ENVIRONMENTAL PROBLEMS IN NORTHERN CYPRUS: A DESCRIPTIVE STATISTICAL ANALYSIS AND FORECASTING OF AIR POLLUTION AND SOLID WASTE

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Approval of the Board of Graduate Programs

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ABSTRACT

ENVIRONMENTAL PROBLEMS IN NORTHERN CYPRUS: A DESCRIPTIVE STATISTICAL ANALYSIS AND FORECASTING OF AIR POLLUTION AND SOLID WASTE

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Environmental problems have reached to global dimensions towards the end of the twentieth century. These problems are serious matters and gaining significance due to the threat on humanity: thinning in the ozone layer; global warming; greenhouse effect; natural balance deterioration; rainforest destruction; and air and water pollution. However, the most serious and globalized environmental problem for both developed as well as developing countries is the climate change. Mainly due to anthropogenic and industrialization activities concentration levels of greenhouse gases (GHGs) have increased, and greenhouse effect has emerged, therefore; degradation of the environment has begun, air and water pollution has appeared. Especially in the Mediterranean, which is one of the inland seas, has faced extreme contamination. Cyprus as the third largest island in the Mediterranean after Sicily and Sardinia has affected. More or less similar environmental issues can be observed in the whole island of Cyprus. Especially Northern Cyprus has encountered problems sourced by thermal power plants, road transportation and fuel-based energy uses, and wastes. In this study, environmental issues are examined for Northern Cyprus in terms of air pollution and solid wastes. A descriptive statistical analysis is done. Time series forecasting by Exponential Smoothing and ARIMA techniques are conducted for air emissions measurement and generated solid waste of Northern Cyprus in order to predict leading period variables. Descriptive results are derived, as well as different implications are also be included regarding the results of prediction analysis for Northern Cyprus. The predicted values are also measured by a forecast accuracy method of MAPE, and as a result it is obvious that ARIMA model provides better forecasts than Holt-Winters exponential smoothing method. In brief, as a conclusion of the analysis of both air emission measurements and solid waste generation indicate that the level of emitted ozone for five measurement stations will increase, as well as, there will also be an increment in the total generated waste.

Keywords: Air pollution, solid waste management, Northern Cyprus, time series analysis, ARIMA forecasting

ÖZ

KUZEY KIBRIS'IN ÇEVRE SORUNLARI: HAVA KİRLİLİĞİ VE KATI ATIKLAR ÜZERİNDE AÇIKLAYICI İSTATİSTİKSEL ANALİZ VE ZAMAN SERİSİ KESTİRİMİ

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Çevre sorunları, yirminci yüzyılın sonlarına doğru küresel boyutlara ulaşmıştır. Bu sorunlar, insanlık üzerinde tehdit unsuru teşkil ettiğinden ciddi meseleler olup günden güne büyüyen önem kazanmaktadır. Bu sorunlara; küresel ısınma, sera etkisi, ozan tabakasındaki incelme çevrenin dengesinin bozulması, ormanların yok olması, hava ve su kirlilikleri dâhildir. Ancak, ciddi ve küresel boyutlara ulaşan, hem gelişmiş hem de gelişmekte olan ülkeleri etkileyen sorunlardan en önemlisi iklimsel değişiklik olarak kabul edilebilir. İnsan kökenli ve endüstriyelleşmeye bağlı olarak sera gazlarının salınımı artmış ve çevreye tahribat olarak yansımıştır. Dolayısı ile çevre degredasyonu ile hava ve su kirliliği doğmuştur. Akdeniz, bir iç deniz olarak fazlasıyla kirlenmiştir. Akdeniz'in Sicilya ve Sardunya'dan sonra en büyük adası olan Kıbrıs ise dünya ülkeleri aynı türden çevre sorunlarından etkilenmiştir. Ada genelinde benzer sorunlar gözlemlense de, özellikle Kuzey Kıbrıs'ta termik santrallerden, yakıta dayalı ulaşımdan, sıvı ve katı atıklardan kaynaklanan çevre problemleri gözlemlenmektedir. Bu çalışma kapsamında Kuzey Kıbrıs'ın önde gelen sorunlarından olan hava kirliliği ve katı atık sorunu ele alınmıştır. İstatistiksel tanımlayıcı analiz çalışması yürütülecektir. Zaman serisi tahmin metotlarından üstel düzleştirme ve ARIMA kullanılarak Kuzey Kıbrıs'ın hava emisyon ölçümleri ve ortaya çıkan çeşitli katı atık miktarları üzerinde kestirim yapılarak açıklayıcı sonuçlar yorumlanarak olası öneriler sunulacaktır. Tahmin edilen ileriki dönem değerleri MAPE metodu kullanılarak tahmin doğruluğu sorgulanmıştır. Holt-Winters üstel düzleştirme yöntemine kıyas ile ARIMA modelinin gerçek gözlemlere daha yakın değerler ürettiği bulunmuştur. Genel sonuç olarak, ölçüm yapılan her istasyondaki salınan ozon gazı seviyesinin ve toplam üretilen katı atık miktarının artacağı elde edilmiştir.

Anahtar Kelimeler: hava kirliliği, katı atık yönetimi, Kuzey Kıbrıs, zaman serisi analizi, ARIMA kestirimi

To My Family and Husband

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ABBREVIATIONS

ACF	Autocorrelation Function
AIC	Akaike Information Criterion
AR	Autoregressive
ARIMA	Autoregressive Integrated Moving Average
BIC	Bayesian Information Criterion
EC	European Commission
EIA	Environmental Investigation Agency
EU	European Union
FCS	Fully Conditional Specification
GHG	Greenhouse Gases
IWMH	Integrated Waste Management Hierarchy
LT	Landfill Tax
MA	Moving Average
MAPE	Mean Absolute Percentage Error
MAR	Missing at Random
MICE	Multivariate Imputation by Chained Equations
MSE	Mean Square Error
MSW	Municipal Solid Waste
NISP	National Individual Symbiosis Programme
PACF	Partial Autocorrelation Function
RAE	Relative Absolute Error
SLRM	Simple Linear Regression Model
STL	Seasonal Decomposition of Time Series by Loess
SWM	Solid Waste Management
TRNC	Turkish Republic of Northern Cyprus
WHO	World Health Organization
WPP	Waste Protocol Project

CHAPTER I

INTRODUCTION

The set of natural, structural, economic, social and cultural values and their interrelation form the environment. Sustainability is the most significant aspect for the environment because environment is changing continuously. Accordingly, environment is a continual problem throughout the World. Natural resources either renewable or non-renewable are provided by the planet itself. Yet, all the essential resources for living have been treated as unlimited and free commodities by the population. Although the humanity is aware that the natural resources are scarce and are consumed away one day, emergence of capitalist system and industrial revolution have forced the capacity limits of the environment in order to produce more goods and products. As a result, the quality of the environment has begun to worsen, degradation of the ecosystem has appeared, and serious environmental problems have been reached to global dimensions.

Profit-based economic system and anthropogenic activities are the major causes of all the problems. In conjunction with the population growth, production has also increased, and the concept of industrialization emerged. After The Industrial Revolution, the use of fossil fuel has increased for making machines to work faster to promote the mass production. Capitalist system production for profit gaining has been raised in order to meet the needs of the population which in turns resulted in waste products. In other words, the absorption ability of the environment is exceeded by emissions from factories and solid wastes left from consumption. Hence, environmental balance is deteriorated.

Due to population increase and industrial development solid waste problem grows continuously, too. Urbanization, technological improvement, and changing consumption habits make solid waste issue to be listed as the third biggest environmental problem after air and water pollution because of its adverse effect on the environment and human health. (Palabıyık & Altunbaş, 2004) Even though solid waste discharges deteriorate the environmental balance in the long-term, it is a natural and inevitable problem of humanity. Generating waste and removing all the created ones are almost impossible due to continual consumption of the community.

Furthermore, the atmosphere has begun to be influenced by human-driven facilities. In other words, anthropogenic activities are in charge of air pollution and share the greatest portion of greenhouse emissions. From raw resource to product disposal almost in every stage of economic cycle, pollutant air emissions appear. Therefore, in both developed and developing countries the emitted emissions lead to diversified amount of serious health and environmental problems like air quality worsening, climate change, air resources deterioration, and ozone layer depletion (Gurjar, Molina, & Ojha, 2010).

Similar to other world countries, as a part of the Mediterranean, Northern Cyprus faces serious environmental problems, too. The emissions from thermal power plants, exhausts of vehicles, and industrial facilities are resulted in air pollution. The lack of a proper solid waste management lead to solid waste sourced environmental matters. Additionally, salinization problem can be realized in underground water sources, which are the main suppliers of water to a large extent of the country due to excessive draw of water. Sewage systems are recent development in infrastructure in Northern Cyprus. Therefore, the absence of sewage and treatment systems throughout the country lead to wastewater challenges.

Solid waste problem grows continuously in the country. After air pollution, which is caused basically by thermal power plants and road transportation, waste disposal and sustainable management are from the greatest environmental problems which should be dealt with in Northern Cyprus. Major problems under solid waste management are classified as uncontrolled disposal and dumping. (Mahrum & Jones, 2009) Yet, developing disposal policies, and measurements as well as constructing required technology, and better techniques for disposal may help to reduce solid waste issue. In order to overcome waste disposal related problems, it is very important to identify the source and components of solid waste. It would be better to develop solutions and take precautions in pursuance of solid waste characterization study. In other words, measuring generated aggregate waste and classifying solid waste according to its contest will be beneficial in improving legislations regarding disposal facilities.

In the context of economics and environment relationship, air pollution, waste management and disposal establish a direct connection with one another in terms of economic development. It can be said that waste is a consequence of economic activities. The capitalist system is in a continuous production process that reveals humanity always demand goods and products to consume. The profit based capitalist economic cycle is unplanned, and make production as though human beings always need something new for consumption. Therefore, capitalist production and consumption follows a continuously increasing pattern which is resulting in increased amounts of generating waste and environmental pollution. A higher portion of consumed products leave behind as garbage due to their chemical ingredients and packing.

It is a necessity to arrange programs for decreasing waste production which is also a goal taking place under European Union targets. It should be the very first responsibility of communities' to care about the environment. Without involving society into preventative measures, success is not achieved. Correspondingly, a chain needs to be ensured between the upper and lower mechanisms, or authorities, to provide a successfully activated participation.

Adopting sustainability concept into environmental management policies are required for reducing the adverse impacts on the environment like implementing sustainable management strategies for decreasing pollution. For an operative waste management, the integrated waste management hierarchy, abbreviated IWMH, needs to be applied which follows steps of waste preventing, reduction to minimum level, reuse, recycle, energy recovery, and disposal. (TRNC Environmental Act, 2012) The hierarchy that arranges waste management facilities will be discussed in detailed following sections.

1.1. The Island of Cyprus and Northern Cyprus

After Sicilia and Sardinia, Cyprus is the third largest island in the Mediterranean Sea in terms of population and scope. The island is situated in the Eastern Mediterranean and lies on the coordinates of 35^0 N and 33 E^0. After 1974, Cyprus is a divided into two parts as Northern and Southern. The area size of the island is about 9251 km^2. Northern Cyprus covers 3335 km^2 of the total area, while 5916 km^2 belongs to the southern part. (Özverel, 2014) It has neighboring countries of Turkey, Rhodes, Egypt, Syria, Lebanon, and Greece.

Cyprus represents a typical Mediterranean climate, that is; mostly it has sunny days during a whole year, and rainfall is observed during winter season. Thereof, it is lend to sustainable energy production systems due to its solar radiation.

The demographic information of Northern Cyprus is a controversial issue, because the results of population census are not clear. According to State Planning Organization, as expected the population has been increasing gradually. The report published by the organization in 2014 on the economic and social indicators reveals that the population has been increased by 22.36% from 2005 to 2009 and reached to 283,736 by 2009. And in 2014 the total population of Northern Cyprus is estimated as 320.884. (SPO, 2016) Unfortunately, the results of the census may not reflect the truth about the population size because dwelling zones in Green Line and remote sites could not be reached to register the population. Moreover, unregistered workers hid away themselves not to be disclosed. (Hatay, 2007)

The economy of Northern Cyprus is basically depends on agriculture, education and tourism sector. When compared to 2014, the economic growth has been higher in 2010 and 2011 at rates of 3.7% and 3.9%, respectively. However, even though economic growth has continued to increase at a slower rate in 2012 and 2013, an increment of 4.9% in gross domestic product has been experienced in 2014. (SPO, 2016)

Being a part of a divided island constitutes some drawbacks for Northern Cyprus. Although the entire island of Cyprus is entered into the EU as a member in 2004, Northern part is still internationally an unrecognized country. Therefore, economic and political embargos are employed on the Turkish Republic of Cyprus. (Mahrum & Jones, 2009)

1.2. Limitations

Lack of explanatory data makes the assessment process very difficult and complicated. The quality of the collected data sets is an open question because how the observations of the data sets are collected is not known in detailed and not investigated, that is; data sets are used as given. There is no official statistical agency which could deliver a report on these issues. The used data sets are obtained from the official agencies of The Ministry of Internal affairs, and Environmental Protection Department of TRNC. Having access to the data sets took time. A petition should be made initially to the concerning administrative department, then a response is required by the authority. The applicant has to wait longer in order to get a response. Sometimes, the share of the demanded data set is done after months. However, presented data sets include missing values. Even, sometimes applications for data sharing are rejected after the waiting-period. Similarly, the request for obtaining cancer types, data set by the Ministry of Health was rejected, and was not shared to be used in this study. A revised request is made to the Ministry of Health again, after a meeting with an oncology doctor, but still awaiting a reply. Furthermore, for the air pollution due to transportation analysis a request is also submitted to the Vehicle Registration Office in order to get data on the number of registered vehicles in terms of their types. Although it is approved after the waiting period, still the data set cannot be handed in.

It can be noted that the initial topic and initial intention for this study were different, but, deficiency and incompleteness of data forced to change the direction. An economic and statistical analysis on environmental problems in Northern Cyprus was proposed to be done by including environmental issues' impacts on human health. Yet, lack of economic indicators has pretended constructing a causal model on environmental issues in order to reach explanatory implications between economic activities and environmental degradation.

Solid waste amounts and air emission measurements are the two gained data sets. Data sets are composed of univariate time series. Due to the fact that other economic variables are not available, any mathematical modelling cannot be constructed. Therefore, forecasting on time series is performed.

Moreover, the present legislations and laws on the environment are not efficient. Revised master plans on solid waste management, air pollution, and environmental protection needs to be developed.

1.3. The Aim and Objective of the Thesis

The main aim of this dissertation is to investigate the current environmental problems of Northern Cyprus and to contribute to overcome determined issues by developing possible solutions via obtaining useful results. Specifically, analyzing air pollution, solid waste disposal and management activities by making prediction about the future.

In order to be successful in achieving this goal, the current conditions are investigated. Depending upon the obtained data sets on solid waste and air emissions, analyses are performed as univariate time series to forecast the leading cycles. Deficiencies are emphasized in conformity with the results.

The contributions of the thesis can be summarized as follows:

- This study is the first systematic quantitative study, which is done for environmental problems in Northern Cyprus.
- A theoretical environment related literature is surveyed in Northern Cyprus context.
- Environmental problems of Northern Cyprus are listed and systematically examined, and especially air pollution and solid waste problems are investigated.
- Missing values of the time series of the air pollution gases and solid waste variables are filled in with imputed values. Both simple and multiple Chained Equation imputation approaches are used.
- Series stationarity is investigated and non-stationary series are transformed into stationary ones.
- After stabilisation of the series, three months' forecasts are done using both exponential- Holtz exponential and Holt-Winters seasonality correction exponential forecasts and ARIMA types of forecasts.
- Forecast accuracy is measured in order to get the closeness of the predicted values to the actual observations.

Conclusions will be drawn, and recommendations will be brought for a better and well-organized environment regarding waste management, disposal and air pollution. The missing parts of the literature for Northern Cyprus on environmental issues tried to be filled in the light of the study results.

1.4. The Organization of the Thesis

This thesis constitutively covers two parts as Air Pollution Solid and Waste Management in Northern Cyprus. The organization of the thesis is summarized as follows:

- Chapter I is a brief introduction to the critical issues that will be discussed within the thesis by introducing Northern Cyprus, and summarizes the aim and objectives of the research. Also, encountered limitations regarding research period are explained.

- Chapter II reviews the background research and knowledge on air pollution by highlighting the important points of the headings and especially focuses on thermal power plant- and transportation-sourced air pollution. Also, it gives information about the air pollution and summarizes the main pollutants.

- Chapter III presents the Northern Cyprus case for air pollution basically caused by thermal power plants and road transportation. Also, stone quarry and agricultural activities in terms of air pollution are explained in short.

- Chapter IV is the statistical analysis part of air emissions of Northern Cyprus. Measurements of variables are used to get time series plots for identifying the characteristics of them in order to conduct a prediction analysis.

- Chapter V is an introduction to solid waste management part.

- Chapter VI explain the concepts related to solid waste management by introducing types of wastes. Moreover, social and environmental impact and problems of SWM are determined by giving examples from other countries management and disposal applications.

- Chapter VII focuses in Northern Cyprus solid waste management and disposal activities. Uncontrolled dumps, incineration activities and rehabilitation of uncontrolled site are addressed. Güngör landfill is explained by determining limited recycle and reuse activities, and referring the waste profile of the country.

- Chapter VIII clarifies the data and univariate time series variables of solid waste of Northern Cyprus. Prediction models of time series are stated and decomposed. A forecasting model of ARIMA is used in order to make prediction for leading values.

- Chapter IX briefly concludes the results obtained from the analysis and makes prominent implications of the study. Recommendations are offered in this chapter and thesis is concluded.

CHAPTER II

AIR POLLUTION DUE TO THERMAL POWER PLANTS AND TRANSPORTATION IN NORTHERN CYPRUS

AIR POLLUTION LITERATURE REVIEW

Almost in every second of their lives, living beings are exposed to polluted air that is resulted in permanent damage both on human beings and the environment in long-term. Air pollution implies the entry of biological, chemical and physical materials into the atmosphere that can lead to damage and disturbance on human beings or other free-living organisms as well as cause natural environment deterioration. Emissions emitted to the atmosphere either natural sources or human driven facilities.

The atmosphere of the earth is composed of gases and particulate matters naturally where the most concentrated gases are nitrogen (N_2) and oxygen (O_2) by 78% and 21% respectively. (Godish, Davis, & Fu, 2014) However, the chemical structure of the atmospheric natural gases has changed due to mixing with other harmful molecules that resulted in formation of the new harmful gases in the atmosphere. Although N_2 and O_2 are the most abundant gases, they give rise to the formation of greenhouse gases. The reaction of nitrogen with oxygen produces an inert gas of nitrogen oxides (NO_x). Similarly, oxygen is necessary to the continuation of life, yet it is a substance that precedes Ozone (O_3). The concentration level of ozone has been increasing due to anthropogenic activities, and resulted in affected ozone layer. On the other hand, carbon dioxide (CO_2) as a primary greenhouse gas and food for plants shares a lower concentration level inside the atmosphere by 0.037%. (Godish et al., 2014) Even though CO_2 is important in managing the heat balance of the atmosphere due to its capability of absorbing thermal, excessive concentration level of CO_2 with other greenhouse gases lead to an increase in average temperature, and atmospheric pollution.

In Northern Cyprus air pollution is one of the primary environmental problems caused mainly by thermal power plants, road transportation, pesticides, and dust clouds. Smoke from industrial and power plants and excessive car use are effective in the degradation of air quality at the first degree. The emitted carbon monoxide (CO), Sulphur dioxide (SO_2) and hydrocarbons (C_XH_Y) are carcinogenic substances that resulted in serious health problems such as types of cancer and asthma.

2.1. Air Pollution and Sources

Air pollution is recognized as a recent phenomenon. Economic development factors are resulted in uncontrolled technological improvement, increased energy consumption, unplanned urbanization, and industrial waste. In consequence of increment in all these activities the ratio of the released gases into the atmosphere have changed formation, and lead to atmosphere contamination, that is; the concentration levels of naturally exist gases of nitrogen, oxygen, carbon dioxide and other gases have increased.

According to WHO (2013) vehicle emissions, power plants, agricultural pesticides, industrial chemicals, and fuel-based heating systems in buildings are responsible for air pollution. (WHO, 2013) The Figure 1 below illustrates the shares of greenhouse gases emissions by economic sectors in EU-28 for 2011. As can be seen from the pie chart the largest contributor to GHGs emissions in 2011 was electricity, steam, gas and air conditioning by 27%. Transportation seems to have a lower share, but in fact it is not. Here only commercial transport was encompassed. In other words, privately owned vehicles were excluded. (Eurostat, 2015)

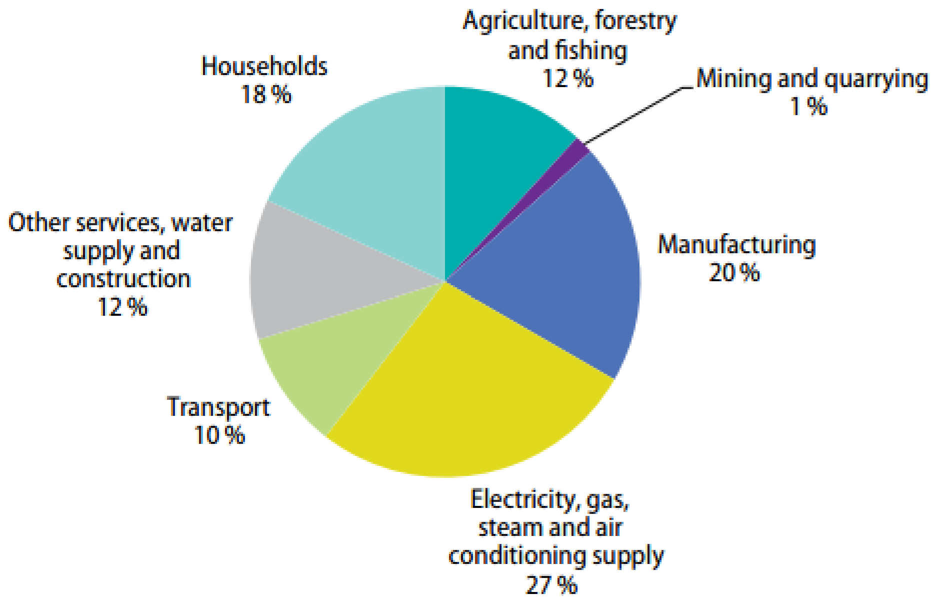


Figure 1: Greenhouse Gases Emissions by Economic Activity, 2011 Estimates (Eurostat, 2015)

Generally, the concept of pollution indicates quality loss, negative environmental influences, degradation, and cleanliness departure. Alike, air pollution comes out when gaseous substances, particulate-phase matters, and heat and radioactivity energy forms get involved into the air. Accordingly, the structure of the atmosphere has altered not only regionally but also in a global manner. Hence, the changed atmosphere introduces damage to ecological system, human beings and atmosphere itself. (Godish et al., 2014)

In addition to outdoor air pollution, contaminant substances caused by indoor activities are also considerable and domestic factors on public health and environment problems. People are subject to indoor pollutants more than out-door since they spend most of their time inside a building. According to Environmental Protection Agency (EPA) it is noted that indoor air pollutants are at the fifth place among the environmental risk factors, and they are about 100 times more intense than outdoor air particles. (Seguel, Merrill, Seguel, & Campagna, 2016) There is a strong relationship between health and quality of air.

Different parts of the body, organs and systems are affected negatively. Air pollution is resulted in various diseases in nervous, respiratory, urinary, cardiovascular and digestive systems of human body. (Kampa & Castanas, 2008) Intense concentrations of air pollution are culminated in respiratory infections, decreased lung functions, pulmonary diseases, asthma, and cancer types.

International Agency for Research on Cancer (IARC) on behalf of WHO indicated that air pollution is categorized in the same category in terms of other cancer-causing substances like tobacco smoke, plutonium energy source, and UV radiation. Moreover, it is estimated that approximately 223,000 people die every year in the world because of air pollution. (WHO, 2013)

Furthermore, compared to developing countries developed ones generate higher pollution concentrations connected to socio-economic aspects. (Bruce, Perez-Padilla, & Albalak, 2000) Solid fuel like biomass and utilize coal are used for heating and cooking by approximately 3 billion people in the world. The percentage shows variation depending on region and country. For instance, the percentages of Sub-Saharan Africa, the Western Pacific Area, and South-East Asia are around 77%, 74% and 74%, sequentially. (Perez-Padilla, Schilmann, & Riojas-Rodriguez, 2010)

Since air pollution is based on natural resources such as volcano eruptions and forest fires, occurrence of air pollution can be observed starting from the beginning of the planet when atmosphere came into existence. With the discovery of the fire the human factor entered into air quality aspect, and with industrial development pollution has reached global dimensions. Several matters of environmental facilities, i.e. energy generation, transportation, agricultural pesticides and quarries, provide a basis for air pollution. So, the atmosphere contamination appears as a result of both natural drivers and anthropogenic activities (human facilities).

