated for dumping at sea, landfill disposal and beneficial use of DM as MT in landscaping applications

Sample Code	Sampling Points	Estimated Dredging Amount (m^3/year)	Unit Dredging + Dumping Cost at Sea (TL/m^3)	Unit Cost of Transportation to Land (TL/m^3)	Unit Landfill Cost- Dredging, Unloading, Transportation to Land (TL/m^3)		Unit Landfill Cost- Dredging, Unloading, Transportation to DM Pre-Treatment in Land (TL/m^3)	DM Pre-Treatment Cost (TL/m^3)
					Min.	Max.		
DM-1	Istanbul Tuzla Marina	300,000	16.96	2.36	488.4	512.9	22.52	25.00
DM-2	Istanbul Ambarlı Port	50,000	21.05	2.41	330.2	510.9	21.47 - 26.47	25.00
DM-3	Samsun Port	400,000	19.53	3.54	299.5	488.5	18.54	25.00
DM-4	Samsun Alaçam Yakakent Fishery Harbour	50,000	9.91	4.74	286.7	289.7	27.52	25.00
DM-5	Rize Port	300,000	16.85	2.36	338.3	503.4	17,43	25.00
DM-6	Muğla Göcek Marina	50,000	22.41	2.41	299.6	474.4	29.31	25.00
DM-7	Izmir Karaburun Tepeboz Village Fishery Harbour	50,000	9.42	3.54	282.7	307.7	19.56	25.00
DM-8	Izmir Nemrut Gulf Batıçim Harbour	100,000	17.22	2.37	300.5	488.5	24.01	25.00
DM-9	Izmir PETKİM Container Port	100,000	17.03	2.37	297.5	484.5	23.82	25.00
DM-10	Istanbul Tuzla Shipyards Area	100,000	16.81	2.37	488.4	512.9	22.40	25.00
DM-12	Kocaeli Eskihisar Fishery Harbour	75,000	10.08	3.54	287.6	505.4	20.22	25.00
DM-13	Kocaeli TUPRAS Yarımca Port	100,000	29.13	2.37	487.4	483.3	40.35	25.00
DM-14	Mersin Erdemli METU Campus Port	100,000	17.92	2.37	335.2	510.1	24.72	25.00
DM-15	Mersin Erdemli Fishery Harbour	50,000	6.70	2.41	318.2	487.4	13.59	25.00
DM-16	Mersin International Port (MIP)	2,000,000	19.06	2.36	307.4	512.9	25.82	25.00

6. CONCLUSIONS AND RECOMMENDATIONS

Dredging operations are so crucial for the progress of shipping operations in ports and harbours. They are also essential for the maintenance of Turkey's commercial ports and fishery harbours in order to provide sustainable development of Turkish foreign trade. Until now, the most favourable DM management option applied in Turkey has been dumping at sea, followed by upland disposal in low quantities. At present time, the large quantities of DMs are generated throughout the world and most of them remain in the aquatic system. Thus, the management of DMs is a global problem. Managers are encouraged to find environmentally sound solutions for DMs like beneficial use for the reduction of dumping at sea/disposal at landfill; hence, several opportunities have been identified as follows: topsoil creation/enhancement, construction uses, road applications, landfill daily cover/liner, mine reclamation, beach nourishment, wetland creation and habitat restoration, etc. Before the selection of appropriate beneficial use alternative, DM characteristics should also be determined. In this study of concern, the beneficial use of marine DMs as MTs in urban landscaping applications was investigated in terms of technical, environmental and economical aspect, respectively.

The key findings obtained as a result of this thesis study are as follows:

- The physico-chemical, morphological, toxicological properties, usability characteristic in soil and leaching potentials of DMs dredged from fifteen sampling points in the shores (Mediterranean, Marmara, Aegean and Black Sea) of Turkey were determined and the analysis results were compared with the relevant Turkish Legislations' (AYY-Appendix-3B, ADDDY-Appendix-2 and EKAÇTKY-Appendix-IIB) limit values.
- It can be clearly observed that the entire DMs can be defined as "non-hazardous waste" with a waste code of 17 05 06 (dredging spoil other than 17 05 05) in compliance with AYY Appendix 3B: Hazardous waste threshold limits.
- According to ADDDY-Appendix-2 analysis results, it is discovered that DMs can be stored at "Class II: non-hazardous waste" landfill sites due to the

eluate concentrations of F^-, Cl^-, SO_4^{2-}, TDS, Mo, Cu, Ni, Mo and Sb. These concentrations were found above the limits of Class III (Inert waste) landfilling criteria.