2.1.1. Natural Sources

The ordinary chemical compounds released from natural events like volcanic eruptions and forest fires take part under natural sources of air pollution. (Gurjar et al., 2010) for instance, such chemical substances exist without any interference of any external supply. These types of compounds already present within the unpolluted atmosphere inherently. (Fenger & Tjell, 2009) Vegetation is also another aspect of emitting volatile organic chemicals produced by animals, microorganisms and plants.

Moreover, emitted gases from the decay of organic substances, Sulphur gases emitted from the seas, mixed dust as well as aerosols from wind are also takes part under natural sources. Similarly, desert dusts of Asian and African countries move to other countries by wind affect the air quality of the region it arrives. (Jaffe et al., 1999) However, the density of these natural sourced pollutants is low and limited with surrounding of the intervened air.

2.1.2. Anthropogenic Sources

Anthropogenic sources are mainly related to man-made activities. Artificial pollutants involve into air during chemical processes which are more dangerous chemicals. Fuel usage for obtaining energy and heat, industrial organizations functions, chemical operations could be the main contributors of man-made pollution. Anthropogenic sources are divided into classes into itself such as mobile and stationary.

Mobile pollutants arise from various vehicles i.e. road vehicles, air crafts, rail transportation and marine vessels. Vehicular emissions are generated while transporting from one destination to another from the exhausts. Exhaust emissions show variations depending on many aspects like fuel additives, combustion systems, conditions of driving, and type of fuel and engine. Furthermore, brake lining, asphalt and worn tires also increase the amount of gases in the atmosphere due to the exposed road dust. (Gurjar et al., 2010)

Stationary sources are associated with smoke, coal and biofuel combustion. Fuel burning, industrial activities, transportation, electricity generation, waste disposal etc. are the suppliers of pollutant gases i.e. greenhouse gases.

Coal is used as a source of fuel in industries to produce goods and services, and inconsequence smoke is released which is very harmful to the environment and human health. Emitted gases from combustion progress are extreme in degree. (Godish et al., 2014) Therefore, fossil fuel haze is the keystone of serious environmental issues because it is the basic argument for the most crucial global concern of climate change.

Smog, arise when the smoke from burning fuel and fog are mixed, is also an aspect of poor quality air conditions. Because smog is a photochemical, it produces visibility-decreasing substances and gas-phase particulates. An area source is the composition of both mobile and stationary suppliers. While individually these sources impacts are not very big, jointly they might create extreme outcomes. (Rajput, Khemani, & Lakhani, 2008)

2.2. Air Pollutants and Types

As mentioned above, the major contributors of air pollution are resulted from energy conversion, transportation, agriculture, and production operations. Thus, fuel combustion of liquid, solid or gaseous are significant factors for pollutant emissions. (Fenger & Tjell, 2009) The most significant air pollutants are nitrogen dioxide (NO_2), Sulphur dioxide

(SO_2), ozone (O_3), and particulate matters (PM). Whereas, the abundance of other harmful pollutants is low that do not even reveal any considerable effect.

Air pollutants are also classified into two groups as primary and secondary according to source that form contamination.

2.2.1. Primary Pollutants

Compounds that involved into air from directly their sources are primary pollutants. Pollutants occur from human being facilities or natural manner. Carbon monoxide, nitrogen oxide (NO), nitrogen dioxide (NO_2), ammonia (NH_3), volatile organic compounds (VOCs), particulates (PM) etc. are examples of primary pollutants.

2.2.2. Secondary Pollutants

A higher portion of solid or liquid suspended in atmosphere are secondary pollutants. They are formed subsequently in the atmosphere. In other words, when primary pollutants undergo a chemical change, another substances, or secondary pollutants, are formed in the atmosphere.

Examples for secondary pollutants in consequence of chemical reactions could be Sulphur trioxide (SO_3), nitric acid (HNO_3), Sulphuric acid (H_2SO_4), ozone (O_3), ammonium (NH_4^+), particulates (PM) and so on.

2.2.3 Major Air Pollutants

The major air pollutants are greenhouse gases mainly carbon oxides, Sulphur compounds, nitrogen compounds, ozone, particulates. Some of the important pollutants are listed in Table 1 with their formation sources and causable potential diseases.

Sulphuric compounds are accumulated due to volcanic eruptions, and fuel and biomass combustion. Carbon oxides are toxic gases that increased concentrations lead to global warming. Nitrogen oxides can be observed in tropical forests, marine environment as well as urban and suburban regions at different concentration rates. Ammonia emission increment danger vegetation and enrich artificial nutrient process that kill the sea marine animals. (Godish et al., 2014)

Particulate matters (PM) is the mixture of very small drop of liquid and solid particles in the air. Although microscope is required in order to detect particulates in the air, sometimes the pollution appears in dark color that can be observed even with the naked eye. For example, smoke, dust, soot and dirt are usually dark. Thus, they can be directly observed in the air through eyes. In addition, PM contains PM_{10} and $PM_{2.5}$. $PM_{2.5}$ are fine inhalable particles that have a diameter of 2.5 micrometers and less. On the other hand, PM_{10} are at 10 micrometers size or smaller, and are inhalable particles. PM_{10} are more harmful than $PM_{2.5}$ due to the fact that they are inhalable and penetrate into lungs and bloodstream. (EPA, 2016)

Moreover, particles that are carried by wind for long distances, land on water and ground. Environmental damage vary depending on the chemical compound of the particulates. The nutritional balance in lake, rivers, and water change, and they become acidic. The soil nutrients are also disappear which influence agricultural crops. Besides, PM lead to acid rains that damage stone and other materials. (EPA, 2016)

Table 1: The Sources and Possible health effects of Major Air Pollutants (Fenger & Tjell, 2009)

Pollutant	Sources and Characteristics	Potential Health Effects
Nitrogen dioxide (NO_2)	Fuel combustion applications Vehicular exhaust emissions Insoluable in water	Respiratory infections Allergies in asthmatics Wheezing and asthma Lung function reduction
Sulphur dioxide (SO_2)	Domestic heating Industrial activities Fuel and biomass combustion	Wheezing and asthma Exacerbation of chronic pulmonary disease Bronchical constriction Cardiovascular diseases
Carbon monoxide (CO)	Transportation Heating equipments Biomass burning Cook tops and ovens Charcoal grills Tobacco smoke	Headaches, dizziness Perinatal deaths Concetration difficulty Heart attack
Carbon dioxide (CO_2)	Naturally emitted Fossil fuel combustion Fossil energy sources Incineration of solid waste Aerobic biologival processes Land use change	Chloracne (due to skin contact, ingestion, inhalation) Cardiovascular diseases Diabets Liver disease Thyroid hormone production Types of cancer
Particulate matter (PM 2.5 - 10)	Fires and smoke Cooking Cigarettes Power plants Automobiles	Acute illnesses Premature death Lung cancer Irregular heartbeat and heart attacks Raspiratory symtoms
Ozone (O_3)	Office machines Diesel engines Infiltration of outdoor air	Reduction in lung development Cardiovascular diseases Pulmonary morbidity
Ammonia (NH_3)	Anaerobic decomposition of organic matter Animal wastes, agricultural practices Traffic Soil formation Biomass burning Coal combustion and industrial emissions	Cough Eyes and skin hirritation Lung diseases (but may not be cancer)

2.3. Thermal Power Plant Sourced Pollution and Impacts on the Environment

Due to the continuously increasing population, energy demand has also triggered and started to follow an increasing trend. It can also be said that the use of the energy in the world has overtaken the population growth. It is estimated that the world population will reach around 10 billion at the end of the 21^{st} century. Approximately 85% of the total energy is generated by burning fossil fuels which will be ended in air pollution owing to emissions of greenhouse gases such as oxides of Sulphur (SO_x), carbon (CO_x) and nitrogen (NO_x). (Fenger & Tjell, 2009) Moreover, fast growing industrialization lead to release of higher level of many compound concentrations.

Although electricity is a useful technological development, the adverse impact of electricity can be seen clearly. The detrimental impacts could be caused via smoke and smog arises from industrial activities which are resulted in environmental degradation besides carcinogenic gases emissions. Even before installing the power plant, the effects have been begun and continue quite a while after the installation and development. (Ball & Frei, 1999)

The principal of thermal power plants is to convert the heat obtained by the combustion of coal or petroleum products into electricity through a turbo generator. Conventional energy sources are the most dominant methods in producing electricity. To illustrate, petroleum products, coal, wood and hydro electrical sources are more frequently used ones. (Ertürk, Akkoyunlu, & Varınca, 2006) On the contrary to the renewable energy sources like solar and wind, conventional methods could be produced whenever it is necessary in a controlled manner. But, it is not possible to control over the level of energy while using solar and wind resources, because sunbeams as well as direction and violence of the wind might vary during a day that affect the production efficiency.

The obtained heat or energy from burning variety of fossil fuels (coal, fuel oil, natural gas etc.) in thermal power plants is heated with water in order to be converted into high pressure steam. Electrical generators are rotated very quickly via steam that lead to intensification of electrical impulses within generators. Therefore, electricity generation takes place. Power plants are installed near coalfields. An interdependent process from coal extraction to storage of coal ash created by combustion is pursued by environmental pollution. This pollution influences human beings, animals and plants. (Ertürk et al., 2006)

Even though electricity generation is a helpful economic development for a country, the released greenhouse gases like CO_2, SO_2 and NO_2 due to coal burning are disadvantageous which causes air pollution, global warming and acid rains. (Ertürk et al., 2006) The effect of greenhouse gases on atmosphere is triggered so that adverse impacts on human health also occur.

The major pollutants arise from fuel burning process and spread inside the atmosphere are Sulphur oxides (SO_x), carbon dioxides (CO_2), nitrogen oxides (NO_x) and particulate matters (PM). These emissions vary with regard to fuel type, fuel composition and combustion technology. Thus, the type of fuel used in power plant gains significance. Due to consumption of poor quality fuel type, emerging pollutants of electricity generation per unit is also very high. Therefore, air pollution appears.

Some type of fuel-based thermal power plants run with coal burning. The mineral substances inside the coal abandon the reactor as fly ash since they are not fired. The electro filters located at the exit of reactor is able to purify around 99.4% of the dust normally. (Ertürk et al., 2006) However, some power plants and the ones that filled their lifetime period do not have filtration system on their chimneys. Sometimes, during the maintenance and repair moments again the filtration system is no longer in use because of using substitute plant. Hence, the released emissions contribute to air pollution substantially.

As an outcome of coal combustion, internal temperature of the reactor is approximately 880-1150^{0}C. The primary components carbon (C), hydrogen (H), and oxygen of coal react with secondary substances like Sulphur (S) and nitrogen (N). Newly formed chemical reaction blends into chimneys' smoke and gaseous emissions arise such as carbon monoxide (C) and carbon dioxide (CO_2), as well as depending upon the ratio of Sulphur (S) and nitrogen (N) in coal Sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and ozone

(O_3) are presented. If temperature is increased more, poisonous gases occur. (Ertürk et al., 2006) (Ball & Frei, 1999) By this way, air pollution created by thermal power plants affect agricultural lands besides forests of a country adversely due to the increment concentration level of gases. As well as, average weather temperature and sea water temperature are increasing due to climate change sourced by increased emissions of GHGs. It is reported that GHG emissions of Cyprus including international aviation and land use, land use change and forestry have increased by more than 47% from 1990 until 2012. (Eurostat, 2015)

The degree of the impacts of emissions' concentrations on the receptor, who are influenced by the pollution i.e. human beings, animal and plant groups, and ecosystem, are assigned with the emitted gases height, irregular atmospheric/air motion and emitters distance.(Ball & Frei, 1999)

Furthermore, liquid, solid and other wastes from fossil fueled plants occur alongside gaseous emissions. Liquid wastes occupied by thermal power plants are flowed to the nearest rivers or seas. Due to the fact that wastewater is diluted into water a living receptor can be influenced indirectly through food chains. Noise, smoke, and aesthetic and visual pollution have a part in other aspects. (Ball & Frei, 1999)

The smoke that comes from power plant's chimney surrounds the local region by emitting harmful gases. The pollutant particulates adhere to plant leaves and body, and then manage to get through inside the plants. Thereby, the natural mineral and nutrient balance of plants is deteriorated which lead to an unproductive progress of photosynthesis. Moreover, spreading of particulates like SO_x and NO_x also make the soil infertile. Similarly, installation of thermal power plant necessitates large land area. The nature of the soil would be disturbed, and its characteristics would be altered. (Pokale, 2012) In consequence, flora as well as fauna of such a region might be destroyed because the growth of plants cease and biodiversity decline.

The inevitable ash from a coal-based plant is a kind of waste in a solid form, in spite sometimes it might not be possible to measure whether flying ash is at significant levels or not. (Ball & Frei, 1999) A 500 MW thermal power plant produces around 200 metric tonnes SO_2, 70 tonnes NO2 and 500 tonnes fly ash on a daily basis. The health effects could be observed in the long term. Fly ash is composed of a variety of substances and roots in particulate matters (PM). These particulates from ash attain to lungs' pulmonary part of the body and act as poisons while staying in there for a long time. As deeper tiny particles enter into lungs, the more it causes damage on body regions like trachea, bronchi, and pharynx and nasal passages. (Senapati, 2011)

2.4. Air Pollution due to Road Transportation

Transportation plays a key role almost in every piece of one's life. From production of food to waste all are transported through different modes of transport. Transportation covers a third of total energy consumption, and around a fifth of greenhouse gases emissions in EEA member states. Also, they are responsible for a higher proportion of noise and air pollution. (EEA, 2016)

Transportation boosts a community's economy and living standards. Because building a connectivity road network in between cities and regions, as well as developing better infrastructure may increase trade and create new job opportunities. Unfortunately, this situation ends up with downsized nature space. Moreover, in order to build the road network the ecological balance of the nature is deteriorated. From gravel roads air pollution appears because particulate matters and dust are arise from the roads while transporting.

Around 13.7 million new passenger cars have been registered in EU by 2015. 9% increment has been experienced from 2014 to 2015. The consumption of road fossil fuels has also increased from 52% (in 2000) to 70% in 2014. Thus, 17% rising transportation has doubled the international aviation emissions. The highest GHG emissions from transportation is sourced by passenger cars with a share of 44.4% in 2014. (EEA, 2016)

The ascending use of transportation vehicles endanger both human health and environment. In most of the countries in the world domestic transportation is based on road transportation. Fossil-fuel dependent vehicles and internal combustion engine technologies are traditionally used. However, as a result of fuel combustion motors, carbon monoxide, carbon dioxide, unburnt hydrocarbons, nitrogen oxides and particulate matter are emitted from the exhausts of the gases. These greenhouse gases stimulate the effect of greenhouse and resulted in climate change.

Releasing pollutants conduce abundance of gases like particulates (PM), ozone (O_3) and nitrogen dioxide (NO_2) which in turns come out as pressures on the natural habitat. Tree growths slow down, crop yields decrease, and lakes become acidic. (EEA, 2016) Another concern about transportation is noise pollution.

The air pollution and physical environmental issues are caused by exhaust emissions and dusts. Depending on the type of the pollutant whether primary or secondary the degree of effects may change in terms of environment and human health.

CHAPTER III

AIR POLLUTION IN NORTHERN CYPRUS

In Northern Cyprus the principal matters of air pollution are energy generation, transportation, agricultural chemicals and quarry activities. The quality of the air is measured for four gases emissions (NO_2, SO_2, O_3, and PM) at seven stations in hourly basis.

3.1. The Current Applications in Energy Generation and Pollution

Electricity generation and distribution have been a continual problem since the beginning of old times in Northern Cyprus. Although the whole island of Cyprus has a great potential for solar and wind energy power due to its climatic features, alternative and renewable energy systems are not well-developed besides the infrastructure systems. The deficiency of required financial budget makes installation of renewable energy sourced power plants more complicated. Hence, the cost of alternative energy systems could be a mandatory reason that they are not preferred by the public. Yet, recently due to the encouragement by the government the demand for solar and wind energy has been ascending. When the system is connected to the grid, discount is provided.

KIB-TEK (Turkish Electricity Institution of Cyprus) is the principal responsible authority from electricity production to distribution. In 2014, the total produced energy is approximately 1374.04 MWh. Two thermal power plants, Teknecik and Kalecik (AKSA), are the main suppliers of energy in Northern Cyprus. However, total consumed energy is around 1,379.61 MWh which means that the energy generation in Northern Cyprus is not adequate to cover the demand. Therefore, a lower proportion of 0.04% (5.58 MWh) is received from Southern Cyprus. (KIB-TEK, n.d.) In the first half of 2016 approximately 52% of total electricity production is supplied by Kalecik power plant via diesel engines.

Teknecik power plant was built on the coast of Kyrenia city. Gas turbines, steam turbine and diesel generator are installed to produce energy in Teknecik power plant. The thermal power plant is designed according to Rankine cycle system where in the boiler water is heated to get steam, and steam is transferred through the turbines for generating energy.

Kalecik power plant is installed by a build-and-operate model in a village near Famagusta. A private company called AKSA manages the operation. Kalecik works at full capacity. The higher proportion of electricity demand in the country is covered by the private sector in accordance with an agreement signed between AKSA Company and the government. (SPO, 2016)

The renewable energy source in Northern Cyprus is only Serhatköy photovoltaic power plant with a capacity of 1.27 MWh. (Yenen, 2015) However, recently 1-MW photovoltaic power plant has been built on Middle East Technical University Northern Cyprus Campus for the use of the campus itself. Serhatköy PV power plant shares 0.14% of the total production.

The majority of aggregate electricity generation is mainly depends on a cheaper type of oil, Fuel Oil Number 6. Fuel oil No.6 is the worst-quality type of reminds oil that should be warmed before activating combustion. Compared to other types of oils, No.6 is thick, sticky, and heavier. (Erciyas, 2014) The stress of Fuel oil No.6 is very tremendous not only on the local ecological balance, but also on population living close to power plants.

The burned residue of the fuel mixes with air into gaseous form. Although nitrogen and oxygen naturally exist in the atmosphere, their concentrations have gone up, and newly formed gases released. Due to combustion operations on diesel engines, chemically reacted gases of water vapor (H_2O), carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxides (NO_x), Sulphur oxides (SO_x), particulate matter (PM) and hydrocarbons (HC) are emitted. (Erciyas, 2014) Therefore, greenhouse concentration levels follow an increasing trend.

Although civilized world burns fossil fuels that contains Sulphur concentration level of less than 3%, Teknecik thermal plant produce electricity by burning Fuel oil No.6 that containing Sulphur more than 3%. This is a very harmful kind of oil. Due to this reason plants and animals are dying and human beings become cancer. Breathing related problems like asthma emerge in the region.

The twin steam turbines in Teknecik power plant do not have any infiltration system to decrease releasing harmful gases. Thus, smoke and gases from unfiltered chimney holes cover the region where power plant is located. Population who live close to the plant like Esentepe and Çatalköy is affected by the smoke. Breathing and lungs functional diseases and types of cancer can be observed. Furthermore, the natural environment is deteriorated because of the aerosols and smoke in the air. The change in the structure of the soil can be resulted in soil productivity and crop yields fallings. Overall, both flora and fauna are affected.

Figure 2: Teknecik Power Plant (Retrieved from: http://www.fotokritik.com/2980184/kktc-teknecik-elektrik-santrali)

Furthermore, water that is used in the combustion of fuel process comes out as wastewater. As can be seen from Figure 2 both thermal power plants are located near the sea. Hence, wastewater is spilled into sea. Wastewater not only pollutes seas, but also damage human health indirectly. Pregnant women and children get round to polluted sea frequently in summer season.

The fuel oil is brought from abroad by pipelines to the thermal plants. This transportation method of fuel is very risky, because sometime explosions may happen during discharging. An environmental disaster occurred in 2013 in Kalecik plant. AKSA Company's pipeline exploded due to high pressure, and approximately 100 tonnes of fuel oil leaked into the sea, and created sea pollution in Kalecik/Famagusta region.

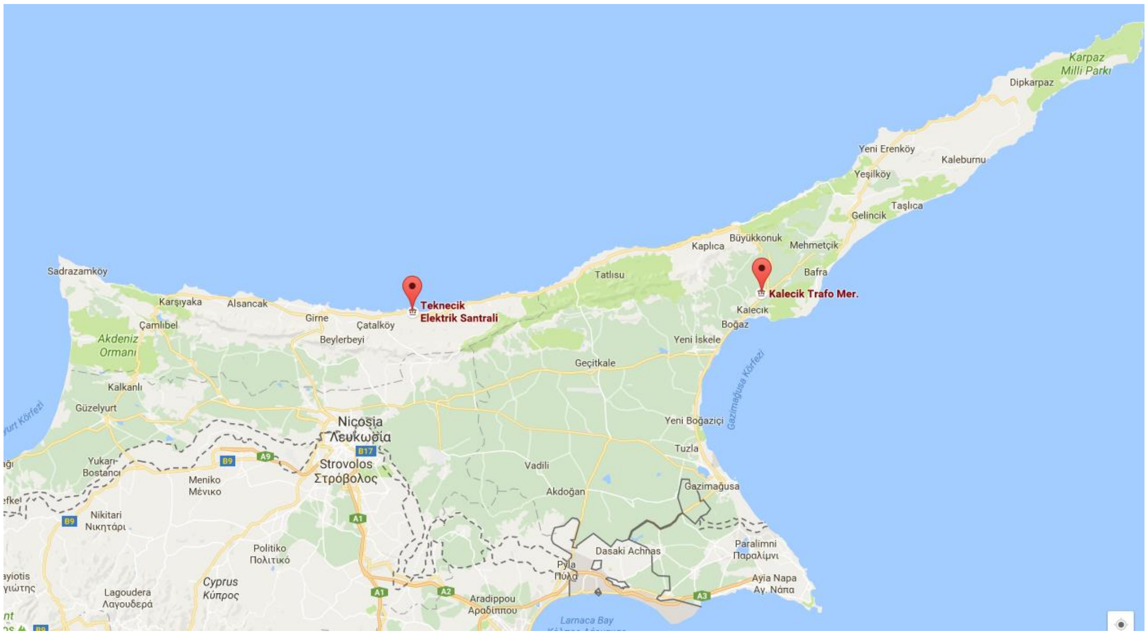


Figure 3: Locations of Teknecik and Kalecik Thermal Power Plants (Google Maps)

3.2. Road Transportation related Pollution

Rapid and unplanned urbanization have increased merchandize transportation. Excess shipment makes insufficient road transportation and the undeveloped infrastructure in Northern Cyprus worsen. Road transportation is becoming among major problems in areas with high population density. Traffic safety might be another important aspect in road transportation. Heavy vehicles are a reason for reduction of traffic safety. To illustrate, 29 people died and 780 people injured in a traffic accident in 2014. (SPO, 2016) This indicates that immediate and effective solutions are required to road transportation as being one of the most important issues of Northern Cyprus.

The total road length is about 2500 km. Approximately 1500 km of the total road length is coated with asphalt, whereas 500 km is gravel roads. (SPO, 2016)

Public transportation services in the country are not developed. Therefore, transportation in the country is mainly based on private vehicles owned by households. Although an increasing motorization rate is related to life quality and economic development, it is a burden on the environment because increased energy use is resulted in air pollution. According to a report published by Eurostat, the number of passenger cars in Cyprus per a thousand inhabitants has been increased to 549 in 2012 from 419 in 2003. On the other hand, the number of lorries and road tractors per a thousand inhabitants has slightly declined to 132 by 2012 from 167.6 in 2003. (Eurostat, 2015)

Petrol-driven cars that are powered by internal combustion technology are more intensely used. In 2012, among EU-28 Member States Cyprus shared the highest percentage of petrol-driven cars by 90%. It is followed by Sweden and Netherlands by 83% and 80%, respectively. (Eurostat, 2015) The contribution of alternative fuels in Cyprus was shared by diesel-driven passenger cars around 9%, and the rest 1% was the other alternatives. Greenhouse gases abundance from exhausts have been triggered. Thereby, climate change effects can be felt during a year.

3.3. Stone Quarries

Activities of quarries have a place under industrial sector. The natural resources of the country are used in the production. The sub-sector of quarrying produces sand and gravel at a rate only covering the needs of internal market. In 2008, the total number of quarries is around 38 for producing variety of materials like sand, gravel, lime stone crushing and screening, plaster, mosaic, clay and building stone. (Toraman, n.d.) The number of quarries has reached to 56 in 2014. The majority of quarries that is 31 of them have been still active, while 25 of them have stopped their operations. Recently, opening new quarry facilities is not permitted by the government. (SPO, 2016) Moreover, quarrying is common in mountainous regions especially in Beşparmak Mountains, which is the biggest mountain in Northern Cyprus. However, unfriendly technological methods are used for digging. Beşparmak Mountains takes its name from its similarity to five fingers of a hand. In order to produce quarry-related materials explosives like ammonium nitrate ($N_2H_4O_3$) and dynamite are used to detonate the mountains. As a result, as can be seen from Figure 4 and 5 mountains are devastated and almost one finger of Beşparmak Mountains is disappeared.

In addition, visual, air, soil and noise pollution emerge, and the dust arising from activities lead to lung cancer, asthma, allergies, and breathing problems. Due to the lack of quarrying management and strategy plan, a comprehensive one should be developed to protect the natural environment.

Sustainable and environmentally friendly quarrying efforts are insufficient. Strategic management planning needs to be prepared for the improvement of activities.

Figure 4: A view from Beşparmak Mountains (Havadis Newspaper, http://www.havadiskibris.com/tas-ocaklari-besparmaklari-kemiriyor/)

Figure 5: A view from Karpaz Region (Retrieved from Ada Basını Newspaper)

3.4. Agricultural activities

The agricultural sector is one of the primary economic activities along with tourism, public services and education sectors. It speeds up economic and social development by contributing to national income of Northern Cyprus. However, climatic factors and water scarcity have restrained consistent development of the sector to a large extend. On the other hand, due to its political situation it is not easy for Northern Cyprus to export agricultural products to abroad.

Agricultural activities are usually based on traditional methods. The current water potential of the country has been reducing every passing day. The wild irrigation methods worsening agricultural problems are still in application. (SPO, 2016) Sinking wells do not only decrease the water level in aquifers, but also sea water mixes with water and salinization problem emerges. Economic lifetime completed machinery use in the agriculture increase the greenhouse gases emission concentrations in the atmosphere that are arising from the exhausts of vehicles with a darker smoke.

Stimulated industrial sector has reduced the size of agricultural land. Therefore, increase the efficiency in agriculture can be possible by encouraging farmers with incentive pays and credits. Moreover, providing seeds, seedlings, fertilizer, technological equipment and machinery, irrigation, animal breeding and pesticides can be another way of support. (SPO, 2016)

The increment in the use of chemical pesticides against crop diseases, pests and weeds penetrates into the soil. Hence the soil structure is change. The used packages are thrown away randomly to the environment which creates pollution. In addition, agrochemicals say suspended in the air and affect the environment and population for a longer time period. The people living around breathe toxic air, and also eat chemicals through agricultural products.

Farming is intensely made in Güzelyurt region and Mesaria Plain. Güzelyurt is known with its citrus gardens. The excess use of agrochemicals, and mining activity wastes are resulted in cancer cases intensely in Güzelyurt-Lefke region. (Gökyiğit & Demirdamar, 2016)

CHAPTER IV

STATISTICAL ANALYSIS – OBSERVATIONS AND VARIABLES OF AIR EMISSIONS DATA SET

In this section a statistical analysis on air emission measurements of Northern Cyprus will be performed. Air emission measurements data set of Northern Cyprus is obtained from Environmental Protection Department of TRNC. The data set includes measurements that observed from five locations during a certain time period covering the years of 2012-2014.

Time series process is determined by making and collecting measurements during a certain time period. The numerical quantities of series are analyzed mathematically, and the physical behaviors are observed within the analysis process.

However, the data set includes missing values. With missing values efficient results would not be obtained. After imputing missing values, a statistical distribution analysis will be conducted. Then, by completing the data set and obtaining the descriptive statistics, future values will be forecasted.

4.1. The Data Set

Three-year data set includes measurements from five stations for six univariate variables. The variables are mainly four types of gases which are nitrogen dioxide (NO_2), ozone (O_3), particulate matter 10 (PM10) and Sulphur dioxide (SO_2) and labeled as *no2, o3, pm10* and *so2* in the analysis. Each gases is measured in micrograms per cubic meter of air (ug/m^3) which is also equivalent to one-millionth of a gram per cubic meter air. The observations are recorded at stations of Nicosia, Kyrenia, Teknecik, Kalecik and Famagusta. Nitrogen dioxide (NO_2) and ozone (O_3) time series covers a time period of three years from 2012 to 2014, and measured for every hour of a day of a year. In total the observation numbers of NO_2 and O_3 makes 26280 for three years. Similarly, PM10 and SO_2 series comprise three years from 2012 to 2014. But, these gases are measured at a time in day. In other words, PM10 and SO_2 are in daily basis and total observation number is 1095 for three years. The descriptive statistics of the data set can be seen from Table 2.

The summary of descriptive statistics for each indicator is shown in Table 2 where observations of PM10 from Teknecik and NO_2 from Famagusta are excluded from the data set due to the fact that they exceed the missingness threshold. The values for mean, median, skewness and kurtosis provide information about the distribution of each sample. Mean is the value at the middle of the summarized distribution, median is the 2^{nd} Quartile that is the one in the middle between the largest and smallest values of the sorted distribution. In addition, skewness and kurtosis gives information about the symmetry and shape of the distribution. (Gerbing, 2013)

The data set emissions of gases for Northern Cyprus have three-year observations from stations of major cities of Nicosia, Kyrenia, and Famagusta. Moreover, hourly and daily measured data is available in a specific unit (ug/m^3) of amount of gases or dust in the air for the villages of Kalecik and Teknecik where power plants are located, as well.

The analysis will continue by identifying forecasting methods that can be applied to the available samples. Two fundamental prediction techniques of Exponential Smoothing and ARIMA will be performed in order to decrease the uncertainty about the future values, and get how the unit amount of chemical gases will be change in the upcoming months of the series. Regarding the stationarity of series either ARMA or ARIMA is used. If the series is stationary, ARMA is used because there is no need take difference in order to get the integrated order (I). On the other hand, ARIMA is applied to nonstationary series since integrated order is obtained by taking difference of the series.

Table 2: Descriptive Statistics of Air Emission Measurements (ug/m³)

Descriptive Statistics of Imputed Date Set

	Nicosia				Kyrenia				Teknecik			Kalecik				Famagusta		
	NO_2	O_3	PM10	SO_2	NO_2	O_3	PM10	SO_2	NO_2	O_3	SO_2	NO_2	O_3	PM10	SO_2	O_3	PM10	SO_2
nobs	26280.00	26280.00	1095.00	1095.00	26280.00	26280.00	1095.00	1095.00	26280.00	26280.00	1095.00	26280.00	26280.00	1095.00	1095.00	26280.00	1095.00	1095.00
NAs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Minimum	0.00	1.10	15.80	0.20	0.00	4.40	10.90	0.00	0.00	24.00	0.00	0.00	12.10	7.60	0.00	1.10	10.40	0.00
Maximum	137.40	127.10	354.60	11.20	134.60	140.60	382.40	50.60	127.70	161.40	131.20	128.60	150.90	402.10	155.20	126.80	228.80	14.00
1. Quartile	8.70	33.80	36.85	1.29	15.80	47.10	32.64	0.90	1.10	73.70	1.75	0.80	69.10	23.20	0.40	38.00	32.80	0.20
3. Quartile	26.40	65.01	64.61	3.70	38.30	68.20	48.71	5.40	5.00	96.80	10.71	7.80	95.60	41.50	5.50	69.40	49.10	3.30
Mean	19.86	49.45	54.85	2.66	2.87	57.68	43.03	4.08	4.11	85.07	8.39	6.21	82.48	35.46	4.22	53.57	43.65	2.00
Median	15.70	49.70	48.60	2.30	27.22	57.90	40.08	2.60	2.80	85.10	5.30	3.20	82.00	31.50	1.90	55.40	39.86	0.70
Sum	522084.00	1299525.00	60060.20	2916.66	752838.00	151601.00	47118.78	4464.30	108132.50	2235605.00	9183.34	1.63	2167728.00	38829.74	4624.84	1408055.00	46789.00	2188.58
SE Mean	0.10	0.14	0.86	0.05	0.10	0.10	0.63	0.15	0.04	0.10	0.33	5.89	0.11	0.77	0.22	0.14	0.62	0.08
LCL Mean	19.67	49.18	53.14	2.56	28.44	57.50	41.80	3.77	4.05	84.87	7.73	6.09	82.22	33.94	3.79	53.32	42.42	1.84
UCL Mean	20.06	49.71	56.56	2.76	28.85	57.88	44.26	4.37	4.18	85.21	9.04	6.32	82.71	36.98	4.66	53.84	44.87	2.15
Variance	256.94	480.59	828.58	2.90	283.76	249.54	427.97	26.05	32.95	281.30	121.38	91.14	339.06	655.54	53.42	457.56	416.36	6.43
Stdev	16.03	21.92	28.79	1.70	16.84	15.77	20.69	5.10	5.74	16.77	11.02	9.54	18.41	25.63	7.31	21.39	20.40	2.54
Skewness	1.68	0.02	3.34	0.87	0.82	0.04	6.35	3.20	5.91	-0.02	3.99	3.93	0.11	7.31	9.33	-0.18	3.67	1.38
Kurtosis	3.99	-0.48	21.34	0.52	1.07	0.12	81.91	15.31	62.41	0.13	29.01	22.79	-0.18	84.48	168.38	-0.53	23.81	1.06

Nevertheless, it is very critical to identify the characteristics of series whether they are stationary or non-stationary. The observed series need to be fitted into a systematic approach. To illustrate, the series have to be fitted into stationary forms to get accurate estimates. Therefore, the beginning work is to check whether the series are stationary or nonstationary. Apart from plotting time series, Dickey-Fuller and unit root tests can be applied to be sure about the stationarity of the time series. From the technical point of view, stationary time series are explained with constant mean and variance, as well as variance is a function of lagged variables instead of time. In other words, the mean of a series does not change from observation to observation, and the variance must be a constant value.

Referring to the results of stationarity tests, stationary series can be used as they are, but nonstationary series have to be transformed into stationary by taking difference of the observations. Moreover, decomposition can be another method for removing the non-stationarity from series. Decomposition is to divide the original time series into its components of trend, seasonal, and residual (the remainder). Thus, removal of trend and seasonal effects will convert series into stationary.

Before beginning to the analysis of time series, checking for the missingness pattern of the data is considered to be a matter of great importance because if a time series have missing data, the results would not be sufficient and beneficial to go further. Due to the fact that the series or air emissions are long, then the missingness threshold can be taken as 20%. In other words, series with more than 20% of missing data will be excluded from the data set to get better results of leading values in forecasting to reach utilizable conclusions. The missingness pattern of data sets are illustrated in Table 3. Dark-colored variables are excluded from the data set as the percentages exceed the missingness threshold of 20%, i.e., nitrogen dioxide (NO_2) data set of Famagusta, and particulate matter 10 (PM10) data set of Teknecik are excluded from the analysis. The rest series that have missingness ratio less than 20% are completed by an imputation package in R called MICE, multivariate imputation by chained equations.

Table 3: Missingness Pattern of Air Emissions Data Set

Pattern of Missing Data			
Station	**Variable name**	**Missingness Ratio (%)**	**Non-missing Ratio (%)**
Nicosia	no2	9.2	90.8
	o3	17	82
	pm10	9.8	90.2
	so2	20	80
Kyrenia	no2	17	83
	o3	14	86
	pm10	15	85
	so2	14	86
Famausta	no2	22	78
	o3	6.1	93.9
	pm10	5.8	94.2
	so2	5.2	94.8
Teknecik	no2	15	85
	o3	2.2	97.8
	pm10	40	60
	so2	17	83
Kalecik	no2	9.8	90.2
	o3	3.5	96.5
	pm10	9.6	90.4
	so2	1.2	98.8

4.2. Imputation of Missing Observations

According to the missing data pattern, missing data presence in more than one variable create a challenge for analysis. Among imputation methods the most convenient one for completing missing data of air emission measurements is multivariate imputation of chained equations (MICE). MICE is also known as “fully conditional specification” (FCS) or “sequential regression multiple imputation”. Instead of generating a single attribution such as mean, multiple outcomes are obtained because uncertainty aspect is taken into consideration, and as well as outcome standard errors are more accurate. (Azur, Stuart, Frangakis, & Leaf, 2011) An open source of R software programming has a package called “mice” in order to easily create multiple series with completed values.

The rest missing values are considered as totally random. This randomness is explained by the concept of missing at random (MAR). (Azur et al., 2011)

As a result of imputation via MICE, five random completed data sets are estimated separately for each variable’s missing values. In this study, the average of each row is taken, and the data set is completed with mean values of chained equations. In other words, the missing observations in the data set are completed by taking arithmetic mean of the imputed multiple chained outcomes instead of choosing one of the series randomly. Averaged samples are merged with the original data set.

4.3 The characteristic of Time Series and Decomposition

As mentioned above, the very beginning step of the analysis starts by plotting and checking for stationarity. Figure 6 and 7 illustrate the time series of each specified air emissions (NO_2, O_3, PM10, SO_2) specifically for Teknecik and Kalecik stations. Due to the fact that thermal power plants of Northern Cyprus are located at Teknecik and Kalecik, the prediction analysis is focused on these two power plants’ stations. However, to remind that PM10 emission measurements are excluded from Teknecik observations because it has 22% of missing data. As can be seen from figures ozone (O_3) emissions are cyclic.

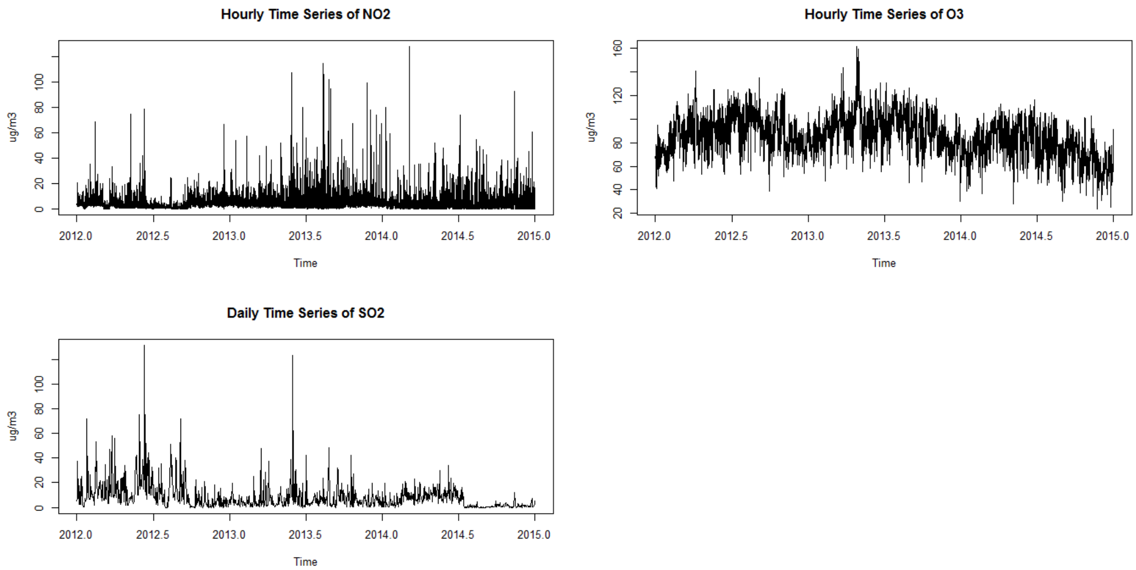


Figure 6: Time Series Plotting of Variables for Teknecik

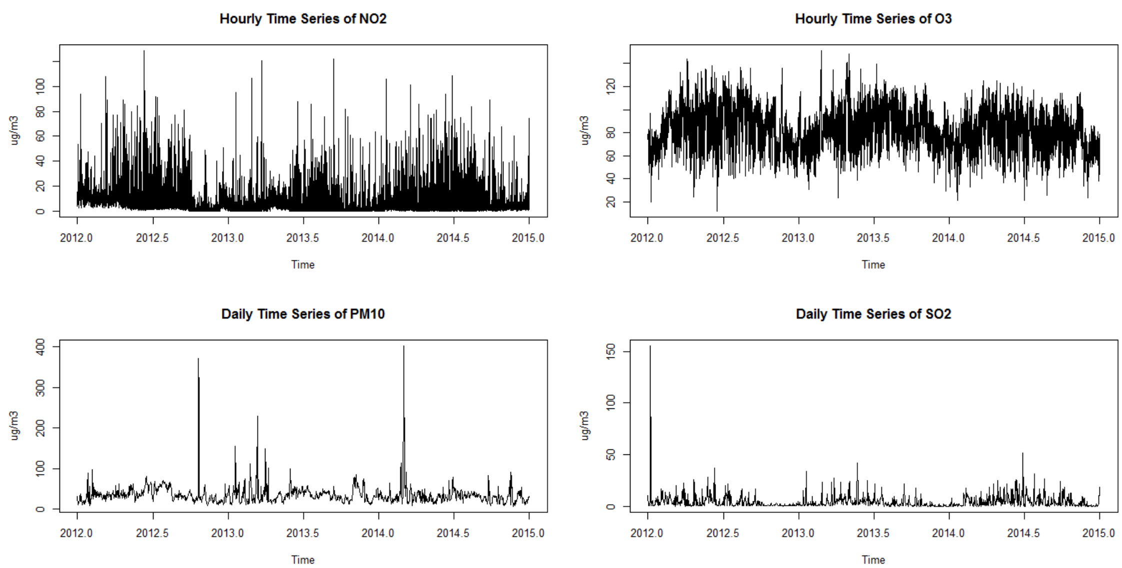


Figure 7: Time Series Plotting of Variables for Kalecik

For explaining the difference between stationarity and no stationarity on a univariate time series, autoregressive model of order one, AR(1), can be a useful example as only one lag is concerned. In the equation, the variable (y_t) is proportionally (ρ) explained by the value of previous period, y_{t-1}, and error term, v_t; that can be expressed as:

$y_t = \rho y_{t-1} + v_t$, $|\rho| < 1$ where the errors v_t are ~$N(0, \sigma^2_v)$

However, a special case called random walk occurs when ρ is equal to 1. It is named as random walk because the trend of the series does not follow a regular pattern. The equation includes a stochastic trend due to the component of error term v_t. Every time it is added to the equation as a constant number, it will provide a direction for the curve as trend. The mean of random walk is equal to its initial value (i.e. $E(y_t) = y_0$), whereas variance is increasing over time (i.e. $var(y_t)= t\sigma^2_v$). Hence, despite the constant mean, the increasing variance indicates that series is nonstationary.

Among many test for determining stationarity of a time series, the Dickey Fuller test is the most popular one. The Dickey Fuller test is designate in three variations regarding inclusion or exclusion of constant term and trend within an autoregressive model.

Dickey Fuller Tests:

- No constant no trend:

$$y_t = \rho y_{t-1} + v_t$$
$$y_t - y_{t-1} = \rho y_{t-1} - y_{t-1} + v_t$$
$$\Delta y_t = \gamma y_{t-1} + v_t \quad \text{where } \gamma = \rho - 1$$

Hypothesis testing:

H_0: $\rho = 1$ or $\gamma = 0$. The time series is nonstationary.

H_1: $\rho < 1$ or $\gamma < 0$. The time series is stationary.

- With constant but no trend:

$$y_t = \alpha + \rho y_{t-1} + v_t$$
$$y_t - y_{t-1} = \alpha + \rho y_{t-1} - y_{t-1} + v_t$$

$$\Delta y_t = \alpha + \gamma y_{t-1} + v_t \qquad \text{where } \gamma = \rho - 1$$

Hypothesis testing: $H_0: \gamma = 0$. The time series is nonstationary.

$H_1: \gamma \neq 0$. The time series is stationary.

- With constant and with trend: $y_t = \alpha + \rho y_{t-1} + \lambda t + v_t$

$$y_t - y_{t-1} = \alpha + \rho y_{t-1} - y_{t-1} + \lambda t + v_t$$

$$\Delta y_t = \alpha + \gamma y_{t-1} + \lambda t + v_t,$$

where $\gamma = \rho - 1$

Hypothesis testing: $H_0: \gamma = 0$ The time series is nonstationary

$H_1: \gamma < 0$ The time series is stationary.

All three types of Dickey-Fuller hypothesis testing is estimated through testing equations by least squares. However, here instead of t-statistic, τ (tau) statistic is used because increasing variance can be misleading. When null hypothesis H_0 is not rejected, dependent variable of y_t is nonstationary with a changing variance. Because, the distribution changes due to increasing variance when H_0 is true. Therefore, tau test is used instead t-test. The obtained results from Dickey Fuller test displayed in Table 4 are compared to the critical values for the Dickey-Fuller.

Table 4: Critical Values for the Dickey-Fuller Test (R. Carter; Hill, Griffiths, 2011)

Model	1%	5%	10%
$\Delta y_t = \gamma y_{t-1} + v_t$	−2.56	−1.94	−1.62
$\Delta y_t = \alpha + \gamma y_{t-1} + v_t$	−3.43	−2.86	−2.57
$\Delta y_t = \alpha + \lambda t + \gamma y_{t-1} + v_t$	−3.96	−3.41	−3.13
Standard critical values	−2.33	−1.65	−1.28

As a result of the Augmented Dickey Fuller test, all test results holding for identified five locations indicate that NO_2, O_3, PM_{10} and SO_2 are all stationary series for the five stations of Teknecik, Kalecik, Nicosia, Famagusta, and Kyrenia (see Table 5). In other words, no unit root exist in tested time series. However, this can be a misleading result of observations which are obtained in very short time periods, that is; it can be an ordinary expectation to get stationary series from 26280 hourly observations for three year time period (2012-2014).

Shortening the three-year observations of NO_2, O_3, PM_{10} and SO_2 for each station will be helpful in understanding the background behavior of the series whether their mean and variance are constant or changing from one month of a year to the same month of another year. Therefore, by transforming the original data set meaningful results can be established. The hourly observations of each month starting from January to December will be summed up separately to transform the data set into a monthly form. Then, randomly chosen months' accumulated observations will be tested for stationarity. When the randomly chosen monthly observations are tested, it can be observed that the time series are nonstationary. In other words, their mean and variances change from observation to observation.

Table 5: ADF Test Results of Air Emissions

Augmented Dickey Fuller Test Results	Kalecik				Teknecik				Nicosia			
	NO2	O3	PM10	SO2	NO2	O3	PM10	SO2	NO2	O3	PM10	SO2
No constant no trend	-54.29	-6.06	-6.81	-14.48	-42.46	-4.07	-5.11	-8.52	-31.74	-11.57	-5.08	-4.27
With constant but no trend	-68.56	-28.27	-13.75	-19.05	-56.23	-21.47	-12.90	-12.58	-54.33	-27.96	-13.12	-8.15
With constant and with trend	-69.48	-28.53	-13.90	-19.06	-56.70	-23.03	-12.97	-13.51	-56.24	-27.98	-13.17	-8.21

	Kyrenia				Famagusta			
	NO2	O3	PM10	SO2	NO2	O3	PM10	SO2
No constant no trend	-23.77	-4.36	-5.15	-4.84	-25.28	-9.49	-5.69	-5.69
With constant but no trend	-51.07	-16.26	-14.57	-6.30	-48.97	-26.60	-17.23	-7.26
With constant and with trend	-51.17	-16.90	-14.58	-8.62	-49.46	-26.71	-17.23	-10.18

To illustrate, Kalecik can be given as an example that monthly time series are nonstationary. The plot is also demonstrated in Figure 8 and 9 with a decomposition where the first panel displays the original time series plot. Among all the gases Ozone (O_3) is chosen to be explained because almost in every observation for all stations it is cyclic. The Augmented Dickey Fuller results (no constant and trend: -0.506, with constant but no trend: -2.809, with constant and trend: -3.187) that is valid for all three Dickey-Fuller cases indicate that O_3 emissions of Kalecik is a nonstationary time series, although Figure 8 demonstrates a stationary series.

It can be concluded that transformation of the data set is necessary. Yet, although the outcomes are misleading, the forecasted pattern of leading values would not change too much. The time series are converted into monthly basis in order to achieve to get better conclusions. Therefore, prediction with the transformed data set is conducted. The analysis is proceeded by the monthly basis data.