- Pursuant to EKAÇTKY-Appendix-IIB analysis results, it is seen that there is no substantial risk for DMs in order to be used in soil applications.
- Due to the fact that raw DMs showed moderate water content, slightly saline and high alkaline nature, low total nitrogen, low organic matter content and high C/N ratio pursuant to "BS 3882:2015-Topsoil specifications", they are inadequate for plant growth; thus, DMs required significant pre-treatment procedure such as sieving, desalination (washing), dewatering, organic amelioration via peat and sheep manure and pH adjustment were conducted on DM samples in order to transform DMs into an alternative natural soil (MT soil).
- Soil quality analyses were realized in a total of 33 MT samples prepared in three different mixture ratios (33%, 50%, 67%) by using improved DM, peat and manure; then, grass seeds and seasonal outdoor ornamental plant seeds were planted into the relevant MTs in order to follow their growth performances, respectively. The monitoring of grass growth performances was performed during 180 days and six harvests were carried out totally for each mixture where performances of the entire MT samples has begun to decrease at the end of 120 days.
- When the soil quality measurements at the end of growing season are compared with the related soil analysis before grass planting period, it is observed that the contents of available macronutrients, TN and TP are still quite high compared with measurements conducted before grass planting.
- Topsoil mixture prescription showing the best grass growth performance is $DM_{Mixture\text{-}C6}$ (washed) 67% + Peat 16.5% + Sheep manure 16.5% having loamy sand soil structure.
- Plant growth habits of MT mixtures having soil texture of loamy sand were better than those of having sandy loam.
- In all cases, MT samples comprising washed DMs showed better grass growth performances than those of having unwashed DMs as expected. This finding is also supported with the results of seed germination rate (%),

average and total growth height (cm/day) and biomass production (kg/m^2).

- Due to the physico-chemical structure, no substantial differences were observed between topsoil samples of control mixture and C6 mixture in terms of plant growth performances.
- It is observed that the salt contents of the whole MT samples derived from DMs have been reduced because of the regular irrigation.
- Salts found in the soil's root zone can increase the osmotic pressure; thus, decrease the plant product efficiency due to the deficiency of water and nutrients to be taken by roots in MT samples.
- According to the nutrient analysis results of the harvested grasses, the concentrations of macronutrients and micronutrients have been mostly found in plant's sufficiency ranges with some little exceptions. Green colour of grasses indicated that they have a healthy structure in terms of nitrogen and phosphorus.
- It is observed that the entire harvested grasses have adequate amounts of macro and micronutrients, show healthy structure in terms of nitrogen and phosphorus.
- On the other hand, the seasonal outdoor ornamental plants (marigold, geranium and carnation) were also planted into MT samples at the end of six months period having good plant growth performances and plant growth performances were followed for three months at this time. It is seen that MTs prepared by DMs are technically not feasible for growing seasonal outdoor ornamental plants due to their physico-chemical structures.
- As part of laboratory-scale washing-sieving experiments of the entire DMs, the characterization and management of DM’s washing wastewater resulting from the DM washing-sieving processes was also performed. Besides, the design of “DM pre-treatment plant” to be stimulated to the laboratory scale DM washing-sieving experiments was made theoretically.
- It is observed that washing wastewater resulting from the laboratory-scale DM washing-sieving attempts are not foreseen a risk in terms of heavy metal concentrations.
- In the context of cost analysis, marine dredging cost, dumping cost at sea, landfill disposal cost, together with the beneficial use cost of DM as MT in

landscaping applications were determined, the first investment and operating costs of DM pre-treatment plant were also actualized.