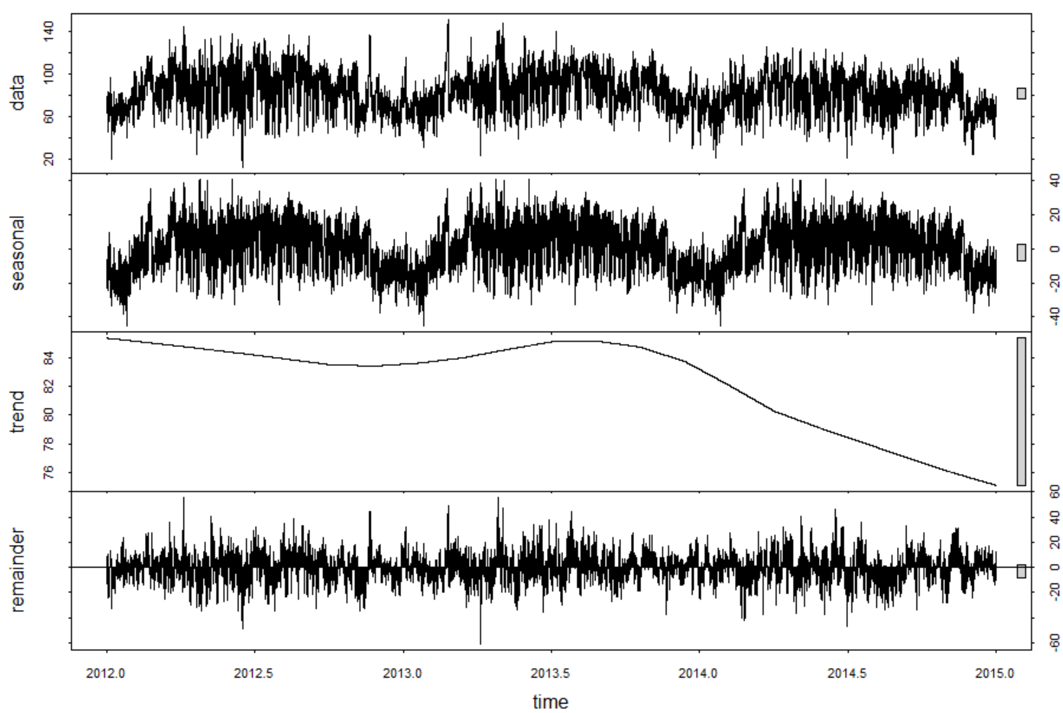


Figure 8: Decomposition of Kalecik O_3 (Hourly)

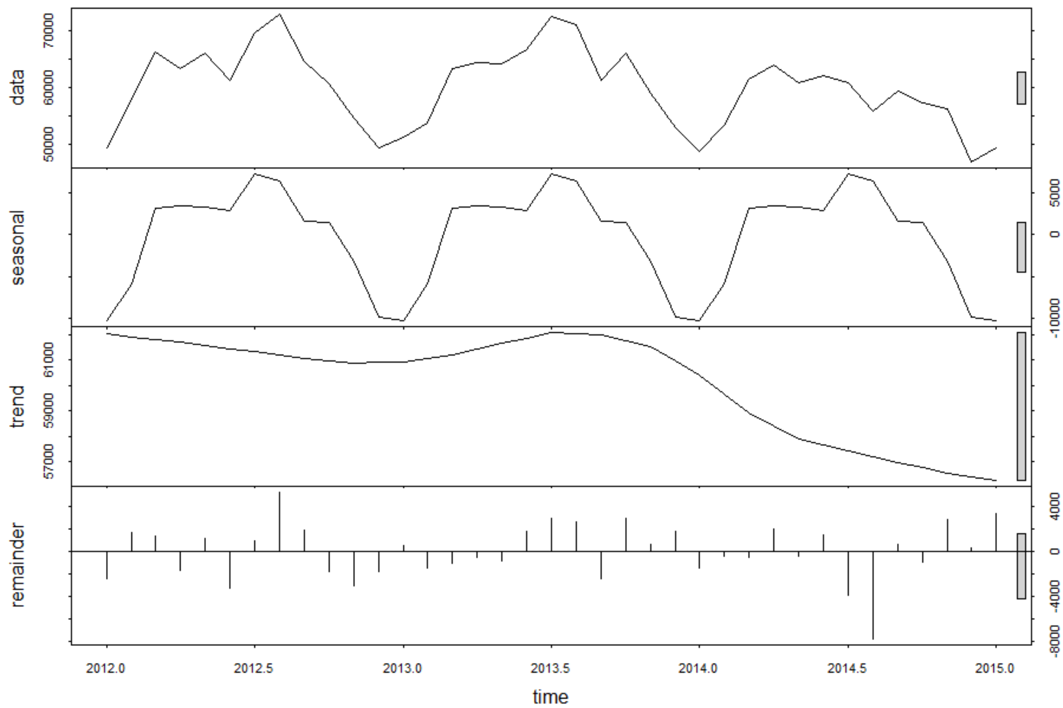


Figure 9: Decomposition of Kalecik O_3 (Monthly)

4.4. Time Series Analysis and Prediction with Holt Winters Exponential Smoothing

Making a prediction about the future concentration levels of pollutants will help to take precautions accordingly. Proper forecasts about leading abundance amounts of substances are required so that population might change their attitudes accordingly. Therefore, a change in the route of the traffic or controlling over industrial activities can be done in order to reduce emissions.

To begin with the analysis, a time series data set is constituted by components, mainly trend and irregular components, and seasonality component in time series. Decomposition is helpful in setting apart each component to get a clear picture about the time series. STL package in R is assigned for separation since it does not skip any observation of time series. STL is decomposing time series by Loess function and estimating the trend, seasonal and irregular component within the data. Figures of decomposition are displayed in Appendix. There are four panels in each figure. One shows the original data set time series plotting, and the others are the components of trend, seasonal and reminder/random. The random part is the estimated residuals of the data set which is the difference between the observed (original observations of the data) and the expected values of the observations.

Transforming non-stationary series to stationary necessitate removal of trend and seasonal effects. The analysis of time series entails decomposition of the basic components (trend, seasonal, cyclic) that comprise the series. Two structures are assumed for decomposition which are additive and multiplicative models designated in accordance with either the summation or multiplication of the components. From the statistical perspective, the aim is to investigate to what extent of each element is effective on the event values. (Şanlıoğlu & Kara, 2009)

In this study, additive model will be assumed due to the fact that the data for each variable do not demonstrate any proportional change. In other words, the magnitude of fluctuations in seasonal element moves independently from the level of the time series. (Kalekar, 2004)

The following equation is used to express the additive model where y_t is the sample data at period t, β_1 is the intercept coefficient, β_2 is the linear trend-cycle factor, S_t is the additive seasonality component, and ε_t stands for the reminder component which is the residuals.

$$y_t = \beta_1 + \beta_2 t + S_t + \varepsilon_t$$

Trend illustrates the development and progression of the series in the long-term. The direction and intensity of it do not always remain constant. It might be either linear or curvilinear. (Şanlıoğlu & Kara, 2009) While, seasonality is the factor repeating itself at regular time intervals is represented by regular peaks and troughs between a specific time periods.

According to figures of STL, it can be inferred that the trend of NO_2 of Teknecik increases until the middle of 2013, then it falls down again. The trend of O_3 is also follows a similar pattern with a higher rate than NO_2. On the other hand, trend of SO_2 displays a consistently decrement. For Kalecik, NO_2 and SO_2 decrease at first, then starts to increase. Yet, SO_2 remains constant in a plain way, then it is ascending.

Furthermore, in order to make a short-term forecast for the future values of time series many methods are used depending on which components the data have such as simple exponential smoothing, Holt's Exponential Smoothing, and Holt-Winter's Exponential Smoothing. Here Holt-Winter's exponential smoothing model is applied to obtain next three months' values, i.e. for January, February and March of 2015. The prediction period is short because the transformed data set is composed by three-year monthly observations for NO_2, O_3, PM_{10} and SO_2. In this study, regarding STL decomposition of time series demonstrated in Appendix Holt-Winter's exponential smoothing model is used for making prediction because all the series include time trend and seasonality.

Figures below demonstrate the predicted values of the next three months period obtained via Holt-Winters exponential smoothing method graphically. Three-month future values are predicted with two confidence intervals of 80% and 95%. The darker color in the graphs shows the 80% prediction area, while the lighter one is 95% prediction interval. O_3 and SO_2 in Teknecik where the power plants are located will increase a little bit in January, February and March of 2015. While, NO_2 will follow a straightforward fluctuation that will not vary too much compared to the observed NO_2 time series. The graphs of Holt-Winters exponential smoothing obtained for Kalecik, Nicosia, Kyrenia and Famagusta are also displayed. As can be seen there is no constantly followed pattern in the prediction of the leading values of variables, but, ozone (O_3) values will increase at all stations for the leading periods. O_3 is the alarming emitted gas at all stations that it follows an increasing trend at all stations for the future predicted time period. Except for Nicosia, there is no linear trend for NO_2 at other stations, while it is following a declining pattern in Nicosia. Similarly, there is no any linear, followed the pattern for SO_2 and PM_{10} at all stations except for Teknecik and Kyrenia. Released gases of SO_2 in Teknecik will increase, on the other hand PM_{10} amount will decline in Kyrenia.

Moreover, total predicted values are shown in Table 6 and 7 below, too. However, the performance of forecast for accuracy, is not measured due to the fact that all the series have missing values and imputed by multivariate imputation by chained equations. Therefore, the results would not measure the accurracy effectively.

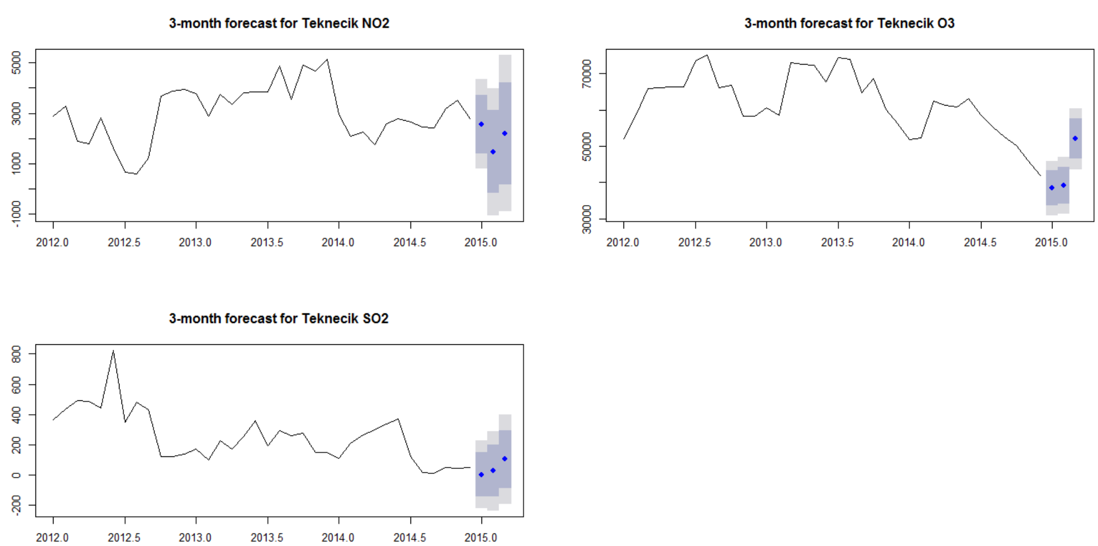


Figure 10: Holt-Winters Prediction of Teknecik

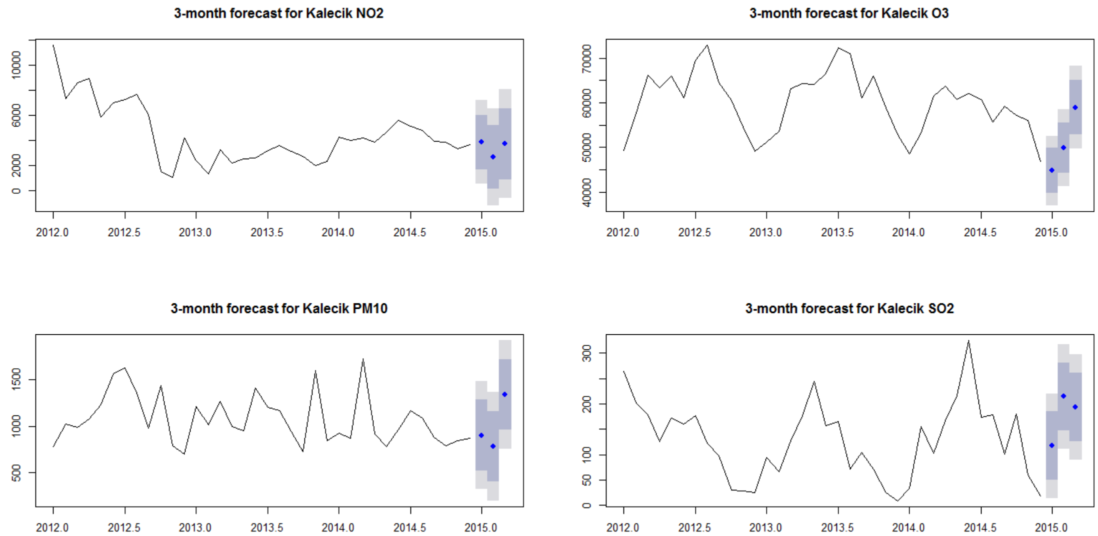


Figure 11: Holt-Winters Prediction of Kalecik

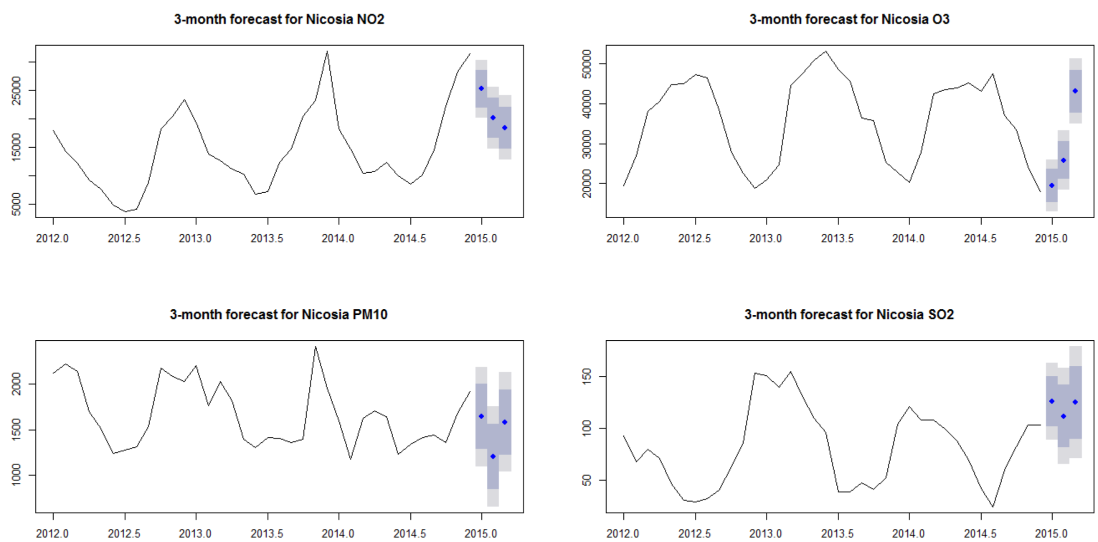


Figure 12: Holt-Winters Prediction of Nicosia

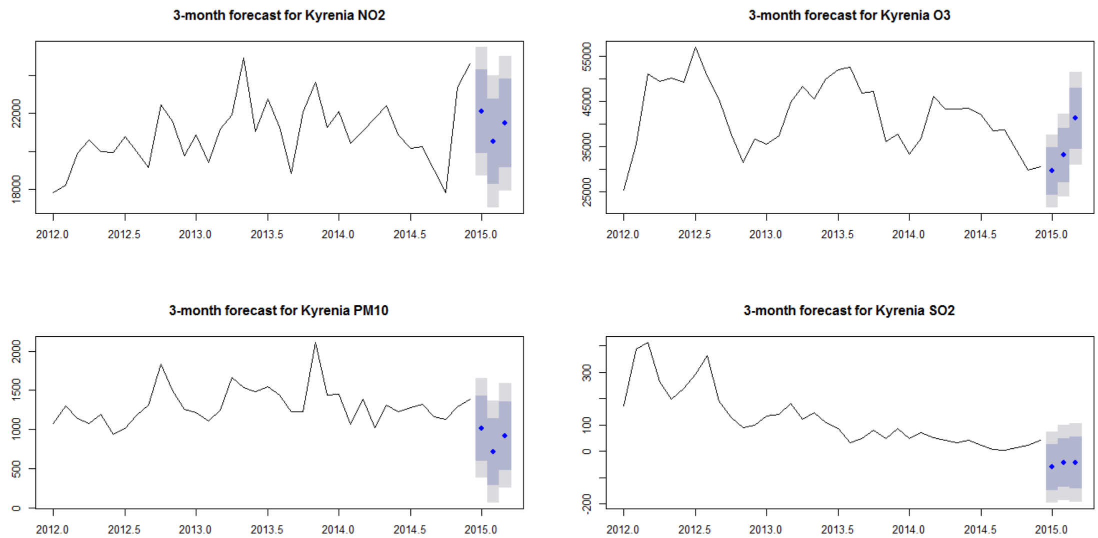


Figure 13: Holt-Winters Prediction of Kyrenia

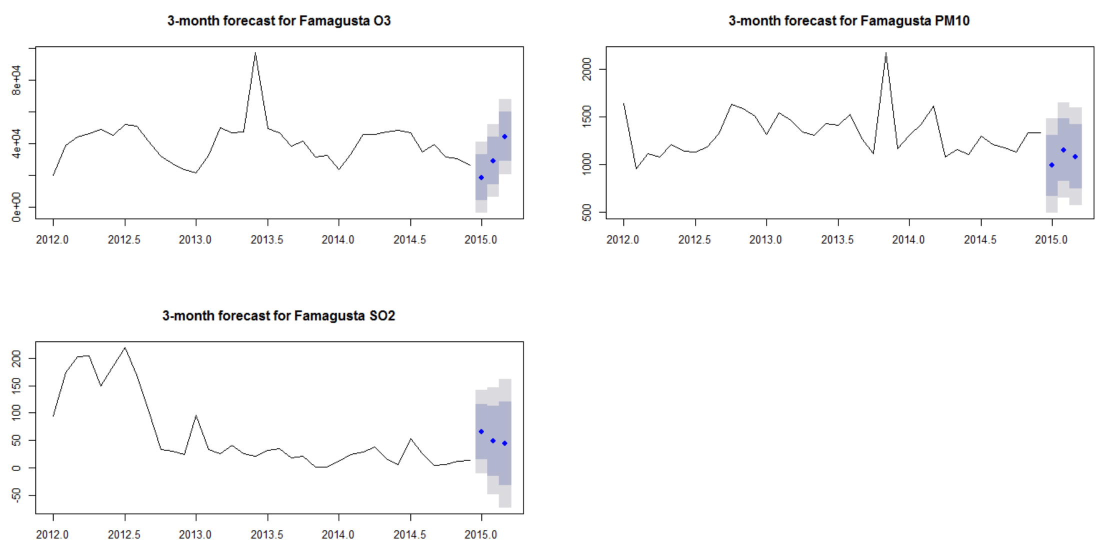


Figure 14: Holt-Winters Prediction of Famagusta

Table 6: Holt-Winters Predicted Values for Air Emissions

3-Month Holt-Winter's Forecasting for Solid Waste Time Series							
Station	Variable	Prediction	Forecast	Low 80%	High 80%	Low 95%	High 95%
Teknecik	NO2	Jan 2015	2559.577	1402.283	3716.87	789.6492	4329.504
		Feb 2015	1472.756	-168.9587	3114.472	-1038.03	3983.543
		Mar 2015	2204.428	187.5481	4221.308	-880.1236	5288.98
	O3	Jan 2015	38457.44	33557.01	43357.87	30962.88	45952
		Feb 2015	39234.73	34121.3	44348.15	31414.42	47055.03
		Mar 2015	52011.41	46448.49	57574.33	43503.65	60519.16
	SO2	Jan 2015	2.711944	-144.3851	149.809	-222.2536	227.6775
		Feb 2015	27.03903	-144.4652	198.5432	-235.254	289.3321
		Mar 2015	103.0454	-89.8012	295.8921	-191.888	397.9789
Kalecik	NO2	Jan 2015	3859.957	1687.607	6032.308	537.6333	7182.282
		Feb 2015	2680.933	165.2465	5196.62	-1166.478	6528.344
		Mar 2015	3731.408	892.6611	6570.155	-610.0806	8072.896
	O3	Jan 2015	44812.5	39733.67	49891.33	37045.1	52579.9
		Feb 2015	49889.07	44298.78	55479.37	41339.45	58438.69
		Mar 2015	58902.42	52843.68	64961.16	49636.38	68168.46
	PM10	Jan 2015	902.1109	520.7067	1283.515	318.8034	1485.418
		Feb 2015	783.1521	401.7479	1164.556	199.8447	1366.46
		Mar 2015	1339.975	958.5703	1721.379	756.6671	1923.282
	SO2	Jan 2015	117.1607	49.94299	184.3784	14.36009	219.9613
		Feb 2015	213.9967	146.5554	281.438	110.8542	317.1392
		Mar 2015	193.3104	125.381	261.2397	89.42139	297.1993
Nicosia	NO2	Jan 2015	25252.17	21927.2	28577.13	20167.07	30337.26
		Feb 2015	20184.06	16668.14	23699.98	14806.93	25561.2
		Mar 2015	18441.57	14744.55	22138.59	12787.47	24095.68
	O3	Jan 2015	19447.13	15233.63	23660.63	13003.14	25891.12
		Feb 2015	25809.81	20999.75	30619.88	18453.45	33166.17
		Mar 2015	43091.02	37750.63	48431.42	34923.59	51258.45
	PM10	Jan 2015	1640.898	1280.85	2000.945	1090.253	2191.542
		Feb 2015	1202.319	842.238	1562.399	651.6229	1753.014
		Mar 2015	1582.352	1222.196	1942.507	1031.541	2133.162
	SO2	Jan 2015	125.9512	101.5554	150.347	88.64101	163.2614
		Feb 2015	111.7258	81.36567	142.086	65.29397	158.1577
		Mar 2015	125.0238	89.69222	160.3555	70.9888	179.0589

Table 7: Holt-Winters Predicted Values for Air Emissions (con't)

Kyrenia	NO2	Jan 2015	22085.78	19876.11	24295.45	18706.38	25465.18
		Feb 2015	20509.67	18245.32	22774.03	17046.64	23972.71
		Mar 2015	21473.55	19155.8	23791.3	17928.85	25018.24
	O3	Jan 2015	29605.77	24395.73	34815.81	21637.7	37573.84
		Feb 2015	33188.41	27197.2	39179.62	24025.65	42351.17
		Mar 2015	41255.99	34574.33	47937.66	31037.27	51474.72
	PM10	Jan 2015	1014.903	597.5962	1432.209	376.6875	1653.118
		Feb 2015	715.922	290.7146	1141.129	65.62338	1366.221
		Mar 2015	918.9293	481.949	1355.91	250.6256	1587.233
	SO2	Jan 2015	-60.2314	-147.8876	27.42477	-194.29	73.82715
		Feb 2015	-43.5121	-136.3564	49.33231	-185.5052	98.48114
		Mar 2015	-42.5929	-140.3505	55.16462	-192.1002	106.9143
Famagusta	O3	Jan 2015	18530.55	4077.342	32983.76	-3573.725	40634.83
		Feb 2015	28966.38	13982.96	43949.81	6051.21	51881.55
		Mar 2015	44174.19	28678.68	59669.7	20475.86	67872.52
	PM10	Jan 2015	984.3157	662.0783	1306.553	491.4961	1477.135
		Feb 2015	1149.042	821.9459	1476.137	648.792	1649.291
		Mar 2015	1080.339	745.09	1415.587	567.6202	1593.057
	SO2	Jan 2015	65.50052	15.44524	115.5558	-11.05242	142.0535
		Feb 2015	48.26372	-15.84421	112.3716	-49.78089	146.3083
		Mar 2015	44.05652	-32.50149	120.6145	-73.02885	161.1419

CHAPTER V

SOLID WASTE MANAGEMENT AND FORECASTING TIME SERIES DATA SET OF TRNC

5.1. Introduction

Solid waste management dates back to 1970s when the oil crises had occurred due to increased oil prices and threat to cut off oil supplies in the Middle East. At the same time, population had become aware of the environmental problems, thereby reduction, reuse and disposal of waste were controlled.

Although waste management and disposal are not recent problems, the fight against to these problems are a recent issue. A part of developed world has adopted a plan of actions to accomplish sustainable solid waste management. While the others, less developed and developing nations like Northern Cyprus still have challenges to overcome this problem.

Discharged wastes; influence the quality of life, living standards, social and economic aspects within a community. Therefore, what have been done today are assumed as investments of the future. Everything inside the nature is raw materials, and they are used as natural resources in various sectors for different purposes. Thus, reducing, reusing and recycling in line with the waste hierarchy would be efficient measurements that can be supported by a community.

Due to the increment in the total generated waste amount, waste management has become one of the greatest environmental problems of urbanization. Waste management issue needs to be addressed with a systematic approach. Systematic approach includes fundamental aspects like waste generation, collection and disposal besides employment, productivity, resource and environmental protection. (Palabıyık & Altunbaş, 2004)

A well-organized sustainable solid waste management is significantly required for the protection of environment. A healthy environment comprises less polluted surface water and groundwater, clean air. On the other hand, air and water of poor quality has adverse impacts on both environment and human health. Waste increment lead to serious health problems and greenhouse gases emissions which causes change on the climate. Therefore, it is very important for the improvement of solid waste management to remove all the negativity that threatens human health and environment.

World Health Organization (WHO) explains the concept of health as both keeping away adverse health issues and being in physical, mental and social wellness. However, in order to be a healthy human the environment should also be in a good quality. Solid wastes are either directly or indirectly within an interaction with human beings inside a waste cycle from production to disposal phase because manufactured products are purchased and consumed by public are resulted in garbage. (Palabıyık & Altunbaş, 2004)

The management issue of solid waste is an economic activity that should be considered together with its negative impact on the environment and human health. In other words, growing urbanization and industrialization require the development of municipality services for collecting and transporting waste by applying new management approaches and models within sustainability concept. The main aim is to collect and remove almost all the generated solid waste within a favorable economic condition. Thus, management would be very efficient and productive from environmental, technical and social aspects. (Palabıyık & Altunbaş, 2004)

Similar to other facilities in the Turkish republic of Northern Cyprus, solid waste management and disposal are also problematic. In the Turkish Community of Cyprus municipalities are the main responsible administrative organization. Discharged wastes are collected from households, industries and commercials by storage vehicles and transferred to the area where they are disposed. Some are transferred through stations to common landfill while some others are carried to wild dump yards. Furthermore, waste are separated into different types depending on their chemical substances by a characterization study, and thereby it is decided whether they should be disposed, re-used or recycled. On the other hand, it costs highly and is a financial burden for municipalities, as well as, if solid waste is not evaluated properly, then it can also be an economic loss.

CHAPTER VI

SOLID WASTE MANAGEMENT LITERATURE REVIEW

Literature review part gives an extended knowledge on affairs associated with solid waste management and disposal methods by combining the relevant literatures on significant aspects. This part will include a brief definition of solid waste by introducing its relationship with economics, environment and human health. Then, starting from the general situation in the World, the case of Northern Cyprus will be discussed. The main focus will be on the current practices, legislation and policies of Northern Cyprus.

A large quantity of published literature on solid waste, and empirical studies of making prediction by using time series data set are available. Literature also includes the contributions to the field from various points of view. However, an empirical study on forecasting of solid waste in Northern Cyprus has not been conducted before. Exponential smoothing and ARIMA model are chosen as statistical analysis methods in order to make prediction of the leading future values of monthly produced solid wastes. However, due to the absence of economic data on the field. The effects of economic factors on solid waste could not be investigated due to the absence of necessary data on the subject.

6.1. Definition of Waste

Waste is a broad concept and has a range of definitions. Fundamentally, waste can be defined as the unwanted materials that are thrown away by human beings, because they no longer want or need them. (Özverel, 2014) Although wastes are generally useless solid materials, they can be recycled or reused for being a resource for electricity generation and industrial production. (Tchobanoglous & Kreith, 2002) Accordingly, a proper sustainable waste management system is essential to preserve the environment and public health.

However, solid waste does not indicate the same meaning with municipal solid waste. Wastes comprise different categories depending on the sources such as residential, commercial, institutional, construction, industrial and agricultural. On the other hand, MSW covers all the produced wastes of the country from households, industrial and commercial, and institutional, excluding municipal services, and agriculture. (Tchobanoglous & Kreith, 2002)

Waste can be basically categorized into eight groups corresponding to the source of where, how and by whom it is generated. (Tchobanoglous & Kreith, 2002)

1. Residential: The waste produced by families' dwellings. Examples: food wastes, paper, cardboard, plastics, textiles, yard wastes, wood, glass, cans, aluminum, metals, special wastes (such as: electronics, yard waste, oil, tires and batteries etc.), and household hazardous wastes.

2. Commercial: The waste generated from restaurants, hotels, markets, stores, offices, auto repair shops, print shops etc.

3. Industrial: Power and chemical plants, refineries, factories, light and heavy manufacturing, construction and demolition (C&D) etc. Types of solid waste: food wastes, metal wastes, paper, glass, cardboard, plastics, ashes, hazardous wastes etc.

4. Institutional: The waste comes from governmental centers, schools, prisons and hospitals. The wastes are the same as commercial waste.

5. Construction and Demolition: Waste generated from road repair, broken pavements, renovation and new construction sites, etc. The waste can be steel, dirt, concrete, wood, etc.

6. Municipal services: the waste produced from street cleaning, parks, beaches, landscaping, etc. Rubbish, landscape and tree trimmings, and general wastes from parks and beaches can be examples.

7. Treatment plant sites: The waste generated due to treatment processes of water, wastewater and industrial waste. Residual materials and sludge are the types.

8. Agricultural: Waste comes from dairies, field and row crops, etc. Examples: Rubbish, food, agricultural, and hazardous wastes.

6.2. Sustainable Waste Management

Sustainable waste management is a system arranged for managing the generated waste in a sustainable manner. Collecting, recycling, and disposal are the main activities of waste management. (Seadon, 2010)

Waste management is like an organization that embodies legal regulation which covering not only disposal of solid wastes around the habitat where human beings are living in, but also contributing to economic development by protecting environment and human health.

Moreover, supporting less waste production, reusing and recycling produced ones as raw materials, and destroying waste products without damaging environment take place under the management system, too. (Çitil, 2009) The significant advantages of a well-planned management are minimizing the pollution and the outcomes like climate change, keeping the environment green and clean, and regaining the resources as recycled products and source of energy. (Reddy, 2011)

Enlargement of boundaries and inclusion of reduction and prevention programs constitutes simple fundamentals like equity, effectiveness, efficiency and sustainability for integrated solid waste management (ISWM). (Özverel, 2014) ISWM is a promoted and comprehensive system compared to the conventional approaches of waste management. Participation of stakeholders, elimination of waste, and recovery of resources are included into the conventional system. (WB, 1999) In general, integrated solid waste management needs to be socially acceptable, environmentally friendly and economically viable.

6.3. The Hierarchy of Waste for Improvement

Waste hierarchy plays a major role in improving the environmental features of ISWM, Waste hierarchy is known as "reduce, reuse, and recycle" in public, and supports the resource recovery and waste reduction. Depending on the characteristics of the waste different methods are applied for the treatment. Moreover, prevention of waste is desired more than disposal and recycling. (Gertsakis & Lewis, 2003) Nevertheless, disposal is the least preferable choice regarding preclusion. As it can be seen from Figure 15, the hierarchy of objectives of waste policy and legislation are classified from the most preferred towards the least one. Member states of the EU shall apply many principals for waste management. Waste should be handled without putting environment and human health in danger, polluting air, soil and water, and creating undesirable odor. (EC, 2008)

Figure 15: Hierarchy of Waste (European Commission, 2008)

Therefore, it is highly obligatory for waste management system to include various treatment options such as prevention, recycling, composting, and disposal via landfill and incineration in order to develop better environmental aspects. (Mahrum & Jones, 2009)

6.4. Social and Environmental Impacts of Waste

The constituent elements of municipal solid waste lead to serious environmental and persistent health problems. Wastes like batteries, oil and electronics that include toxic chemical are called as hazardous wastes. Hazardous wastes are disposed in an uncontrolled manner where wastes could not be decomposed properly, and mix with the water and soil. Therefore, uncontrolled disposal poses a great danger on human health.

There is a higher risk of observing diseases from stroke to cancer on who exposed to the consequences for a long time through water, air and soil. Infections and chronic diseases can be diagnosed in terms of health. Due to the direct touch to the waste, contaminated dust of landfill activities, and waste-fed animal bites, infections of blood, respiratory, skin, eye etc. can be recognized. Moreover, waste treatment plant workers are also influenced adversely from the dust and hazardous substances that are resulted in chronic respiration illnesses. And, injuries and burns can be resulted from contact with poisonous chemicals and landfill methane explosions. (Reddy, 2011) These health factors at the same time hinder the social life of people.

The major environmental problems issued by waste can be listed as: air, and soil pollution, climate change, water toxicity, inorganic resource depletion, and acidification because of acid forming substances like nitrogen oxides (NO_x), Sulphur dioxide (SO_2), and ammonia (NH_3). Furthermore, the collected waste heaps in dumps smell bad.

Waste management has also lead to the worldwide environmental issue of global warming either directly or indirectly. Disposal operations increase the concentration level of greenhouse gases like carbon dioxide ($CO_{2,}$), methane (CH_4), nitrous oxide (N_2O) etc. The increase in the concentration of greenhouse gases causes further warming on the atmosphere that in turns rises the average temperature of the Earth. Open burning, incineration, and landfill generate especially methane which is more effective than carbon dioxide on making the world warmer. (Reddy, 2011)

6.5. The Problems of Solid Waste and Solid Waste Management

Solid waste is a serious problem because it constitutes risks on both the environment and human health. When solid wastes are not stored regularly, then potable water, breathing air, and crops raised lands become polluted which lead to the formation and spread of serious diseases. In the waste dumping areas, where landfilling is not in progress, the organic matter of collected waste degenerated, and poisonous flammable methane gas is emitted. Absence of landfill creates garbage heaps that constitutes visual pollution. Also due to the emitted methane gas, garbage heaps gives off a bad smell. Sometimes heaps fire and emit toxic smoke into the air which leads to air pollution. Moreover, emission of gases has an adverse effect on climate change as the GHG abundance level increase. Air pollution makes breathing difficult, and resulted in serious health problems like asthma and kinds of cancer.

Similar to waste problem, lack of a proper waste management system also leads to many crucial types of pollution and health issues. An efficient and sustainable solid waste management necessitates environmentally friendly disposal solutions in an economically and socially acceptable way. (Morrissey & Browne, 2004) Otherwise, environmental, social and economic drawbacks would be driven. Air emissions from garbage, and transfer vehicles' exhausts, visual pollution, energy consumption, and unconscious consumer behaviors and lifestyles are resulted in costly adverse impacts on the environment and human lives. (Gertsakis & Lewis, 2003)

Besides, implementing education programs on waste conservation, economic instrumentals and social cost values can also be used in order to prevent waste generation and to decrease the negative effects of insufficient management systems. Previously tried and applied economic instruments by different countries are as; user, emission, product fees, voluntary agreements, and eco-friendly subsidies. Although most countries have applied instruments to develop their economies, northern countries like Austria, Netherlands, and England have used these measurements for the protection of the environment. (Çitil, 2009) Hence, financing environmental resources with justice will provide efficient and proper use of the same resources, as well.

Furthermore, energy recovery can be achieved by using the emitted gases. Some biological treatment processes can be applied to landfills in order to expose combustible gases that can be used in electricity generation. Emitted gases might be used as fuel to be combusted inside the incinerator for energy recovery. (Mahrum & Jones, 2009) Moreover, composting can also be performed especially on vegetable wastes in order to produce organic fertilizer.

6.6. Waste Management Examples from Other Countries

Overall, developing communities face many drawbacks owing to deficiencies in administrations, insufficient regulations and legislations, absence of planning either short or long-term, unauthorized dumping, lack of qualified expert on the issue, etc.

2,505 million tonnes total waste is generated EU-28 countries in 2010 of which 2404 million tonnes belong to non-hazardous waste, while 101 million is hazardous waste which is harmful for natural environment and health. The per capita generated waste varies in between 6,731 kg (Estonia) and 17 kg (Croatia) in both EU and non-EU member states. Besides, Serbia (1,529 kg/capita) and Bulgaria (1833 kg/capita) generate high amounts of hazardous waste per person due to quarrying and copper ore mining activities. ın 2010, 49% of total generated waste of EU-28 was gained as recovery (but other than energy recovery), 45% of disposed by usually landfilling instead incineration, and the remaining proportion was destroyed by burning with (4%) and without (2%) energy recovery. (Eurostat, 2015)

In Japan, geographic conditions are not very suitable for building landfill sites because 61% of the country composed of mountains and 6800 islands. Moreover, Japan has a higher population density so that the quantity of waste generated is too much inevitably. Since the population and mountains cover majority of the land, suitable sites for landfilling cannot be provided. Therefore, instead of landfilling, incineration operation has been performed for reducing waste amount. The incinerated quantity is approximately 70% of municipal solid waste of Japan. (Reddy, 2011)

Mainly, non-governmental organizations play an important role in development of waste management issues. Some developing cities like the ones in South Korean the public arrange the facilities of municipal waste management, while some in South and west Asia follow old administrative rules and laws, that is; participation of the public is not integrated into decision making on arrangement aspects. Moreover, most of the developing countries of Asia do not carry out recycling acts. The environmental protection agencies are not upgraded to modern times and therefore, any spending or decision taking entails government approval. (Reddy, 2011)

In Thailand, the total generated waste is about 15.04 million tonnes, and approximately 80-90% of the produced waste is collected in a regular periodic manner. 37% of the collected waste is treated in sanitary landfills, while 67% is disposed in open dumps. Similarly, in the rural regions of Thailand, open dumps are used, and open burning is executed for disposal. Although the potential for recycling is very high in Thailand (80%), only 22% of the materials are recycled which is approximately 3.1 million tonnes. Local governments are the main organizations that are responsible for MSW management. They encourage private sectors beside public in order to follow strategies such as raising social consciousness, investing in clean and green technologies, reviewing available laws and introducing new regulations in order to promote the current management system. (Reddy, 2011)

In Africa, the management issues are diverse and complicated. Disposal process is done without thinking human health and the environment. Due to poor governance and being unconscious about the environment, dangerous methods like open burning operations are applied. (Marshall & Farahbakhsh, 2013) Substandard processes are executed and there are no energy recovery systems for open dumps. Open dumping is a significant problem due to its serious impact on the environment and human health in small, poor, and developing countries like Costa Rica, Caribbean countries, Bolivia, Peru and so on. As mentioned before, exposure to waste lead to many risks assigned with health, surrounding, air and water such as infections, water contamination, poisonous dust, and explosions. (Reddy, 2011)

In Latin America, since the majority of the population live in cities (78% of the total population), about 98 million tonnes of waste is generated annually. Moreover, around 209 million people live in medium and small-sized cities where 56 million waste is produced. In large and urbanized cities 85% of generated waste is collected and 60% of accumulated MSW is eliminated in sanitary landfills, while in small and medium cities the collection levels are on average of 69%, and open dumping treatment is executed. Furthermore, according to survey results conducted in Chile, Colombia and Mexico it can be said that the sanitary landfills are under the generally approved operation standard levels. Thus, EIA does not provide them the essential environmental treatment license. Generally, disposal activities are mainly depend on sanitary landfills. Also, the number of controlled and sanitary landfills has been going up. However, open dumping still presents commonly. (Reddy, 2011)

In developed countries where the majority of public has higher education are conscious about the importance of the environment, resources and economics. Industrialized communities have specialized administrators and organized structure. Landfilling and recycling are the most commonly applied methods by the developed nations like Europe, Latin and North Americas.

Due to the fact that Europe is resource-intensive, and has qualified and skillful specialists so that long-, medium- and short-term waste management plans are widespread. European Commission policies on waste are carried out by most of the industrialized cities in Europe. Key decisions of both disposal activities and resource recovery are adopted. In other words, landfill, incineration and packaging activities are performed with regard to legislations. Additively, policies and economic instruments like taxation, and recycling market supports are introduced in order to make management system better. Governments are the main liable agencies in managing waste. In Western Europe, the well-organized waste hierarchy is implemented where the priority is to prevent the generation of waste, and followed by reuse, recycling, resource and energy recovery, and at the end disposal. (Reddy, 2011)

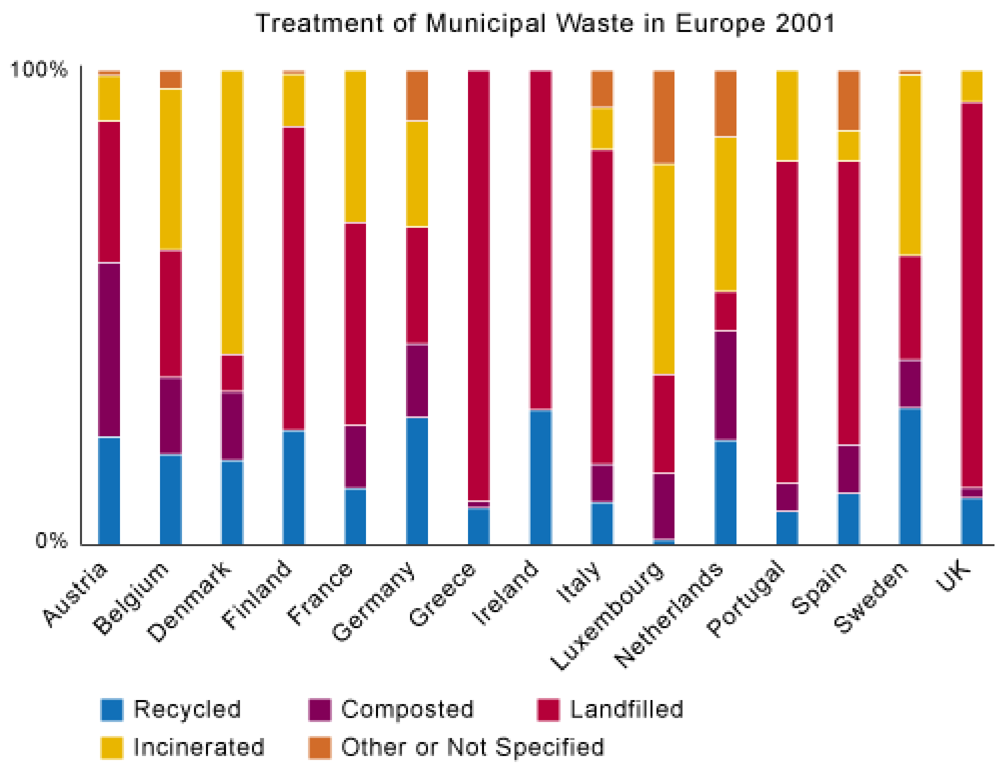


Figure 16: Domestic Waste Management in EU countries. (Reddy, 2011)

Figure 16 illustrates the management of domestic waste for several European Union countries covering the years of 1999 and 2000. The colored fractions indicate treatment operations of recycling, incineration, composting, landfill and others. As can be seen landfilling has been shared the highest proportion among disposal methods in the United Kingdom in 1999-2000.

The government of the United Kingdom presents a blend of monetary, administrative, and voluntary instruments and targets in order to reduce the effects of waste management and generation. Landfill Tax (LT), National Industrial Symbiosis Programme (NISP) and the Waste Protocols Project (WPP) can be the examples of these. The revenue from the taxes are used to improve the programmes for utilizing resources as raw materials and recycled products by taking economic and environmental additions. (Costa, Massard, & Agarwal, 2010) In the UK, decisions are taken by local governments rather than central authority. The emphasis is given to waste reduction from the hierarchy objectives. (Reddy, 2011)

In North America, even though local agencies are responsible for the management, departments of environment and health are also involved. Adequate institutions, comprehensive legal provisions, well-organized planning, experienced specialists, and innovative advances are developed for management system. Moreover, similar to Europe countries financial instruments are also used in order to waste prevention. Private organizations have also taken a part in waste collection progress. Furthermore, the US Environmental Protection Agency (EPA) has found a hierarchy where the disposal methods are ranked with respect to preference under integrated solid waste management. (Reddy, 2011) However, in North America, landfills are inevitable elements of ISWM. Landfilling is one of the primary treatment methods in managing solid waste. About 65% to 70% of the generated waste is processed in landfill areas.

In New York City, since 1950s, most of the generated solid wastes are disposed in huge landfill areas. The population was about 8 million in 2002 and 12,000 tonnes of residential waste generated daily accumulated by private companies. The collection is performed into three division i- recyclable paper ii- recyclable plastics, metals and glass iii- all other wastes (or, black bags). Although, recycling has been promoted recently, and shared around 17% of disposition, landfilling still shares the highest proportion by 71%. Nearly 300,000 tonnes of waste paper and some plastics are recycled yearly. Moreover, in New

York City energy recovery has also be supported. Around 500,000 tonnes of generated waste are transferred to waste-to-energy plants in order to regenerate energy due to flammable properties of the materials. (Reddy, 2011)

CHAPTER VII

THE PROBLEM OF SOLID WASTE IN NORTHERN CYPRUS

This chapter of the dissertation aims to explain the current situation of solid waste management in Northern Cyprus. Depending on the gathered information on that issue uncontrolled dumping sites will be mentioned. How the management system has been improved from the uncontrolled disposal areas to better landfill plants on behalf of Master Plan prepared by European Union will be stated. Then, related to the disposal facilities the main problems of solid waste in TRNC will be discussed.

7.1. The Applications of Waste Management in Northern Cyprus

Northern Cyprus is a developing country so that it exhibits similar structure in terms of waste management with other developing communities. In other words, the management system was not sustainable, and had negative impacts on both environment and human health directly previously. Therefore, the existed system needed to be changed when compared to industrialized countries to minimize the adverse effects.

The problem of solid waste management in TRNC has always been left out. Despite changes have been applied for improving the current management issues, still drawbacks exist regarding solid waste management and disposal. Duties and responsibilities of the main state authorities of the Republic of Northern Cyprus on this issue is complex which lead to ineffective use and coordination of resources in order to achieve pre-defined objectives. (EU Master Plan, 2007)

The environmental management responsibilities are belongs to many administrative institutions. An environmental (18/2012) and a municipality (51/95) laws have been prepared for standardization of waste control and disposal. 51/95 Municipalities law determines the duties and responsibilities of the municipalities. On the other hand, 18/2012 Environmental act is in accordance with EU standards, and determines all the principals regarding waste. According to general principals waste has to be managed within the hierarchy, as well as, precautions should be taken in order to prevent the harm upon the environment and human health. (Alkan, 2015) Municipalities do the duties of collection, organization and disposal, while Environmental Protection Department (EPD) controls the system of waste management. In addition, medical waste control and disposal regulations have also entered into force. Health organizations and especially the Ministry of Health are responsible for the separation at source, transportation, storage and sterilization of generated medical waste. (Alkan, 2015)

Moreover, this issue of Northern Cyprus faces some political restrictions because of being a divided island. In other words, the limitations on waste exporting influence basically solid waste management, as well. (EU Master Plan, 2007) Although TRNC faces some difficulties because of being a developing country, making improvement in the solid waste regulations will bring TRNC closer to EU standards.

There are 28 municipalities in Northern Cyprus. The majority of 28 municipalities in TRNC do the work of waste collection by garbage trucks, and transfer the collected waste to the nearest uncontrolled disposal areas. In 2006, the number of dumping sites was detected as 72 (Röben & Paralik, 2006). However, dumping sites has limited capacities and apply primitive methods for disposal. Waste storage in uncontrolled areas, that did not meet any modern landfill standards, created serious environmental issues because of increasing waste generation linked to increasing population. In most of dumping sites, the trash was just left in the fields, and even the hump was not covered by any materials such as soil. Therefore, fires have been observed in almost all of the existing uncontrolled waste disposal areas.

Accordingly, in 2007 Environmental Protection Department launched a Master Plan and feasibility studies within the European Commission Financial Assistance Programme. As a result of studies, waste policy and solid waste management plan have been approved by the Council of Ministers in TRNC. Thus, they have been prepared by considering the principals of EU on especially residential waste topic (Alkan, 2015). A financial support by European Commission (EC) approximately €21.2 million has been devoted for projects to upgrade the environmental issues of TRNC (Özverel, 2014).

Master and management plans have been developed in order to pass through safe landfill disposal plants from uncontrolled open dumps. A master plan of solid waste management is prepared in order to construct a landfill area with the financial contribution of European Union throughout the time period of 2011 and 2012. It is aimed to set up a sustainable economic development for the Turkish Community of Cyprus. With the approval of the project the construction of safe disposal landfill has been launched in 2011.

Starting from the year 2012, almost 55% of the generated municipal wastes from settlements including Nicosia, Kyrenia and Gönyeli have begun to use Güngör storage landfill. Recently, another large city of Morphou has started to send its municipal solid waste to this landfill, too. Nevertheless, the remaining 18 municipality still continue to dispose generated waste at uncontrolled wild areas.

7.2. Uncontrolled Waste Disposal Sites

7.2.1. Dikmen (Dikomo) Waste Disposal Area

Before installing the regular storage landfill, wild uncontrolled disposal areas were available, and among all Dikmen dump has been registered as the biggest official dump after 1980 in Northern Cyprus (Mahrum & Jones, 2009). Until the year 2008, up to the installation of safe disposal land in Güngör, Dikmen Dump is used as wild garbage storage land where the majority of wastes are burnt. As can be seen from Figure 17, Dikmen Dump takes place in a village called Dikmen located in between Nicosia and Kyrenia, or 5 km north of Nicosia, the capital city of TRNC. Dikmen Dump serves nearly half of the population by 9 municipalities. Wastes collected from households, commercials, factories, and agricultural are transferred to Dikmen Dump site in order to be disposed. Approximately 130 vehicles per day visited, and nearly 500 tonnes/day were transferred to Dikmen dump. (Alkan, 2015) In addition, domestic and industrial liquid wastes were transported to the region through tankers. Groundwater contamination has not happened due to the fact that the region does not have any underground water reserves. However, the area was not operated in a good way from the business perspective. The major problems encountered in uncontrolled dumping site are fires, and especially during rainy winter months liquid wastes reach to the location of settlement through streams.