- Evaluation of the DM management alternatives from a financial perspective is so important. Economic evaluation of three different environmental management options (dumping at sea, disposal at landfill site, beneficial use as MT) was conducted. While the unit cost for dredging + dumping of DM at sea changes between 6.70 TL/m^3 and 29.13 TL/m^3, Controlled/uncontrolled upland disposal unit costs vary between 280 and 506 TL/m^3. In addition DM beneficial use-free of land cost, water supply from WWTP is 25 TL/m^3.As it can be seen, dumping at sea and beneficial use of DM as MT seem to be the most reasonable alternatives. It is observed that, the disposal of DM at the controlled/uncontrolled landfills is a quite costly alternative.
- The sale price of washed final product (DM) was determined as 25 TL/m^3. Also, 1 m^3 of natural soil is about 75 TL in the current situation in Turkey.
- It can be clearly stated that 70%±5% of DMs can be used for the MT application across Turkey as suggested in this work when considering the fifteen sampling points (ports/harbours) of DIPTAR Project representing Turkey's shores, DM amounts generated from these ports/harbours, the related characterization results and the required pre-treatment processes of these DMs under investigation, respectively.
- The outcomes of this study showed that DMs can be efficiently and beneficially used as MT topsoil with no adverse environmental effects; however, several pre-treatment techniques such as desalination, dewatering, organic amelioration and pH adjustment should be performed on DM samples before utilization in municipality's landscaping applications for grass growth.

The recommendations related to the subject of thesis to be undertaken in further studies are as follows:

- In recent years, "green city", which is a popular terminology, is crucial in terms of sustainable environmental management. "Green roof" applications contained in this concept have usage area with an increasing proportion especially in Germany, as well as in other developed countries.

Therefore, plant growing media including the appropriate $DM_{Mixture}$ is emerged as easily applicable new use area in these places. In developing countries like our country, the possibilities providing services of roof in the field of new house, shopping centres, organized industry etc. as “green roof” exhibit great potential in the future. Evaluation of the subject will be in place in such a progressive environmental policy.

- Significantly toxic pollutants (such as especially exhaust, oil from vehicles) pass through the rapid run-off from impermeable urban areas (asphalt, concrete, etc.) and it is known that they pollute to receiving water bodies (rivers, streams, lakes, sea, etc.). In developed countries, some of the techniques applied to the minimization of such pollutants by using porous asphalt or concrete coatings (such as lock parquet) is to ensure passing of contaminated precipitation from this areas and later reaching the receiving environment. $DM_{Mixture}$ via DM obtained directly as material to be used under permeable asphalt or concrete pavements will have suitable permeability tests. Especially, the material under coating to be performed on the beach having low salinity (or reduced amount of salt in a certain proportion) will not do any damage to the receiving environment. Because, the main receiving environment (sea) located in a short distance has already higher salt content. By the application of DM in these areas, the minimization of particularly heavy metal as well as other toxic pollutants would provide substantially.
- Beneficial use alternatives such as use of DM on granular and bituminous layer of highway, evaluation as raw material for the cement and/or brick/tile, beach nourishment practises, use as filler material in the rehabilitation of abandoned mine quarries and/or use as a port/harbour filler should be investigated.
- Since the Cl^- contents of DMs removed during dredging of dam lakes are reasonable levels in our country, laboratory and pilot/industrial scale studies should also be conducted in order to investigate the technical usability of these DMs as MT in landscaping works.
- Considering the intensive dredging operations carried out in ports across our country, permanent industrial scale DM pre-treatment plant having

non-hazardous waste recovery license should be established in order to improve the utilization characteristics of DMs prior to beneficial use.

- Due to the variable characteristics of DMs based on ports/marinas/fishery harbours, it is essential to ensure the same quality properties of DMs excavated from different sources and to provide the sustainability of the material.
- Prior to beneficial use of DMs in Turkey, the relevant "by-product" approval must be taken from the Ministry of Environment and Urbanization in the concept of national AYY Regulation.

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APPENDICES

7. APPENDICES

Appendix A: Limit values and references used in the assessment of soil analysis

Appendix B: Grass Growing Studies in the MT samples

Appendix A:

Table A.1. Limit values used in the assessment of soil productivity and soil salinity-alkalinity analysis results