Figure 17: Dikmen Wild Storage Area Location (Mahrum & Jones, 2009)

No insulation system is installed for decreasing the impact of leachate. Furthermore, the assembled garbage and waste has been spread around the surrounding. Due to trash piles explosions happened on the site which is very harmful to both the environment and human health. The smoke arises from incineration has hanged over the central city of Nicosia. Incineration facility releases toxic gases from the smoke which causes serious health problems besides environmental issues. (EU Master Plan, 2007) As a consequence of incineration, poisonous gases such as dioxins, carbon monoxide, nitrogen oxides and Sulphur oxides etc. are emitted. The environmental impact is enormous even from burning harmless seems substances like papers and yard debris. Open burning leads to global warming because of emitted greenhouse gases. In addition, human health is also influenced negatively due to the exposed smoke up in the air. For example, headaches, red spots on the skin and nausea can be observed in short-term while risky illnesses like heart attacks, types of cancers, liver diseases, reproduction functions and nervous system problems arise in the long-run. In Canada, the concentration levels of dioxins and furans arising from industries are less than the ones caused by open burning process. (Environment and Climate Change Canada)

7.2.2. Rehabilitation of Dikmen Dump

In order to take precautions against the problems encountered because of uncontrolled dumping, landfill project became a current issue in 2004 in cooperation with the Ministry of Environment of Turkey and Environmental Protection Department of TRNC. Correspondingly, domestic waste must be weighted before disposal and stored in regular storage after manually parsed in the scope of the prepared project. Water leakage would be transferred to evaporation pool, and then was purified via evaporation method. (Alkan, 2015)

The management of rehabilitation was done by a private company. However, the company failed to fulfill its contractual obligations. After that, in cooperation with EU Commission a rehabilitation plan is developed and has been implemented successfully. The expenditure that spent on the rehabilitation project installation was about 6 million Euros. (Alkan, 2015) Garbage spread over a wide area of 27.5 hectares with a volume of 1.3 million m^3 were moved to a region of 11.5 hectares, and covered with impermeable material and soil. During the closure, leachate and landfill gas collection systems were installed. Landfill gas is given to the atmosphere by burning. While, collected leaking water was evaporated through evaporation pools. (EPD, 2010)

The visual difference between before and after rehabilitation can be seen from Figure 18 and 19.

Figure 18: Dikmen Dump before rehabilitation (www.kibris724.com, retrieved on: 22/07/2016.)

Figure 19: After rehabilitation Dikmen Dump (EPD, 2011)

7.2.3. Kalkanlı Waste Disposal Site

The disposal site takes place around 7 km north of Güzelyurt city, and 3 km to Kalkanlı village. It covers an area of approximately 6.5 hectares. Not only Güzelyurt, and Lapta municipalities, but also the military also use the site for disposal. (Özverel, 2014) Treatment operations were run by open burning that lead to smoke. The smoke arising from the uncontrolled disposal cover the nearby settlements mainly the village of Kalkanlı and Middle East Technical University NCC. Due to the objections by the community, and construction of a transfer station in Güzelyurt, the wastes of the region have been transferred to landfill in Güngör.

7.3. Güngör Landfill Area

During the Dikmen Dump period solid waste management was run by just collecting and destroying the garbage by incineration methods until the transition to more sustainable solutions through an extended capacity. A new location for a landfill is designated for the first time in Northern Cyprus, and therefore rehabilitation is performed for Dikmen Dump.

The safe disposal landfill plant installed in a village called Güngör which is located about 2 km. southeast of Nicosia where 60% of the collected garbage has been sent to. The area of the landfill of Güngör is illustrated in Figure 20. It has started operation at the beginning of 2012. Güngör Landfill covers an area of 12 hectares and serves to 10 municipalities of TRNC. In other words, 60% of total generated residential waste is transferred to the landfill. Although the total capacity of the landfill is 2.3 million m^3, the volume of the current used cell is 950,000 cubic meters, that is; around 41% of the total area is in use now. (Alkan, 2015)

Figure 20: Waste Landfill Plant in Güngör (Özverel, 2014)

Although the main authority is the Ministry of Internal Affairs that municipalities attached to, the business operation of the landfill is contracted to a private company. First, the ingredient of transferred waste is controlled over by weighting, and then discharged to storage space. Güngör landfill plant is completely suitable to the standards of EU Directive no. 1999/31/EC. The access of leachates into potable groundwater is denied via impermeable ground of the plant. Leaking water is collected inside a pool and disposed through evaporation. Moreover, chimneys are opened in order to release landfill gas to the atmosphere. (Alkan, 2015)

Moreover, office building, garage, water warehouse, and evaporation pond are the constructed auxiliary buildings under the landfill project in addition to landfill plant. The monthly total average amount of waste transferred to Güngör is about 13,500 tonnes. The highest proportion is shared by household waste which is 10,500 tonnes per month. The remaining 3,000 tonnes is rubble and garden waste. While, monthly transferred hazardous waste is 0.2 tonnes (200 kilograms) in average. (EU Master Plan, 2007)

Although the lifetime of the landfill plant is expected as 30 years, it can become full within 10 years due to increasing consumption of the public and absence of recycle and reuse facilities. (Özverel, 2014)

7.4. Recycle and Reuse

Since the demand for recycled materials is less in the market, recycle facilities are almost negligible. Yet, reuse and recycling facilities are becoming recent steps towards sustainable structure. To stimulate recycling political and economic instruments should be implemented. Also, recycling facilities should be promoted and assisted by regulations.

Glass, metals, cardboards, papers, plastics, and demolition waste have the potential of recycling. In Northern Cyprus, no recycling operation framework is available. The collection and transportation of reusable materials are run by several licensed private companies. (Özverel, 2014)

However, the treatment of the collected waste is not performed in the country. Since recyclable materials can be exported, some of them are carried to Turkey via ports, while some are moved to Southern Cyprus on the basis of Green Line regulation. Regulation states that a kind of waste can cross the border line that divides the Cyprus Island into two parts as Turkish and Greek parts. (Özverel, 2014)

7.5. Medical, Hazardous and Other Waste Management

An area about 480 m^2 in Güngör landfill is reserved for temporary storage of hazardous waste. Hazardous waste is stored into separate containers. Commercial and industrial activities lead to generation of hazardous waste. Due to the absence of a detailed data, an inventory on generated waste is prepared depending on short-term deliveries. As a result, on the basis of retrieved data set from Southern part of the island it is obtained that the generated industrial waste is equivalent to 0.066 kg per capita per day. (Alkan, 2015) The generated amount of hazardous waste is around 200 kilograms per month, and transferred to Güngör landfill with separate containers and stored within a distinct space.

Moreover, in the past medical wastes were collected by municipalities without separating from other types of wastes and transferred to uncontrolled dumps for disposal. As a result of feasibility report, it is decided to gather and sterilize all the medical waste of the country at the central hospital of Dr. Burhan Nalbantoğlu in Nicosia. In this context, sterilization building and cold storage warehouses are built, and two high-steam sterilization machine are assembled inside cold storage warehouses. The generated waste from public and private hospitals are collected and treated in accordance with the regulation of medical waste control and disposal. (Alkan, 2015)

In addition, batteries wastes are another issue in Northern Cyprus. It is very important to make the public aware about battery waste collection. Thereby, batteries can be collected apart from the residential waste. In the context of awareness project, collection points have been installed in many schools, universities, shopping centers and municipalities. About 5 tonnes of batteries are collected in this manner and stored temporarily in Değirmenlik region. Two private companies collect waste batteries in order to produce lead ingots to export abroad. (Alkan, 2015)

7.6. The Waste Profile of Northern Cyprus and Characterization Study Results

In Northern Cyprus, the most concentrated waste production is observed in the middle region of Nicosia including the city of Nicosia and Kyrenia. Famagusta is another important district in the production of waste. Besides, in the western part of the country, which is Morphou district including not only Morphou but also Lefke, the waste generation is less when compared to other cities. (EU Master Plan, 2007)

The lack of detailed data on solid waste makes analysis for management and disposal troublesome. Furthermore, essential data sets on socioeconomic and demographic factors are also absence. Thus, making an assessment becomes more difficult in terms of taking precautions, developing effective solutions and policies.

For the determination of the amount and content of generated waste; garbage have been picked up from different cities of the country in different seasons and at different time intervals. Moreover, laboratory analyses are performed in order to determine the proportions of carbon, nitrogen, and moisture inside of the generated waste.

In order to maintain a sustainable management characterization of gathered solid waste is studied in terms of identifying solid waste for supporting with an integrated solid waste management. The main purpose of management system is to regain the financial loss and cost. However, transition to a sustainable management plan would be more costly. (EU Master Plan, 2007)

It is aimed to make TRNC a clean and high-standardized island by making waste collection and management at international standard levels. Accordingly, in order to improve the quality of the island on both the environment and human health it is very important to use the most appropriate technology for disposal. (YAGA, 2014) The characterization of solid waste shows variations with regard to seasonal, regional and socioeconomic conditions. In the characterization study, Nicosia was chosen as the pilot city and distinguished into main three groups in terms of socioeconomic aspect as low-, medium and high- income levels. From different points of the city solid waste representing samples were collected and transferred by uncompressed trucks to Güngör landfill where the analysis was performed. The transferred waste were weighted and decomposed with regard to substance groups. About 650 kilograms per capita waste was analyzed. As a result, the percentage averages of types of waste according to socio-economic income levels are represented in Table 8. The greatest portion of solid waste for all income levels is formed by the type of household. For high-income sample household waste is followed by plastics by 16.02 % and other combustible waste by 14.90%. For middle- and low-income groups household waste is followed by other combustible waste and plastics. (YAGA, 2014) Thereby, it could be reported that the main three generated waste are formed by household, combustible and plastics wastes at all income levels.

Moreover, it can be said that the grand contributor of solid waste generation is the high-income classes, whereas the low-income ones have the lowest contribution not only to the solid waste production, but also to the environmental pollution. When the percentages of the table are ranked, low-income groups are basically responsible for the generation of metal waste and other combustible waste like tissues, textile materials and shoes. On the other hand, high-income level classes create the majority of the pollution from the perspective of solid waste. In brief, it can also be inferred from Table 8 that the majority of total generated waste is mainly composed of organic and recyclable wastes.

Table 8: Characterization Study Results According to Socio-economic Income Level

Waste Types	High-income (%)	Middle-income (%)	Low-income (%)
Household	46.31	33.49	29.96
Paper	2.96	4.05	2.82
Cardboard	6.22	5.00	3.03
Plastics	16.02	10.45	13.86
Glass	7.16	6.32	6.23
Metal	1.65	0.99	2.48
Electrical & Electronic Equipment	1.10	0.17	0.00
Hazardous Waste	0.77	2.56	2.16
Yard waste	0.37	6.43	5.93
Other Non-combustible Waste	0.23	2.56	2.18
Other Combustible Waste	14.90	20.04	25.95
Other	2.31	7.94	5.40

Household wastes include not only food waste, fruit and vegetable wastes but also expired food. Cloth diapers, shoes, slippers, pillows, carpets, rugs and bags are evaluated in the context of combustible waste. Lastly, plastics comprise all the groups of plastics such as plastic bottles, plastic packing packages and foams that are used in food packaging.

In addition, the types of waste listed in Table 8 are re-grouped extensively within 5 main groups categorized below:

- Organic waste: Household and yard waste
- Recyclable: Paper, cardboard, plastics, glass, metal
- Hazardous waste: Electrical and electronic equipment, hazardous waste
- Other Combustible Waste: Combustible waste, other flammable-volume waste
- Other Waste: Non-combustible waste, other non-flammable volume waste

According to this grouping organic waste shares the highest portion among all the types of waste that is followed by recyclable and other combustible wastes. The total percentage share of these three types is approximately 90%. (YAGA, 2014) Depending on the results from the characterization study for the pilot city of Nicosia, a generalization can be done for Northern Cyprus. Due to the fact that Nicosia is the central city and the most crowded city of Northern Cyprus, other cities can demonstrate almost the similar consumption behavior and distribution in waste generation.

CHAPTER VIII

STATISTICAL ANALYSIS – OBSERVATIONS AND VARIABLES OF SOLID WASTE DATA SET

In this section of the study, a statistical analysis will be performed by using univariate time series data set on solid waste for Northern Cyprus.

Recording the successive values of a variable within time intervals reveals time series. Time series process is determined by making and collecting measurements during a certain time period. The numerical quantities of series are analyzed mathematically, and the physical behaviors are observed within the analysis process. (Şanlıoğlu & Kara, 2009)

8.1. The Data Set of Solid Waste

The data set on the generated solid waste for Northern Cyprus is obtained from The Ministry of Internal Affairs Local Government Department of TRNC. The data set is composed of mainly five univariate time series. One of them indicates the aggregate generated amount of waste, and others are waste disposal, garbage and construction, industrial and commercial, household waste labeled as *total*, *dispo*, *garco*, *indco*, and *hh*, respectively. The variables which are explained in a codebook in Table 9 below indicate tonnes of different types of solid waste generated comprising the time period from January 2013 to December 2015. However, disposed solid waste has two missing values which are the observations of January and February of 2013.

The procedure in the analysis that will be utilized in this part of the dissertation will start by representing graphs visually related to the data set and plotting time series to identify every components' behavior. The absence or presence of any component will be a direction indicator in selecting a model in order to bring out prime forecasts. Then, model specification practice will be done via choosing proper variables to be included. Then, model specification practice will be done via choosing proper variables to be included. Here autocorrelation and partial autocorrelation of series residuals are checked. Sometimes error measurements like MAPE, RAE and MSE are used for validation. (Kalekar, 2004) Here autocorrelation and partial autocorrelation of series are checked.

Table 9: Time Series for Solid Waste Data Set

Variable Label	Variable	Description	Missing Values	Descriptive Statistics Before Imputation	Descriptive Statistics After Imputation
dispo	Waste Disposal	It indicates the amount of waste disposed in tonnes.	2	Min. = 12.70 1st Qu. =39.41 Median = 58.68 Mean = 108.01 3rd Qu. = 132.47 Max. = 411.16 NA's = 2	Min. = 12.70 1st Qu. = 39.80 Median = 62.47 Mean = 106.15 3rd Qu. = 129.34 Max. = 411.16 NA's = 0
indco	Industrial and Commercial Waste	The amount of waste generated due to industrial and commercial activities such as fabrication, heavy manufacturing chemical and power plants, and from locations of stores, restaurants, service stations and auto repair shops.	None	Min. = 356.3 1st Qu. =677.6 Median = 1050.5 Mean = 1105.0 3rd Qu. = 1413.0 Max. = 2315.7 NA's = 0	Min. = 356.3 1st Qu. =677.6 Median = 1050.5 Mean = 1105.0 3rd Qu. = 1413.0 Max. = 2315.7 NA's = 0
garco	Garbage and Construction Waste	The amount of waste generated due to construction facilities like new construction sites, road repair and pavement.	None	Min. = 614.5 1st Qu. =1244.4 Median = 1640.7 Mean = 2059.2 3rd Qu. = 2673.2 Max. = 5301.7 NA's = 0	Min. = 614.5 1st Qu. =1244.4 Median = 1640.7 Mean = 2059.2 3rd Qu. = 2673.2 Max. = 5301.7 NA's = 0
hh	Household Waste	Residential dwellings, and apartments including wastes of food wastes, papers, plastics, cans, yards etc.	None	Min. = 8844 1st Qu. =10724 Median = 11229 Mean = 11068 3rd Qu. = 11487 Max. = 12973 NA's = 0	Min. = 8844 1st Qu. =10724 Median = 11229 Mean = 11068 3rd Qu. = 11487 Max. = 12973 NA's = 0
total	Total Generated Waste	It indicates the aggregated amount of waste generated in tonnes.	None	Min. = 11117 1st Qu. =13439 Median = 14498 Mean = 14334 3rd Qu. = 15351 Max. = 18619 NA's = 0	Min. = 11117 1st Qu. =13439 Median = 14498 Mean = 14334 3rd Qu. = 15351 Max. = 18619 NA's = 0

* Data set types of each variable is "Time Series".
* Each time series covers the time period of 2013-2015
* Source of Data Set: TRNC International Affairs

Missing information proportion is straightforwardly identified with the nature of measurable derivations from the summary of descriptive statistics. However, there is no compromise about the satisfactory rate of missing information in a data set for substantial statistical derivations. Moreover, it is also cited from Schafer that proportion of missing data 5% or less is negligible. (Dong & Peng, 2013) Yet, extend of missing information could vary depending on the size of data set.

Too much missing values are problematic within data sets. For small data sets the acceptable safety threshold is assumed as 5%, whereas it can be 20% for longer data sets. If the missing data is more than 5%, it can be better to exclude the sample from the data set. The sample can be checked through a function in R software program whether the maximum threshold is greater than 5% or not. The lighter colored part in Figure 21 below indicates that the data set of solid waste has 5.6% missing information for the variable of waste disposal, while the pattern plot helps us understanding that almost 95% of the samples are not missing any necessary information for the analysis. As a result of the plot, it can be said that the sample of waste disposal is acceptable to be included within the assessment.

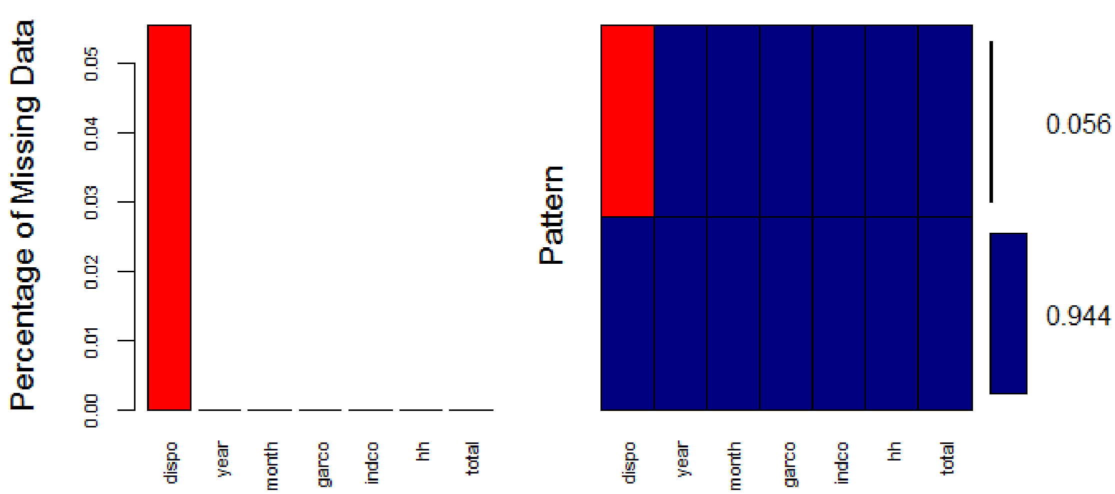


Figure 21: Graph indicating the percentage of missing data.

Since the missing observations are only two, regression imputation method would be very helpful in dealing with missing data in order to complete them. For imputation, Simple Linear Regression Model, which is a model where an independent variable is expressed by one explanatory variable, is constructed. The Simple Linear Regression Model is generally expressed as in the following equation:

$$y = \beta_1 + \beta_2 x + \varepsilon$$

Through Simple Linear Regression Model (SLRM) the missing two-month waste disposal observations are predicted and derived. In other words, the time period of month is expressed starting from the 3rd month to 36th month including the entire three years period but omitting two-month non-available observations of waste disposal variable. After excluding missing values linear regression model is constructed on waste disposal, that is, waste disposal amount is linearly regressed on defined time, and as a result, intercept and slope coefficients are obtained. Missing values of January and February are obtained via using the extracted coefficients of the regression model.

While SLRM is used to predict two-month missing observations, main assumptions of this model are hold. (See Appendix) Here for the imputation the equation below is used:

$$Dispo_t = \beta_1 + \beta_2 \, Time_t + \varepsilon_t$$

β_1 and β_2 stand for intercept and slope coefficients, respectively, and ε is the error term which is the nonsystematic part of the equation.

Due to the fact that the obtained data set on solid waste is only include the tonnes of generated waste amount for different types, any causal model on defining the effect of waste on the environment cannot be constructed. Therefore, forecasting will be performed to make prediction for the next few months since the time series is short in order to predict how the amounts of generated waste will change in the future.

The future is uncertain so that the effect of a decision which is taken now have uncertainties about the results of the future. For this reason, accuracy of forecasting increase the effectiveness of decision making progress. Forecasting helps to create important plans, as well as decrease instability of occasions in the future. The solid waste management system should match the total produced solid waste amount with the installed capacity in Güngör waste storage area. Therefore, it is necessary to predict how much space is needed to store generated waste. Moreover, depending on the waste characterization, it will be easier to decide what should be done to collected solid waste. The decomposition of collected provides clue about what should be done with the waste such as recycle, landfill or reuse.

Estimation includes time, that is; observations within a time period are required especially based on the past data and information. In order to make prediction certain steps should be followed. To begin with, a purpose needs to be determined, and depending on the objective a model should be developed. After model selection, proper methods are applied and tested, accordingly model should be estimated and the validity of it will be evaluated, and if any correction is supposed, then the correction will be performed. At the end, the obtained results are interpreted with regard to the available data set. (Kalekar, 2004)

8.2. The Waste Sampling

The data set for waste sampling contains the amount of several kinds of solid waste in tonnes, that is; solid wastes are measured by tonnes. The observations are collected from the measurements of solid waste transferred to the storage area in Güngör where higher proportions about 60% of total solid waste are gathered together. Among all kinds of solid wastes household shares the highest proportion of the total with 77.21%, and this proportion is followed by garbage and construction, and industrial and commercial by 14.36%, and 7.70%, respectively. The destroyed waste has the lowest rate with 0.74%.

Capability of management systems of solid waste being achieved is usually affiliated with precise forecasting of solid waste generation. Common forecasting models are generally based on per-capita socioeconomic and demographic indicators. (Chang & Lin, 1997) However, in the case of Northern Cyprus the essential socioeconomic and demographic indicators are absent. The solid waste time series data is made up of observations covering three-year period for a kind of solid waste generated from different sectors, as well as, the series are univariate time series where only one independent variable takes place. Hence, the solid waste composition data are analyzed based on three-year period from 2013 to 2016. Mainly two methods might be applied to analyze and to forecast time series data which are exponential smoothing and ARIMA. The most commonly used one is Box-Ljung Test, while non parametric regression method is started to be used recently. Box-Ljung Test is known as Autoregressive Integrated Moving Average (ARIMA). (Erdogan & Uzgören, 2009) Therefore, prediction analysis will be performed by a common technique of the Box – Jenkins model which developed a methodology called Autoregressive Integrated Moving Average, or ARIMA. In other words, by using explanatory variables themselves statistical prediction is extracted to forecast leading values from the current and historical data of time series observations.

According to summary of descriptive statistics (see Table 10) while household and total waste have negative values indicating that their distributions tend to have leftwards tail, other variables of waste disposal, garbage and construction, and industrial and commercial waste are tailed to the right side since their skewness values are positive.

Table 10: Summary Statistics of Solid Waste

Descriptive Statistics of Imputed Data Set of Solid Waste (in tonnes)					
	dispo	**garco**	**indco**	**hh**	**total**
nobs	36.00	36.00	36.00	36.00	36.00
NAs	0.00	0.00	0.00	0.00	0.00
Minimum	12.70	614.48	356.28	8843.76	11117.44
Maximum	411.16	5301.72	2315.68	12972.54	18618.78
1. Quartile	39.81	1244.36	677.57	10723.82	13438.70
3. Quartile	129.35	2673.22	1413.04	11486.87	15350.91
Mean	106.15	2059.17	1105.03	11067.89	14334.09
Median	62.47	1640.72	1050.54	11229.45	14497.56
Sum	3821.36	74129.98	39780.97	398443.98	516027.30
SE Mean	18.07	194.36	80.72	160.70	283.98
LCL Mean	69.46	1664.46	941.15	10741.64	13757.58
UCL Mean	142.84	2453.74	1268.90	11394.13	14910.60
Variance	11759.45	1359907.00	234580.44	929723.31	2903229.00
Stdev	108.44	1166.15	484.34	964.22	1703.89
Skewness	1.67	1.06	0.49	-0.27	-0.09
Kurtosis	1.69	0.17	-0.55	-0.15	-0.20

Furthermore, the scatter plot matrix of solid waste including time period is presented in Figure 22 below. The label names preserve as the names of y-axis or x-axis depending upon rows and columns where labels take place, and each graph represents correlation for any pair of univariate time series. To illustrate, for the second row, variable name *dispot*, disposed waste, serves as y-axis for the graphs on the same row and as x-axis for the graphs on the same column, and it is applied in the same way for the other variables, too. For example, if the graph on row three and column one is considered, it can be said that since the row label in row three is *garcot*, garbage and construction waste, the y-axis is the amount of garbage and construction waste in tonnes. Similarly, column one label is *month*, so that it performs as x-axis. Therefore for the graph on row three and column one, where y-axis is *garcot* and x-axis is *month*, illustrates the monthly change in the amount of garbage and construction waste. *Garcot* follows an increasing trend throughout the time period. Scatter plot matrix demonstrates the correlation between variables, and it appears twice for each pair of correlation one is in the upper triangle area while the other one is in the lower one.

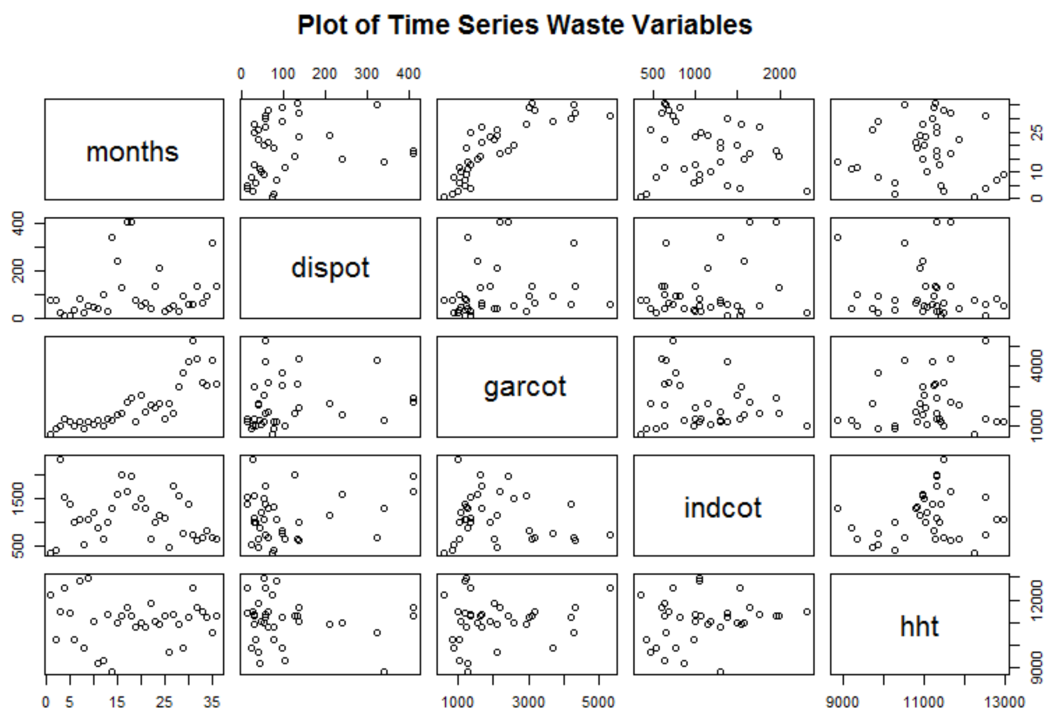


Figure 22: Scatter Plot Matrix of Solid Waste

8.3. Prediction Modelling on Time Series

Before forecasting, it is important to identify the characteristics of each variable. From the systematic point of view, the given observation needs to be fitted into a system, and this type of modelling could be done only if the observation is stationary. From the technical point of view, stationarity means that mean and variance of the series must be constant, as well as, covariance is a function of lag instead of time. Thus, the initial task is to check whether time series are stationary or nonstationary. If they are not stationary, it is not possible to use the series as they are so that it is essential to transform series into stationary in order to continue the analysis.

To begin with, according to the time series plots demonstrated in Figure 23 below since the fluctuations are approximately consistent over time, series are likely explained by an additive model. Additive models are constructed by the summation of the time series components of trend, seasonal and cycle. The plotted time series in Figure 23 demonstrate the quantity of kinds of generated solid waste per month in Northern Cyprus. All the figures illustrate seasonal and cyclic behavior, on the other hand, trend is not apparent in each series over the time period. It can be easily observed from the graphs that all the variables are nonstationary series, that is; the mean is changing, and variance of univariate time series are not constant for all the observations at any time period. To illustrate, slow wandering moves can be observed through the time series plots. Thus, nonstationary time series have to be transformed into stationary series by either taking difference or decomposing the time series. In the following sections, stationarity of time series in the assessment progress will be explained in detail.

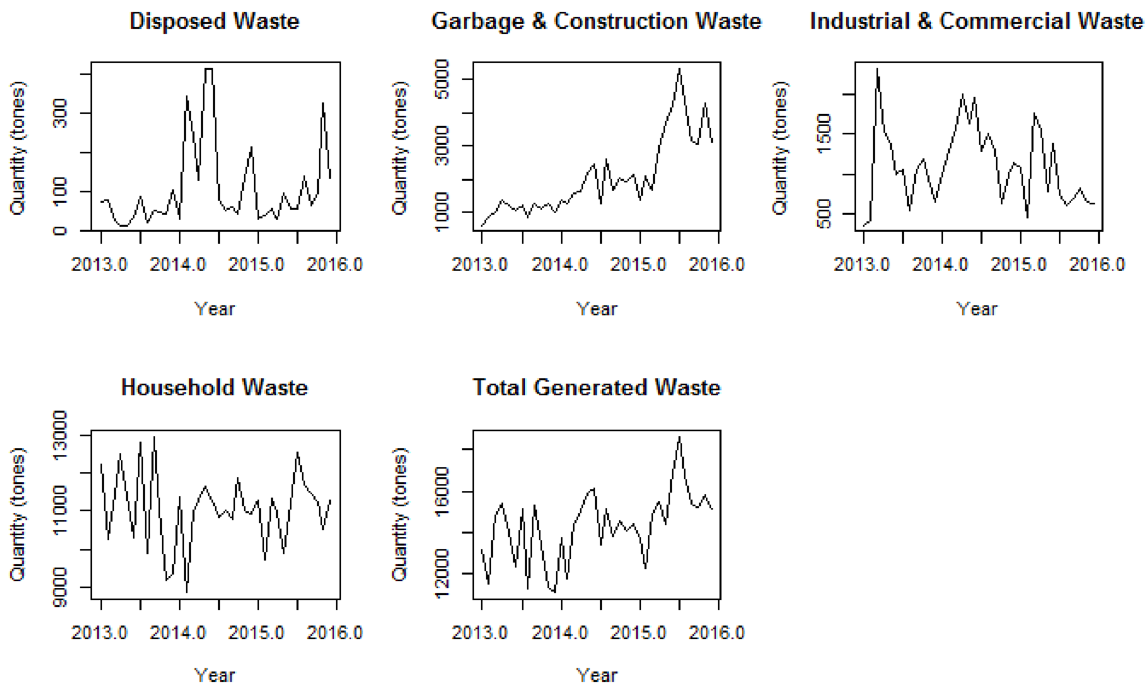


Figure 23: Time series graphs of each sample

8.4 Decomposing Time Series

A time series data set is constituted by components mainly trend and irregular and seasonal time series have seasonal component. Decomposing is to separate time series into its components. (Coghlan, 2014) In a crucial manner, time series decomposing plays a key role during analyed process. (Zucchini & Nenadic, 2011) Decomposition intends to remove the seasonality and periodic effects from the series to make them stationary.

In the case of solid waste data set of TRNC, due to the lack of demographic and socio-economic explanatory variables, it would not be possible to explain physical changes of series with stochastic and deterministic analyses so that conventional methods will be used within the analysis stage which are basically related to decomposition of drift, periodic effects, and reminder irregular, or random behaviors, as well as to make prediction of future values.

As mentioned before, for continuation of the analysis, it is fundamental to have stationary time series. The removal of trend and seasonal effects transforms non-stationary series into stationary ones. Among two types of decomposition, which are additive and multiplicative models, additive model is designated due to the fact that the data for each variable do not demonstrate any proportional change. Hence, it can be easily assessed at what extent of each element is effective on the sample values. (Şanlıoğlu & Kara, 2009)

Decomposed seasonal data figures are obtained by using seasonal decomposition of time series by Loess (STL) function in R software and demonstrated in Appendix. STL function is chosen in decomposition because it does not exclude any observation from the samples. Whereas, other functions like decompose exclude the first and last 6-month period for trend which is too much since the data period is short. Almost one month is missing from 3-year observations.

The figures cover four main plains by a row of observed, trend, seasonal and random. Observed one represents the original data, whereas random plain points out the estimated error terms. Residual is the difference between the observed and expected values of the variables. In the figure, the reminder is what has been left behind from the subtraction of trend and seasonal components from the original data set.

The estimated outputs of seasonality factor for the months January-December are also given in Table 11. The values repeat themselves for every year from the beginning of 2013 until the end of 2015.

According to Table 11 and 12 of seasonal and trend components it is observed that the highest seasonal factor for disposed waste is experienced in May, whereas the lowest one is in October. Similarly, it can also be said that each year there is a peak in disposal approximately 68.83 in May, and a trough of -55.81 in October. Moreover, the estimated trend factor follows an increase until May 2014 which reaches to a peak about 176.62 tonnes, then it starts to fall again to 73.80 in January 2015. After that, it is followed by a steady increase to about 163.14 tonnes by June 2015.

The estimated seasonal component outputs provides information about the monthly changes for other univariate time series, as well. In garbage and construction waste, the largest seasonal element is for June about 537.67, while the smallest is in January with -573.77 tonnes. Garbage and construction represents a continuously increasing trend from the beginning of 2013 until the end of 2015, that is; it is increased from 998.50 to 4075.4. The largest seasonal estimate is appeared in every March (781.91 tonnes) for industrial and commercial waste, while the lowest one is in February (-373.28 tonnes). The trend curve of industrial and commercial waste is inward. Namely, at first trend estimates display an increase until July 2014 with a peak of 1354.40, and then it has fallen to 829.41 at the end of 2015. For household waste, the highest portion of waste is created in the mid-summer. Every July the peak is occurred at 996.57 tonnes, while the though is about -1518.68 in every February. The reason for the peak can be seen because of the summer period consumption habits of the population. The number of tourists that visit Northern Cyprus augments in summer periods. Similarly, the consumption of foods and beverage increase. Most of the people stand late at nights which can be also a causative factor for triggered consumption. The rising consumption will resulted with an increase in waste production. In addition, the reason for the tough in every February can be caused by the education sector. The total number of students in universities is 78,898 for the academic period of 2014 and 2015. The number of Cypriot citizen in universities is 17,950, whereas the majority of university students of around 63,422 of which 43,278 from Turkey, and the rest is from third world countries arrive to Northern Cyprus to get education. In other words, 80% of the university students settle in Northern Cyprus from Turkey and other countries. Hence, the number of population increase during education periods, but at the break times particularly at February break time the decrement in the number of students lead to lower waste amounts since the consumed goods and products decline.

Overall, when the aggregate generated waste is considered, the highest seasonal estimate occurs every July by 1380.01 tonnes, and the lowest seasonal occurrence is about -2205.09 tonnes in the month of February. The highest observed amount of total generated waste in July can be depend on the summer season where majority of the population are on holiday and, the variety of especially fruits increase, as well as students attend to summer schools. As the population spend more leisure time and consume more fresh refreshments, the generated waste amount increases. The trend of garbage and construction, and total generated waste display an increasing trend, whereas other variables do not clearly demonstrate a certain increasing or decreasing trend.

Table 11: The estimated values of seasonal components

		Estimated Values of Seasonal Components from Samples' Decompositons											
Variabe Name	**Year**	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
	2013	-41.25	63.09	14.09	-42.04	68.83	58.29	-40.65	-43.34	-54.38	-55.81	48.27	24.91
Waste Disposal	2014	-41.25	63.09	14.09	-42.04	68.83	58.29	-40.65	-43.34	-54.38	-55.81	48.27	24.91
	2015	-41.25	63.09	14.09	-42.04	68.83	58.29	-40.65	-43.34	-54.38	-55.81	48.27	24.91
Garbage and Construction Waste	2013	-573.77	-359.23	-438.71	63.06	380.29	537.67	515.51	472.34	-146.12	-209.44	140.63	-382.24
	2014	-573.77	-359.23	-438.71	63.06	380.29	537.67	515.51	472.34	-146.12	-209.44	140.63	-382.24
	2015	-573.77	-359.23	-438.71	63.06	380.29	537.67	515.51	472.34	-146.12	-209.44	140.63	-382.24
Industrial And Commercial Waste	2013	-285.77	-373.28	781.91	578.62	151.46	325.83	-94.74	-236.99	-102.85	-223.79	-249.79	-270.61
	2014	-285.77	-373.28	781.91	578.62	151.46	325.83	-94.74	-236.99	-102.85	-223.79	-249.79	-270.61
	2015	-285.77	-373.28	781.91	578.62	151.46	325.83	-94.74	-236.99	-102.85	-223.79	-249.79	-270.61
	2013	483.53	-1,518.68	167.42	512.78	-72.79	-134.36	996.57	-202.59	703.64	362.48	-777.51	-520.49
Household Waste	2014	483.53	-1,518.68	167.42	512.78	-72.79	-134.36	996.57	-202.59	703.64	362.48	-777.51	-520.49
	2015	483.53	-1,518.68	167.42	512.78	-72.79	-134.36	996.57	-202.59	703.64	362.48	-777.51	-520.49
	2013	-432.36	-2,205.09	531.60	1,118.41	532.87	791.62	1,380.01	-8.17	401.77	-125.46	-837.66	-1,147.53
Total Generated Waste	2014	-432.36	-2,205.09	531.60	1,118.41	532.87	791.62	1,380.01	-8.17	401.77	-125.46	-837.66	-1,147.53
	2015	-432.36	-2,205.09	531.60	1,118.41	532.87	791.62	1,380.01	-8.17	401.77	-125.46	-837.66	-1,147.53

Table 12: The estimated values of trend components

Variabe Name	Year	January	February	March	April	May	June	July	August	September	October	November	December
		Estimated Values of Trend Components from Samples' Decompositons											
Waste Disposal	2013	15.36	21.93	28.49	35.85	43.21	51.11	59.00	68.11	77.22	94.25	111.28	130.09
	2014	148.89	158.69	168.48	172.55	176.62	174.70	172.78	159.57	146.37	127.48	108.58	94.08
	2015	79.58	76.69	73.80	82.94	92.09	100.79	109.49	119.13	128.77	139.89	151.00	163.14
Garbage and Construction Waste	2013	998.50	1,011.55	1,024.60	1,048.09	1,071.57	1,101.56	1,131.54	1,160.28	1,189.02	1,246.47	1,303.92	1,385.41
	2014	1,466.91	1,536.02	1,605.13	1,660.05	1,714.98	1,764.08	1,813.17	1,862.05	1,910.92	2,004.65	2,098.37	2,265.41
	2015	2,432.45	2,618.09	2,803.73	2,948.27	3,092.81	3,234.08	3,375.35	3,520.00	3,664.64	3,803.89	3,943.14	4,075.48
Industrial And Commercial Waste	2013	900.04	925.59	951.13	977.99	1,004.85	1,032.74	1,060.64	1,085.53	1,110.41	1,132.78	1,155.15	1,197.55
	2014	1,239.95	1,278.30	1,316.66	1,332.00	1,347.34	1,350.87	1,354.40	1,337.44	1,320.49	1,279.24	1,237.98	1,180.80
	2015	1,123.62	1,074.23	1,024.84	999.98	975.12	951.68	928.24	906.35	884.45	865.30	846.15	829.41
Household Waste	2013	11,803.01	11,690.01	11,577.01	11,466.23	11,355.46	11,248.08	11,140.71	11,037.13	10,933.55	10,865.89	10,798.24	10,780.34
	2014	10,762.44	10,752.20	10,741.95	10,778.86	10,815.78	10,890.63	10,965.49	11,002.90	11,040.31	11,026.81	11,013.31	11,014.02
	2015	11,014.74	11,041.55	11,068.37	11,088.18	11,107.98	11,132.91	11,157.83	11,189.65	11,221.46	11,258.79	11,296.12	11,337.18
Total Generated Waste	2013	13,681.74	13,618.27	13,554.80	13,505.83	13,456.86	13,419.26	13,381.66	13,344.60	13,307.54	13,338.28	13,369.02	13,493.86
	2014	13,618.70	13,725.58	13,832.46	13,943.42	14,054.39	14,179.80	14,305.22	14,361.54	14,417.86	14,438.27	14,458.69	14,554.79
	2015	14,650.89	14,810.93	14,970.97	15,119.28	15,267.60	15,418.67	15,569.74	15,733.55	15,897.35	16,065.52	16,233.70	16,402.18

There is an increment in the amount of total generated waste at the first months of every year that could be caused by the education period of the schools. A great portion of living population are coming from abroad in order to study higher degree level of education, and at the holiday periods students turn back to their own countries. Accordingly, especially in spring period the amount of generated waste go up as a result of increased consumption.

After eliminating effective components of seasonal and trend from series, modeling progress begins. For constructing a proper modeling of prediction for future can be executed by means of past and current observations. A wide range of methods can be applied to time series in order to make forecast. However, depending upon the univariate time series available on hand the most convenient models will be Holt-Winters Exponential Smoothing and ARIMA.

Seasonal adjustment could be applied in order to drop periodic aspect from the original data. Seasonally adjusted data set is what left behind after removing the seasonality from the observed values. For example, the output gotten from seasonally adjusted components will be the difference between the original values of solid waste series at a certain time and seasonal values of decomposed components of series. As a result, the value of the difference will be the de-seasonalized value. Although seasonality is removed from the data, trend and remainder error component still exist within the series.

One of the simple exponential smoothing, Holt’s Exponential Smoothing, and Holt-Winters Exponential Smoothing methods can be applied in order to make a short-term prediction depending on which components the data includes. The issue of which method should be used is identified whether a series has trend and seasonality or not. All the univariate time series of generated solid waste types in Northern Cyprus have both seasonality and trend that can be observed through the decomposition process. Therefore, Holt-Winters Exponential Smoothing will be applied in order to predict the next three-month values for January, February and March of 2016 since the solid waste data set is short and just covering 36 months in total.

In this study, in addition to additive model, time series variables of solid waste have both trend and seasonality factors. Thus, Holt-Winters Exponential Smoothing method will be used for making short-term predictions where trend and seasonality factors are smoothed. α, β and γ are the three controlled parameters in smoothing estimation which takes values between 0 and 1, and values closer to 0 mean that recent observations has little weight on the prediction. (Coghlan, 2014) The controlled parameters are estimated from different equations constructed for each component of time series separately. However, Holt-Winters smoothing predict current time period's slope, seasonal and level components. (Coghlan, 2014) In other words, instead of making forecast for a future value, Holt-Winters exponential smoothing make predictions for the original data sets' time period. In the case of Northern Cyprus, the original series for generated waste of different types are from 2013 to 2015 so that the forecasts also cover the same time period of 2013-2015. The table below summarizes the smoothing parameters for each series which provide information about whether the future estimates are based on recent observations or past observations.

Table 13: Smoothing parameters of Solid Waste Types

Holt-Winters Exponential Smoothing Parameters			
Variable Name	α	β	ϒ
Disposal Waste	0.6725	0.0000	1.0000
Garbage & Construction	0.3921	0.0000	0.0000
Industrian & Commercial	0.3481	0.0105	0.4780
Household	0.0105	1.0000	0.6987
Total Generated Waste	0.0081	1.0000	0.5730

Based on Table 13 the estimates of slope of the trend i.e. β of garbage and construction, disposed waste, and industrial and commercial are equal to zero and very close to zero. Therefore, they are described by their initial values because the estimates are not modernized over the time series. Moreover, according to parameter of gamma of industrial and commercial, household, and total generated waste indicate that the current time period's estimates of the seasonal component depend on both recent and past observations. The estimated value of seasonal component, γ, for disposal is only based on the most recent observations, whereas the one for garbage and commercial waste is just based on the past observations.

Furthermore, an additional parameter needs to be included into analysis to obtain estimated values of the next periods of all the univariate time series of solid waste. The following graphs display the estimates for the next three months for all the kinds of solid waste at where darker area indicate 80% prediction interval, and lighter colored area shows 95% prediction interval. In other words, the future predicted observations are almost certainly realized within the 80% and 95% prediction interval bounds.

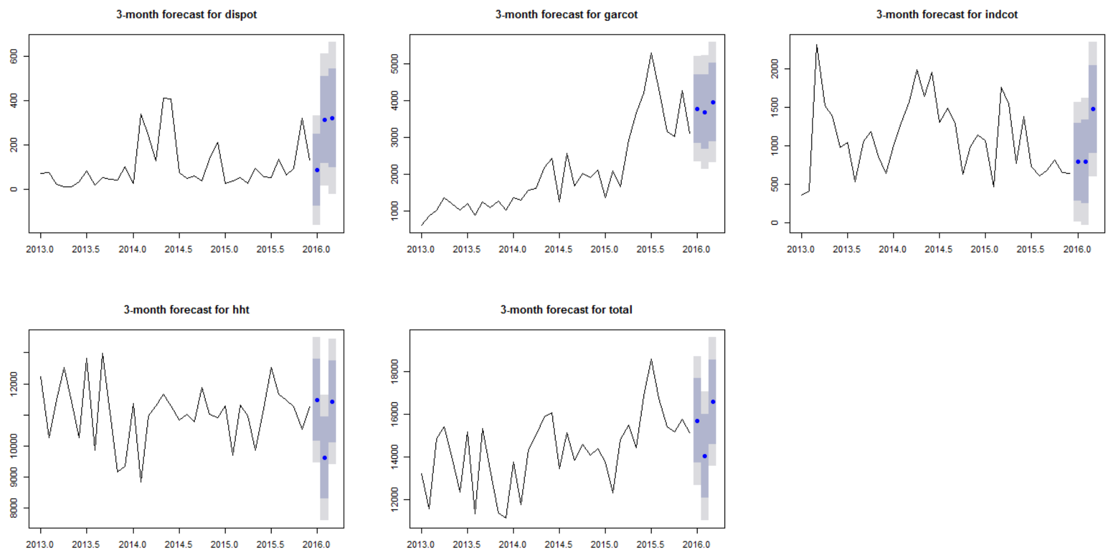


Figure 24: Forecast Graphs based on Holt-Winters' values.

Except for industrial and commercial waste, other series present fluctuation. Yet, industrial and commercial waste follows an increasing trend which means that for the next three-month period the weight in tonnes of industrial and commercial waste generated will increase. Waste disposal amount will decrease first, and then it will rise again. Overall, when the total generated waste is taken into consideration it can be concluded that in January 2016 the quantity of total generated waste will increase to 15709.49, then fall to 14034.99 in February 2016, and once again increase to 16,586.76 tonnes.

Additionally, it is very important to check for autocorrelation between the error terms of in-sample forecast for improvement of the predictive model. (Coghlan, 2014) In time series autocorrelation is the serial correlation between the past and future observations. To check for autocorrelation Ljung-Box test is used. Besides, creating a correlogram in which autocorrelation at different lags can be observed directly will be a useful tool for assessing the significance. However, the error term should represent the properties of stationarity. The error term ε needs to be distributed normally with a constant mean and variance over time. Simply, Ljung-Box is testing for autocorrelation with a null and an alternative hypothesis that can be determined in the following way:

H_0: The error terms are not serially correlated. (No autocorrelation)

$$\rho = 0$$

H_1: The error terms exhibit serial correlation. (Evidence of autocorrelation)

$$\rho \neq 0$$

As a result of autocorrelation function, correlogram of each series indicate that forecast errors do not go beyond the threshold limits. The residuals are white noise due to the fact that correlations are within the significance bounds. Except for waste disposal, the other series have higher p-values. Higher p-values mean that residuals are white noise. However, in spite of the p-value for waste disposal obtained from Ljung – Box test is relatively low (0.0368) the residuals do not exhibit correlation. From the general assumptions forecast errors should be uncorrelated and are normally distributed.

Table 14: Testing for autocorrelation results

Ljung-Box Test Results		
Variable Names	**X-squared**	**p-values**
Disposal Waste	28.914	0.089
Garbage & Construction	11.840	0.922
Industrial & Cmmercial	18.274	0.569
Household	5.674	0.999
Total Generated Waste	10.517	0.958

As a necessity, the output of the tests indicating forecast errors of all the time series are normally distributed with mean zero and constant variance over time i.e. $\varepsilon \sim N(0, \sigma)$. Thus, there is also little evidence for forecast errors that are serially correlated at tested levels of lags. As a result, Holt-Winters exponential smoothing administers an acceptable forecasting method so that there is no need for model improvement. Yet, predictions are never 100% precise, subsequently; there is dependently an opportunity to make models better. What have been done so far is to find the most convenient forecasting method.

8.5. ARIMA Forecasting Modelling

Holt-Winters exponential smoothing has been applied when the series involve trend and seasonality aspects by getting the components of the series through decomposition. Although exponential smoothing is appropriate for prediction, it assumes no correlation between sequential observations of a time series, and it can be applied especially on nonstationary time series. Another model for making forecast might be used which is Autoregressive Integrated Moving Average (ARIMA) for a single variable. In fact ARIMA follows three main steps which are identifying a model, estimating parameter, and checking for validity of the model. (Kumar & Anand, 2014) Model identification figures out the constituent elements of AR and MA orders. ARIMA (p, d, and q) requires three main parameters for selecting the proper model which are p, d, and p, denoting order of auto-regression for the dependent variable, degree of differentiation obtaining stationary series, and order of moving average of the error terms, respectively.