Parameters	Soil Productivity, Salinity-Alkalinity Limit Values						References
	Clay %	**Silt %**	**Sand %**	**Max. Coarse Fraction (>2 mm) %**			
Soil Texture	5-35	0-65	30-85	0-30			BS,2015
	Strongly Acidic	**Moderately Acidic**	**Slightly Acidic**	**Neutral**	**Slightly Basic**	**Strongly Alkaline**	
pH	<4.5	4.5-5.5	5.5-6.5	6.5-7.5	7.5-8.5	>8.5	Richards, 1954; Ulgen and Yurtsever,1995
	Saltless	**Slightly Salty**	**Moderately Salty**	**Very Salty**	**Extremely Salty**		
Total Salt (%)	0-0.15	0.15-0.35	0.35-0.65	>0.65			Richards, 1954; Ulgen and Yurtsever,1995
EC (mS/cm)	0-2	2-4	4-8	8-16	>16		Abrol et al., 1988; Eruz, 1979
	Sandy	**Loamy**	**Clay-Loamy**	**Clay**	**Heavy Clay**		
Saturation with water %	<30	31-50	51-70	71-110	>110		TS 8333:1990
	Very Low	**Low**	**Medium**	**Good**	**High**	**Very High**	
Organic Matter (%)	0-1	1-2	2-3	3-4	>4	>10	Ulgen and Yurtsever,1995; Anonymous, 1988
Available Micronutrients:							
	Little		**Medium**		**Much**		
Available Fe (mg/kg)	< 2.5		2.5-4.5		>4.5		Lindsay and Norvell, 1978
	Not Enough			**Enough**			
Available Cu (mg/kg)	<0.2			>0.2			Follet, 1969
	Very Little	**Little**	**Enough**	**Much**		**Too Much**	
Available Zn (mg/kg)	0.2	0.2-0.7	0.7-2.4	2.4-8.0		>8.0	*Sillanpää*, 1990
Available Mn (mg/kg)	<4	4-14	14-50	50-170		>170	*Sillanpää*, 1990
	Low	**Medium**	**High**	**Very High**			
Available Al (mg/kg)	<1	1-3	3-10	>10 (toxic for plants)			Hill, 2014

Table A.2. Limit values used in the assessment of soil productivity and soil salinity-alkalinity analysis results (continued Table A.1)

Parameters	**Soil Productivity, Salinity-Alkalinity Limit Values**					**References**
Available Macronutrients:						
	Very Little	**Little**	**Enough**	**Much**	**Too Much**	
Available Ca (mg/kg)	<238	238-1150	1150-3500	3500-10000	>10000	
Available Mg (mg/kg)	<50.4	50.4-159.6	159.6-480	480-1500	>1500	*Sillanpää*, 1990
Available K (mg/kg)	<50.7	50.7-109.2	109.2-288.6	288.6-998.4	>998.4	
	Not Enough			**Enough**		
Available Na (mg/kg)	<46			>46		Jackson, 1962
	Limeless	**Little Limy**	**Moderately Limy**	**Limy**	**Very Limy**	
Lime Content (%$CaCO_3$)	0-1	1-5	5-15	15-25	>25	Ulgen and Yurtsever,1995
C/N Ratio	10-14 suitable (for topsoil)			should be< 20		BS, 2015
	Low		**Medium**	**Enough**	**High**	
Available K_2O (kg/da)	0-20		20-30	30-40	>40	Ulgen and Yurtsever,1995
	Very Low	**Low**	**Medium**	**High**	**Very High**	
Available P_2O_5 (kg/da)	0-3	3-6	6-9	9-12	>12	Ulgen and Yurtsever,1995
	Very Little	**Little**	**Enough**	**Much**	**Too Much**	
Available Boron (mg/kg)	<0.4	0.4-0.9	1.0-2.4	2.5-4.9	>5	Wolf, 1971
Total N (mg/kg)	<450	450-900	900-1700	1700-3200	>3200	*Sillanpää*, 1990
Total P (mg/kg)	<2.5	2.5-8.0	8.0-25	25-80	>80	*Sillanpää*, 1990
Heavy Metals;						
Pb (mg/kg)			Max. 750			
Cd (mg/kg)			Max. 10			
Cr (mg/kg)			Max. 1000			
Cu (mg/kg)			Max. 1000			Anonymous, 2010a
Ni (mg/kg)			Max. 300			
Hg (mg/kg)			Max. 10			
Zn (mg/kg)			Max. 2500			
As (mg/kg)			Max. 20			Reid and Dirou, 2004

Table A.3. Limit values used in the assessment of soil productivity and soil salinity-alkalinity analysis results (continued Table A.1)

Parameters	Soil Productivity, Salinity-Alkalinity Limit Values					References
Organic Pollutants;						
PAH (mg/kg)	Max. 6					Anonymous, 2010a
PCB (mg/kg)	Max. 0.8					
PCDD/F (ng TEQ/kg)	Max. 100					
Extractable Cation Concentrations;						
	Low	**Medium**	**High**	**Very High**		
Extractable K (mg/L)	<150	150-250	250-800	>800		Marx et al., 1999
Extractable Mg (mg/L)	<60	60-180	>180			
Extractable Ca (mg/L)	<1000	1000-2000	>2000			
Exchangeable Cation Concentrations;						
	Very Little	**Little**	**Enough**	**Much**	**Too Much**	
Exchangeable K (meq/100 g)	<0.13	0.13-0.28	0.28-0.74	0.74-2.56	>2.56	*Sillanpää*, 1990
Exchangeable Ca (meq/100 g)	<1.19	1.19-5.75	5.75-17.5	17.5-50	>50	
Exchangeable Mg (meq/100 g)	<0.42	0.42-1.33	1.33-4	4-12.5	>12.5	
	Not Enough		**Enough**			
Exchangeable Na (meq/100 g)	<0.2		>0.2			Jackson, 1962
	Low Risk	**Medium Risk**	**High Risk**			
ESP (%)	<5	5-15	>15			Horneck et al., 2007
SAR	<5	5-13	>13			
	Sand	**Sandy Loam**	**Silty Loam**	**Clay Loam**	**Clay**	
CEC (meq/100g)	≤5	5.1-10	10.1-18	18.1-24	>24	Brown et al., 2004

Appendix B:

Table B.1. Germination success rates of MT samples

Sample Codes	Number of Germinated Seed / Number of Planted Seed	Germination Success Rate (%)
Control-1	471/550	93.7
Control-2	483/550	96.1
Control-3	492/550	96.5
Mixture-A1	316/550	62.0
Mixture-A2	312/550	61.9
Mixture-A3	107/550	21.0
Mixture-A4	358/550	70.2
Mixture-A5	407/550	79.8
Mixture-A6	386/550	75.7
Mixture-B1	192/550	37.7
Mixture-B2	145/550	28.4
Mixture-B3	0/550	0.0
Mixture-B4	171/550	33.5
Mixture-B5	281/550	55.1
Mixture-B6	257/550	50.4
Mixture-C1	254/550	49.8
Mixture-C2	97/550	19.0
Mixture-C3	156/550	30.6
Mixture-C4	313/550	61.4
Mixture-C5	280/550	54.9
Mixture-C6	390/550	76.5
Mixture-D1	126/550	24.7
Mixture-D2	167/550	32.8
Mixture-D3	7/550	1.4
Mixture-D4	325/550	6.7
Mixture-D5	108/550	21.2
Mixture-D6	36/550	7.1
Mixture-E1	96/550	18.8
Mixture-E2	36/550	7.1
Mixture-E3	0/550	0.0
Mixture-E4	163/550	32.0
Mixture-E5	92/550	18.0
Mixture-E6	81/550	15.9

Table B.2. Total and average harvest heights of the MT samples

Sample Codes	Total Harvest Height (cm)						Average Harvest Height (cm)					
	First Harvest	Second Harvest	Third Harvest	Fourth Harvest	Fifth Harvest	Sixth Harvest	First Harvest	Second Harvest	Third Harvest	Fourth Harvest	Fifth Harvest	Sixth Harvest
Control-1	4,643	7,725	6,264	6,076	4,851	4,616	9.9	16.4	13.3	12.9	10.3	9.8
Control-2	4,954	8,597	7,631	7,680	4,106	4,154	10.3	17.8	15.8	15.9	8.5	8.6
Control-3	5,215	8,462	8,512	6,790	4,772	4,625	10.6	17.2	17.3	13.8	9.7	9.4
Mixture-A1	1,909	2,623	3,095	3,539	2,149	2,054	6.1	8.3	9.8	11.2	6.8	6.5
Mixture-A2	1,953	3,151	3,245	3,245	1,373	936	6.3	10.1	10.4	10.4	4.4	3.0
Mixture-A3	150	653	771	706	300	54	1.6	6.1	7.2	6.6	2.8	0.5
Mixture-A4	2,672	4,726	4,082	4,332	2,721	2,542	7.7	13.2	11.4	12.1	7.6	7.1
Mixture-A5	3,368	5,047	5,576	5,983	3,663	2,971	8.4	12.4	13.7	14.7	9.0	7.3
Mixture-A6	2,933	5,983	5,520	4,400	1,660	2,084	7.8	15.5	14.3	11.4	4.3	5.4
Mixture-B1	949	1,382	1,613	1,786	1,248	998	5.1	7.2	8.4	9.3	6.5	5.2
Mixture-B2	292	841	986	899	247	377	2.1	5.8	6.8	6.2	1.7	2.6
Mixture-B3	-	-	-	-	-	-	-	-	-	-	-	-
Mixture-B4	768	1,300	1,590	2,360	923	1,129	4.6	7.6	9.3	13.8	5.4	6.6
Mixture-B5	1,747	3,597	3,484	3,288	2,164	2,248	6.4	12.8	12.4	11.7	7.7	8.0
Mixture-B6	1,531	3,110	2,904	2,827	1,465	1,439	6.1	12.1	11.3	11	5.7	5.6
Mixture-C1	1,444	3,023	2,667	2,489	406	330	5.8	11.9	10.5	9.8	1.6	1.3
Mixture-C2	89	834	883	873	504	466	1.1	8.6	9.1	9	5.2	4.8
Mixture-C3	398	1,825	1,607	1,747	1,139	1,123	2.8	11.7	10.3	11.2	7.3	7.2
Mixture-C4	2,454	4,570	3,506	4,507	2,723	3,161	8.1	14.6	11.2	14.4	8.7	10.1
Mixture-C5	2,249	4,396	3,808	4,256	2,548	2,100	8.3	15.7	13.6	15.2	9.1	7.5
Mixture-C6	3,921	6,162	5,031	6,006	5,343	5,538	10.4	15.8	12.9	15.4	13.7	14.2
Mixture-D1	622	1,058	1,109	1,046	743	554	5.1	8.4	8.8	8.3	5.9	4.4
Mixture-D2	929	1,870	1,937	1,820	1,536	1,620	5.7	11.2	11.6	10.9	9.2	9.7
Mixture-D3	4	37	43	55	44	36	0.9	5.3	6.2	7.8	6.3	5.1
Mixture-D4	2,480	3,705	3,770	4,030	2,535	3,250	7.8	11.4	11.6	12.4	7.8	10.0
Mixture-D5	461	1,134	1,156	1,199	886	896	4.9	10.5	10.7	11.1	8.2	8.3
Mixture-D6	115	374	346	378	205	223	3.6	10.4	9.6	10.5	5.7	6.2
Mixture-E1	276	662	730	374	67	58	3.1	6.9	7.6	3.9	0.7	0.6
Mixture-E2	77.5	241	194	227	137	61	2.5	6.7	5.4	6.3	3.8	1.7
Mixture-E3	-	-	-	-	-	-	-	-	-	-	-	-
Mixture-E4	749	1,778	1,646	1,728	1,402	1,092	4.8	10.9	10.1	10.6	8.6	6.7
Mixture-E5	357	929	994	1,049	429	777	4.1	10.1	10.8	11.4	10.1	8.4
Mixture-E6	212	616	669	770	624	527	2.9	7.6	8.5	9.5	7.7	6.5

Table B.3. Biomass production quantities of fresh and dried (40°C) MT samples

Sample Codes	Biomass production (fresh) (g)						Biomass production (dried) (g)					
	First Harvest	Second Harvest	Third Harvest	Fourth Harvest	Fifth Harvest	Sixth Harvest	First Harvest	Second Harvest	Third Harvest	Fourth Harvest	Fifth Harvest	Sixth Harvest
Control-1	6.58	8.91	7.05	3.49	1.21	0.57	0.87	1.20	0.96	0.59	0.25	0.13
Control-2	6.78	11.57	10.21	6.15	0.94	0.44	0.93	1.54	1.31	0.95	0.24	0.13
Control-3	5.34	12.47	8.17	4.17	1.05	0.46	0.97	1.86	1.29	0.86	0.31	0.15
Mixture-A1	1.75	2.16	2.64	2.88	0.99	0.34	0.24	0.33	0.40	0.47	0.19	0.08
Mixture-A2	1.67	3.22	2.99	2.27	0.25	0.07	0.26	0.52	0.49	0.43	0.09	0.02
Mixture-A3	0.07	0.18	0.25	0.39	0.08	0.03	0.01	0.04	0.06	0.10	0.03	0.01
Mixture-A4	2.40	4.12	3.33	2.62	0.87	0.41	0.32	0.60	0.45	0.43	0.17	0.09
Mixture-A5	4.00	6.20	5.01	3.82	1.14	0.41	0.60	0.87	0.71	0.62	0.24	0.10
Mixture-A6	2.75	5.07	4.47	2.78	0.46	0.13	0.40	0.77	0.73	0.50	0.13	0.08
Mixture-B1	1.07	1.73	1.66	1.58	0.65	0.24	0.15	0.28	0.26	0.28	0.12	0.05
Mixture-B2	0.30	0.42	0.44	0.39	0.09	0.06	0.04	0.09	0.06	0.10	0.02	0.01
Mixture-B3	-	-	-	-	-	-	-	-	-	-	-	-
Mixture-B4	0.86	1.63	1.83	1.44	0.35	0.11	0.12	0.24	0.29	0.26	0.09	0.04
Mixture-B5	2.44	2.91	3.35	0.24	1.21	0.47	0.35	0.42	0.51	0.41	0.27	0.11
Mixture-B6	1.70	2.46	2.11	1.78	0.66	0.16	0.24	0.36	0.33	0.32	0.16	0.07
Mixture-C1	2.21	3.97	3.39	0.17	0.09	0.04	0.30	0.55	0.48	0.29	0.03	0.02
Mixture-C2	0.15	0.87	1.33	1.28	0.40	0.09	0.01	0.13	0.22	0.24	0.08	0.01
Mixture-C3	0.51	2.63	2.75	2.76	1.01	0.42	0.07	0.39	0.48	0.52	0.22	0.09
Mixture-C4	3.69	6.00	5.16	3.82	1.46	0.62	0.46	0.77	0.69	0.55	0.27	0.12
Mixture-C5	4.16	6.33	4.90	4.38	1.91	0.74	0.72	0.84	0.73	0.68	0.38	0.16
Mixture-C6	4.11	4.65	3.39	3.58	3.44	2.22	0.69	0.73	0.64	0.69	0.70	0.45
Mixture-D1	0.88	1.16	1.52	0.95	0.28	0.12	0.13	0.25	0.24	0.17	0.06	0.05
Mixture-D2	1.32	3.19	3.13	2.45	1.56	1.08	0.19	0.50	0.51	0.42	0.32	0.23
Mixture-D3	0.01	0.04	0.06	0.13	0.11	0.09	0.00	0.02	0.02	0.02	0.02	0.02
Mixture-D4	3.37	4.28	4.17	2.70	1.10	0.74	0.59	0.59	0.60	0.44	0.20	0.15
Mixture-D5	0.52	0.17	2.07	1.42	0.55	0.31	0.07	0.25	0.32	0.25	0.12	0.07
Mixture-D6	0.16	0.80	0.78	0.65	0.22	0.10	0.02	0.12	0.13	0.11	0.03	0.03
Mixture-E1	0.15	0.45	0.57	0.13	0.01	0.00	0.03	0.08	0.10	0.03	0.01	0.00
Mixture-E2	0.06	0.12	0.17	0.18	0.07	0.02	0.02	0.02	0.03	0.04	0.02	0.01
Mixture-E3	-	-	-	-	-	-	-	-	-	-	-	-
Mixture-E4	0.73	2.47	2.54	1.91	0.73	0.30	0.10	0.38	0.41	0.32	0.16	0.08
Mixture-E5	0.39	1.13	1.75	1.65	0.86	0.45	0.06	0.20	0.29	0.30	0.16	0.11
Mixture-E6	0.14	0.36	0.64	0.68	0.48	0.37	0.02	0.06	0.11	0.13	0.11	0.09

Table B.4. Biomass production quantities of (fresh) MT samples

Sample Codes	First Harvest	Second Harvest	Third Harvest	Fourth Harvest	Fifth Harvest	Sixth Harvest
Control-1	0.43	0.58	0.46	0.23	0.08	0.04
Control-2	0.44	0.75	0.66	0.40	0.06	0.03
Control-3	0.35	0.81	0.53	0.27	0.07	0.03
Mixture-A1	0.11	0.14	0.17	0.19	0.06	0.02
Mixture-A2	0.11	0.21	0.19	0.15	0.02	0.01
Mixture-A3	0.00	0.01	0.02	0.03	0.01	0.00
Mixture-A4	0.16	0.27	0.22	0.17	0.06	0.03
Mixture-A5	0.26	0.40	0.33	0.25	0.07	0.03
Mixture-A6	0.18	0.33	0.29	0.18	0.03	0.01
Mixture-B1	0.07	0.11	0.11	0.10	0.04	0.02
Mixture-B2	0.02	0.03	0.03	0.03	0.01	0.00
Mixture-B3	-	-	-	-	-	-
Mixture-B4	0.06	0.11	0.12	0.09	0.02	0.01
Mixture-B5	0.16	0.19	0.22	0.16	0.08	0.03
Mixture-B6	0.11	0.16	0.14	0.12	0.04	0.01
Mixture-C1	0.14	0.26	0.22	0.11	0.01	0.00
Mixture-C2	0.01	0.06	0.09	0.08	0.03	0.01
Mixture-C3	0.03	0.17	0.18	0.18	0.07	0.03
Mixture-C4	0.24	0.39	0.34	0.25	0.10	0.04
Mixture-C5	0.27	0.41	0.32	0.28	0.12	0.05
Mixture-C6	0.27	0.30	0.22	0.23	0.22	0.14
Mixture-D1	0.06	0.08	0.10	0.06	0.02	0.01
Mixture-D2	0.09	0.21	0.20	0.16	0.10	0.07
Mixture-D3	0.00	0.00	0.00	0.01	0.01	0.01
Mixture-D4	0.22	0.28	0.27	0.18	0.07	0.05
Mixture-D5	0.03	0.11	0.13	0.09	0.04	0.02
Mixture-D6	0.01	0.05	0.05	0.04	0.01	0.01
Mixture-E1	0.01	0.03	0.04	0.01	0.00	0.00
Mixture-E2	0.00	0.01	0.01	0.01	0.01	0.00
Mixture-E3	-	-	-	-	-	-
Mixture-E4	0.05	0.16	0.17	0.12	0.05	0.02
Mixture-E5	0.03	0.07	0.11	0.11	0.06	0.03
Mixture-E6	0.01	0.02	0.04	0.04	0.03	0.02

8. CURRICULUM VITAE

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- **Özoto Sınai ve Tıbbi Gazlar İml. San.Tic.Ltd.Şti.**

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Mesul Müdür (Kalite Kontrol Departmanı)

- **Çetinkaya İlaç Sanayi ve Ticaret A.Ş**

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List of Publications :

1. **B.Güzel**, H. M. Başar, S. Yenisoy Karakaş, S. Dağlı, L. Tolun "Deniz Dibi Tarama Malzemesinin İyileştirilmiş Yüzey Toprağı Olarak Çevre Düzenlemelerinde Faydalı Kullanımının Araştırılması", Çevre Bilim ve Teknoloji, Cilt:1, Sayı:1, 73-91, 2016.

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4. Başar, H.M., Güzel, B., Özer-Erdoğan, P., Tolun, L., Türkiye'deki Deniz Dibi Tarama Malzemelerinin Faydalı Kullanım Öncesi Çevresel Etkilerinin Belirlenmesi: Ticari Limanlar & Balıkçı Barınakları, Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi, (Accepted/In Press).

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Communications to national scientific meetings :

1. **Güzel, B.,** Başar, H.M., Yenisoy Karakaş, S., Dağlı, S., Tolun, L., 2015. Deniz Dibi Tarama Malzemesinin İyileştirilmiş Yüzey Toprağı Olarak Çevre Düzenlemelerinde Faydalı Kullanımının Araştırılması, 11. Ulusal Çevre Mühendisliği Kongresi, 15-17 Ekim 2015, Bursa, TÜRKİYE.
2. Çevikbilen, G., Teymur, B., Karadogan, U., Başar, H.M., Dağlı, S., Özer Erdoğan, P., **Güzel, B.,** Tolun, L., 2015. Kaba Taneli Deniz Dibi Tarama Malzemelerinin Geoteknik Özelliklerinin Değerlendirilmesi, 6. Geoteknik Sempozyumu, 26-27 Kasım 2015, Adana, TÜRKİYE.

Communications to international scientific meetings :

1. **Güzel, B.,** Başar, H.M., Güneş, K., Yenisoy Karakaş, S., Karakaş, D., Tolun, L., 2016. Investigation of Topsoil Production from Waste: Marine Dredged Material Example, Eurasia 2016 Waste Management Symposium, 2-4 May 2016, Istanbul, TURKEY.

2. Başar, H.M., Dağlı, S., Özer Erdoğan, P., **Güzel, B.,** Tolun, L., 2015. Beneficial Use Alternatives for Dredged Materials: Landfill Daily Cover, International Conference on Civil and Environmental Engineering (ICOCEE), 20-23 May 2015, Nevsehir, TURKEY.

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