ARMA models are always applied to stationary time series. When a time series has a constant mean and variance over time, and the covariance does not depend on the lag length, then it is called stationary time series. (Kumar & Anand, 2014) Thus, if a time series is non-stationary, before starting to use in forecasting it should be transformed into stationary by taking the difference. Until obtaining a stationary time series, differentiation will be maintained. Then, the number of difference will give the order of integration for

ARIMA which on the contrary to ARMA is applied to stationary time series. Moreover, since in this study strict stationarity (distribution needs to be the same for all the periods) is not required, there is not necessarily need for achieving the same distribution from one period to another.

In other words, to identify the most suitable model in ARIMA, a few stages are followed. First, it has to be ensured that a stationary time series is obtained. If it is not stationary, then it will be differenced until getting a stationary time series. Autocorrelation function (ACF) can be defined as the serial correlation, or linear dependence, between a variable and any lagged observation of the variable itself. On the other hand, partial autocorrelation (PACF) indicates the autocorrelation after linear dependence removal. After transforming the series into stationary, AR and MA parameters are achieved by observing ACF and PACF coefficients. Theoretically, when ACF is gradually disappearing and PACF moves downwards after the first leg, AR order will be one. In a similar way, when ACF disappears after lag one at a geometric rate, and PACF falls geometrically, that time a first order MA will be suitable. (Ahmad & Ahmad, 2013)

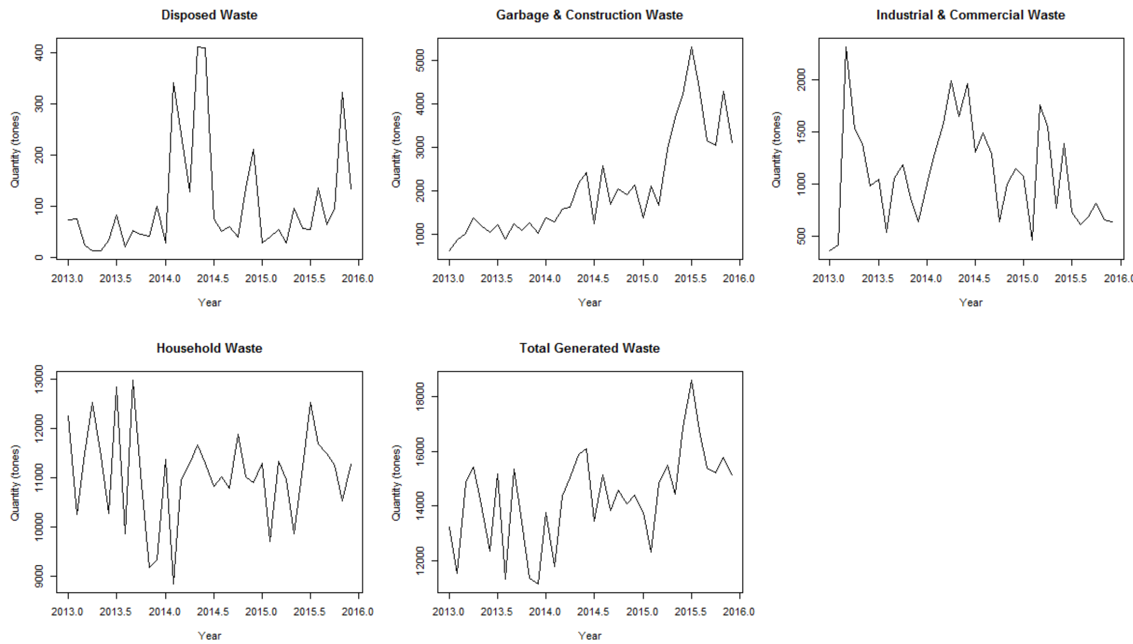


Figure 25: Solid Waste Production (in tonnes) in TRNC from 2013 to 2015

Figure 25 above represents line plots of univariate time series for kinds of solid waste produced in Northern Cyprus. The time series plots clearly figure out that samples are not stationary. However, as it is discussed ARMA cannot be constructed under nonstationary condition. For this reason time series are differenced until making them stationary.

Random walk equation express the presence of unit root where the difference between dependent variable (y_t) and lagged dependent variable (y_{t-1}) is taken. From the theoretical perspective, testing for stationarity or for the existence of any unit root, the hypothesis testing below is assumed for an equation including a constant (drift) and time trend:

$$y_t = \rho y_{t-1} + v_t$$

$$y_t - y_{t-1} = \rho y_{t-1} - y_{t-1} + v_t \quad \text{where} \quad \rho = 1$$

$$\Delta y_t = \alpha + \gamma y_{t-1} + v_t$$

where $\gamma = 1 - \rho$

H_0: $\rho = 1$ or $\gamma = 0$. The time series is non-stationary, or random walk. A unit root presents.

H_1: $\rho \neq 1$ or $\gamma \neq 0$. The time series is stationary, and no unit root exists.

Besides line plotting, Augmented Dickey Fuller test is applied to each univariate time series of solid waste in order to test series whether they are random walk or not. According to results of Augmented Dickey Fuller test the null hypothesis H_0's are not rejected, so that all the time series of solid waste including both time trend and drift (constant) components are nonstationary, and have unit roots. Moreover, both deterministic and stochastic trends are included. Because of being nonstationary, their means and variances change over time. Therefore, since all the univariate indicator series have unit roots, it is crucial to remove unit roots from series.

The results of applied unit root test for all the univariate time series of solid waste seems to be stationary after taking the first difference. *Dispo, garco, indco, hht* and *total* series appear to be constant in levels and variances over time. Due to the fact that stationarity has been achieved at the first difference the parameter d in ARIMA will be 1. To illustrate, an ARIMA (p, 1, q) model can be used all the univariate time series of solid waste data set. These results make able to proceed next steps of finding appropriate orders for AR, and MA.

By differencing the original series trend component has been removed and reminder component left behind. Thereby, autocorrelation function should be tested for the irregular component for sequential values. ARIMA model is fitted when the sequential values of a time series are dependent to each other. (Kumar & Anand, 2014) Correlogram and partial correlogram will be constructed in order to visualize correlation for selecting the most appropriate ARIMA (p, d, and q) model for prediction.

Correlogram of disposed waste infers that auto-correlation is gradually diminish after lag 4, that is; partial autocorrelation is equal to zero after lag 3 (see Appendix). The coefficient at lag 3 is equal to 0.366, and the rest lags are within significant limits. Similarly, estimated partial autocorrelation of disposed waste is zero at lag 2 (-0.474), while all the other coefficients are within the significance bounds. Candidate ARIMA models for waste disposal can be listed as: ARIMA (2, 1, 0), ARIMA (2, 1, 1), and ARIMA (2, 1, 2). In order to choose the best fitted model for prediction among the three candidate models, Bayesian Information Criterion (BIC) and Akaike Information Criterion (AIC) are used as criteria for measuring the goodness-of-fit of the models. The one with the lowest BIC and AIC should be selected as the best fitted model because lower values are assumed to be more likely to be the true model. (Kumar & Anand, 2014) AIC and BIC are used as measures that assess the most appropriate model by minimizing the information loss. AIC and BIC criteria estimate the quality and efficiency of the candidate models as well as the probability of the model of being true are estimated. Additional to BIC, AIC includes more parameter numbers since it introduces a penalty term. The best suitable model is ARIMA (2, 1, and 0) to make forecasting.

Furthermore, The estimated ACF of garbage and construction, industrial and commercial, and household waste tails off to zero at lag 1 by -0.322, -0.341 and -0.540, respectively. While the estimated PACF of garbage and construction waste diminishes at lag 10 (-0.371), it tails off to zero at lag 1 (-0.341) for industrial and commercial, and at lag 2 (-0.420) for household waste. The other lags remind within the significance range. Nevertheless, the estimated ACF of household waste at lags 6 and 7 exceed the significance bound which is assumed to be caused by an error or by a chance.

Table 15: AIC and BIC Values of Fitted ARIMA Models

AIC and BIC Values of Fitted ARIMA Models									
Variable Name	**ARIMA Model**	**AR1**	**AR2**	**MA1**	**MA2**	**Estimated σ^2**	**Log Likelihood**	**AIC**	**BIC**
Disposed Waste	**2,1,0**	-0.394	-0.502			9702.000	-210.640	427.280	431.950
	2,1,1	-0.720	-0.594	0.459		9129.000	-209.690	427.370	433.596
	2,1,2	-0.702	-0.572	0.433	-0.034	9129.000	-209.680	429.370	437.145
Garbage & Construction	**1,1,0**	-0.323				399697.000	-275.440	554.880	557.993
	1,1,1	-0.543		0.246		398290.000	-275.390	556.770	561.440
	1,1,2	-0.729		0.419	-0.097	395991.000	-275.290	558.580	564.803
Industrial & Commercial	**1,1,0**	-0.331				264198.000	-268.200	540.398	543.509
	1,1,1	0.382	-1.000			208832.000	-265.430	536.864	541.530
Household	**2,1,0**	-0.795				1123040.000	-293.850	593.708	598.374
	2,1,1	-0.078	0.054	-1.000		919314.000	-291.780	591.569	597.790
	2,1,2	-0.433	-0.028	-0.651	-0.349	919216.000	-291.830	593.666	601.443
Total Generated Waste	**1,1,0**	-0.449				2785604.000	-309.480	622.950	626.061
	1,1,1	0.200		-0.830		2447072.000	-307.520	621.036	625.703
	1,1,2	0.598		-1.232	0.312	2421044.000	-307.320	622.641	628.863

It is clearly seen from Table 15 above that the most convenient models are marked with a dark colors for each time series. The selected models that fit to each time series data separately are used in order to predict future values of time series. Following Table 16 shows the estimated values for the next three month with low and high prediction intervals of 80% and 95%. The three-month plot of time series are also demonstrated by fitting ARIMA (p, d, q) models for each series of solid waste where two shaded areas of prediction represents 80% and 95% prediction intervals.

Table 16: 3-Month Point Forecasting by ARIMA

3-Month ARIMA Forecasting for Solid Waste Time Series						
Time Series	**Prediction**	**Forecast**	**Low 80**	**High 80**	**Low 95**	**High 95**
Disposed Waste	Jan 2016	94.148	-32.083	220.378	-98.905	287.200
	Feb 2016	204.494	56.885	352.103	-21.255	430.243
	Mar 2016	181.055	29.858	332.252	-50.181	412.291
Garbage and Construction	Jan 2016	3492.538	2682.321	4302.756	2253.418	4731.659
	Feb 2016	3370.788	2392.314	4349.262	1874.342	4867.234
	Mar 2016	3410.101	2244.686	4575.517	1627.752	5192.451
Industrial and Commercial	Jan 2016	914.606	321.154	1508.057	6.999	1822.212
	Feb 2016	1019.921	379.231	1660.610	40.071	1999.771
	Mar 2016	1060.103	410.756	1709.450	67.012	2053.194
Household	Jan 2016	11020.190	9774.514	12265.860	9115.094	12925.280
	Feb 2016	11079.480	9832.648	12326.320	9172.614	12986.350
	Mar 2016	11061.490	9810.584	12312.400	9148.393	12974.590
Total	Jan 2016	15413.500	13408.750	17418.240	12347.500	18479.490
	Feb 2016	15464.790	13327.430	17602.150	12195.980	18733.600
	Mar 2016	15475.040	13282.560	17667.530	12121.930	18828.160

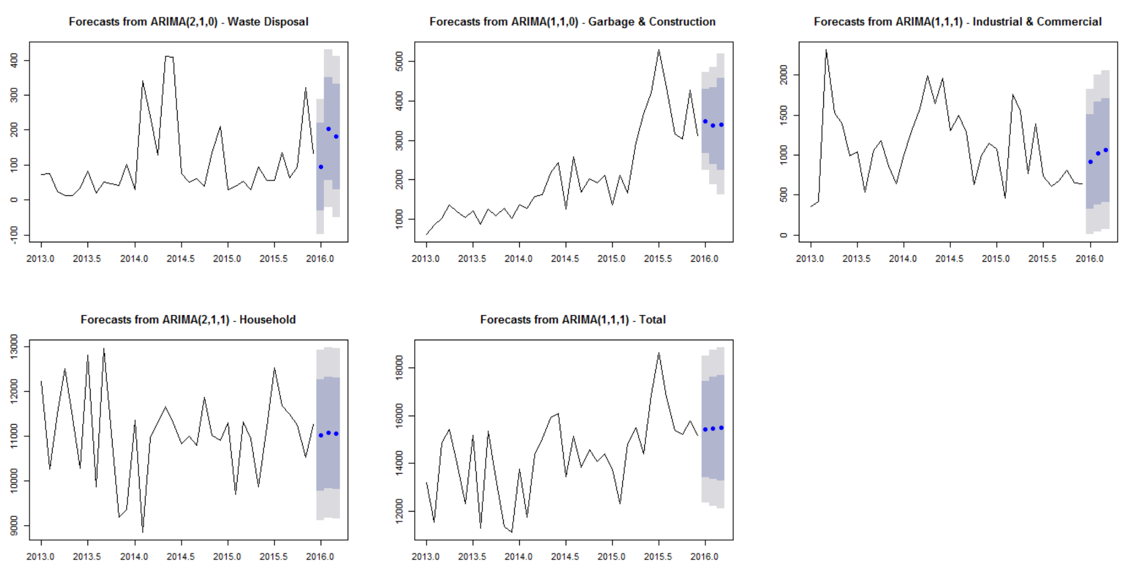


Figure 26: Forecasting Plots of ARIMA (p, d, q)

After obtaining forecasts by ARIMA the next step is to investigate the forecast errors' distributions. The residuals have to be normally distributed and with mean zero, or close to zero, and constant variance. (Kumar & Anand, 2014) As a result of correlogram of residuals and p-values of Box-Ljung test, there is evidence for zero autocorrelation between the forecast errors in at different lags. The distributions of series state that all the solid waste time series are almost normally distributed, and distributions' mean appears to be zero.

Briefly, due to the fact that Holt-Winters exponential smoothing method does not take successive values into consideration as the nonstationary exists, ARIMA model is constructed for each time series of solid waste data set of Northern Cyprus. The time series models are statistically tested separately via the fitted ARIMA, and depending on the general assumptions the obtained results show that sequential forecast residuals in each time series are not serially correlated. As well, the residuals look to be normally distributed with mean equal to zero, and constant variance i.e. $e \sim N(0, \sigma^2)$. Therefore, the selected ARIMAs provide fully sufficient forecasting models for the monthly produced solid waste in tonnes.

In general, the results of solid waste forecasting analysis for Northern Cyprus indicate that in the leading months (January, February, and March 2016) the total generated waste amount will follow an increasing trend. By March 2016 total produced waste is expected to reach approximately 15500 tonnes. Since there will be an increment in the aggregate generated waste, a review for the current capacity of the storage area might be useful.

Despite, similar to the other prediction methods, ARIMA has also shortcomings on the certainty of forecasts, but it is the most widely applied forecasting technique to time series for making prediction about the sequential future values. (Kumar & Anand, 2014)

In conclusion, further analysis needs to be done by using longer time series with variety of variables in order to obtain better results.

8.6. Evaluating Forecast Accuracy

A good prediction is the one with accurate results. In this study, in order to measure the forecast accuracy the time period of the data set is shortened. In other words, solid waste data set is composed of five variables with a length of 36-month, and it is shortened to 33-month for each variable to measure the accuracy of predicted leading values. The last 3-month actual observations of the months October, November and December of the original data set are excluded, and a new analysis is conducted to predict the last three months observations. It is aimed to compare the obtained forecasts with the original observations, as well as to measure the percentage accuracy of the predicted values.

Mean absolute percentage method (MAPE) is used for measuring forecast performance and the closeness between the predicted and observed values. MAPE is chosen as the measurement method because it is simple, scale-independent and most commonly used forecast accuracy measurement. MAPE gives percentage results, therefore it can be applied to any kind of data. The error size is measured in percentage. The formula of MAPE is as follows:

$$MAPE = \left(\frac{1}{n}\sum_{i=1}^{n}\frac{|Actual_i - Forecast_i|}{|Actual_i|}\right) * 100$$

The absolute percentage results for both Holt-Winters exponential smoothing and ARIMA are illustrated in Table 17. The calculated percentage errors are displayed in grey color. Even though it can be inferred from the MAPE values that Holt-Winters provide good results, it is obvious that ARIMA provides better results in prediction compared to Holt-Winters exponential smoothing method. The measured error sizes of solid waste types for ARIMA method are lower than Holt-Winters' values except for the variable of disposed waste. The MAPE of disposed waste is higher than Holt-Winters MAPE. This may be caused by the imputation. Due to the fact that the short-term series of disposed waste has missing values, simple imputation technique is applied for filling the missingness. Hence, the MAPE of exponential smoothing for waste disposal is higher.

The variables can also be grouped according to the forecast accuracy results from lower to higher. Total generated waste and household waste in very low group. In other words, that the average deviation for ARIMA modelling of household and total generated waste are very low, which means that the predicted values of the leading 3-month period (October, November, and December) are close to the actual observed values by 2.90%, and 2.34%, respectively. Due to the fact that household waste shares the greater portion of aggregate produced waste, more or less the rates are close to each other. The MAPE of garbage and construction is under low group as it is 15.17%. The accuracy is comparatively good. However, MAPE of disposed waste and industrial and commercial waste are relatively high. These two variables have to be studied in order to explain by relating the circumstances of available, multivariate factors because here forecasting is brought out by the aspects of the series themselves.

Overall, it can be inferred that in total generated waste amount the predicted leading values are detected very well with an accuracy of approximately 98%. However, disposed waste and industrial and commercial waste need to be investigated by adding other explanatory variables. The underlying mechanism of disposal waste and industrial and commercial waste have to be studied widely.

Table 17: Forecast Accuracy by MAPE

Forecast Accuracy by MAPE						
Disposed Waste						
	Holt-Winter's Exponential Smoothing			**ARIMA (2,1,0)**		
Month	**Actual**	**Forecast**	**Absolute Percentage Error(%)**	**Actual**	**Forecast**	**Absolute Percentage Error(%)**
October	95.14	64.25	32.47	95.14	51.69	45.67
December	322.60	66.59	79.36	322.60	88.85	72.46
November	134.04	98.25	26.70	134.04	81.71	39.04
	MAPE (%) = 46.18			**MAPE (%) = 52.39**		
Garbage and Construction						
	Holt-Winter's Exponential Smoothing			**ARIMA (1,1,0)**		
Month	**Actual**	**Forecast**	**Absolute Percentage Error(%)**	**Actual**	**Forecast**	**Absolute Percentage Error(%)**
October	3036.82	3792.22	24.87	3036.82	3490.45	14.94
December	4283.18	3994.41	6.74	4283.18	3397.92	20.67
November	3115.49	3719.32	19.38	3115.49	3423.86	9.90
	MAPE (%) = 17.00			**MAPE (%) = 15.17**		
Industrial and Commercial						
	Holt-Winter's Exponential Smoothing			**ARIMA (1,1,1)**		
Month	**Actual**	**Forecast**	**Absolute Percentage Error(%)**	**Actual**	**Forecast**	**Absolute Percentage Error(%)**
October	813.30	200.72	75.32	813.30	976.35	20.05
December	656.48	285.50	56.51	656.48	1074.04	63.61
November	638.58	187.70	70.61	638.58	1106.74	73.31
	MAPE (%) = 67.48			**MAPE (%) = 52.32**		
Household Waste						
	Holt-Winter's Exponential Smoothing			**ARIMA (2,1,1)**		
Month	**Actual**	**Forecast**	**Absolute Percentage Error(%)**	**Actual**	**Forecast**	**Absolute Percentage Error(%)**
October	11250.02	11268.23	0.16	11250.02	11078.18	1.53
December	10526.36	9960.07	5.38	10526.36	11096.15	5.41
November	11268.82	9929.97	11.88	11268.82	11070.43	1.76
	MAPE (%) = 5.81			**MAPE (%) = 2.90**		
Total Generated Waste						
	Holt-Winter's Exponential Smoothing			**ARIMA (1,1,1)**		
Month	**Actual**	**Forecast**	**Absolute Percentage Error(%)**	**Actual**	**Forecast**	**Absolute Percentage Error(%)**
October	15195.28	15824.05	4.14	15195.28	15624.04	2.82
December	15788.62	14528.34	7.98	15788.62	15665.45	0.78
November	15156.93	14476.07	4.49	15156.93	15673.01	3.40
	MAPE (%) = 5.54			**MAPE (%) = 2.34**		

CHAPTER IX

CONCLUSION AND RECOMMENDATIONS

This thesis focuses on analyzing the important environmental problems of air pollution, solid waste management and disposal in Northern Cyprus by applying a descriptive statistical analysis making forecasting. Due to the lack of detailed research on this topic, a contribution is desired to be done to the literature by producing all-in-one research in terms of air pollution and solid waste assessment.

At first, although it is aimed to get how the socioeconomic and demographic indicators affect the environmental aspects, non-existing or unreliable data sets were obstacles of performing causal modelling. Therefore, depending on the obtained data set on solid waste and air pollution time series are analyzed. The variables are univariate time series which means that one sample for a specific time period is taken into consideration. The time period comprise 2012-2014 for air emission measurements, and covers 2013-2015 for solid waste data set.

From a statistical point of view, fundamental time series methods for forecasting univariate time series are applied. The key point while performing analysis is to have stationary series, unit root and augmented dickey fuller testes are applied in order to get whether the series are stationary or not. Transforming nonstationary series into stationary would give helpful results. Exponential smoothing techniques are applied to stationary series regarding the series characteristics. In addition, ARIMA forecast modelling for nonstationary series is constructed for each variable of solid waste and the best ARIMA model is chosen on the basis of AIC and BIC. After the selection of the best parameters match, ARIMA prediction is performed. At the end, the forecast accuracy of the predicted values, especially for solid waste data set is measured by excluding the last three months' values and repeating the analysis to make a comparison between the predicted and actual values. The forecast accuracy of the air measurement data set is measured since the time series of all the variables include missing values. Imputation may not result in accurate forecast measures.

Univariate time series analysis can be extended to multivariate time series analysis with a comprehensive data set. Moreover, the absence of data in Northern Cyprus in every field is a serious matter to be solved in the future. If a better system wants to be established, then statistical units should be organized to collect data. Likewise, data on socioeconomic demographic and health variables needs to be collected properly to achieve more successful conclusions about the current situation which values affect the solid waste generation and management, and air pollution mostly, and at what degree they are effective in order to provide better improvements in both management system and regulations applied in the community. Providing a sustainable environment can be achievable in the context of institutional legal policy developments on environmental issues.

As a result of prediction, it is observed that the total generated solid waste amount will increase in the future. This is not a satisfying result because the current capacity of the landfill is designed for 30 years. However, it can be estimated that it will become full earlier than 30 years. According to the forecasting outcomes, it seems that the capacity of the landfill should be expanded, or new disposal sites should be investigated.

In order to prevent or even decrease the adverse development of the environment, public awareness can be stimulated. Education on environmental issues is very significant. Classes or educational seminars needs to be arranged in a regular frame at both public and private sectors. Beginning from the source of waste to removal process comprehensive studies should be presented. Composting of household waste methods can be displayed.

Thereby, one can achieve to use wastes as fertilizer in their own gardens. Instead of disposing solid waste with uncontrolled and primitive methods, municipalities should increase their expense budgets on either installing a transfer station to transport the generated waste to safe landfill in Güngör, or installing innovative recycle and reuse technologies in the cities. A further study needs to be done on characterization study. It should be applied to the entire country Northern Cyprus in order to obtain which city generate what kind of waste. Accordingly, it can be specifies at which locations would be more beneficial for installing improved recycling facilities or a market to trade the generated waste to abroad.

Although air pollution is inevitable, decrement can be possible. As mentioned in detailed, the main reasons of air pollution in Northern Cyprus are thermal power plants, agrochemicals, and road transportation. Since the public transportation services is not a developed sector, improving the existed condition can be the first step through developing transportation sector. As in the past, installing railroads might me an attempt, as well. Therefore, the number of cars in traffic will decrease, and in turns greenhouse gases emissions will decrease, too. Stable roads of the villages can be renovated and developed.

Investing in green infrastructure might be a sustainable and cost-efficient way in both decreasing environmental damage and boosting economic growth. The environment can be protected while the population is benefiting from increasing number of public and private services. Planned network and clean mobility might also helpful in order to construct sustainable modes of transportation. Redesigned cars and car parts can mitigate concentrations of greenhouse gases. Building bicycle and walk ways is another environmental friendly and cost-efficient attempt towards sustainable environment. The citizens of Northern Cyprus might be encouraged for cycling and walking activities which will not only protect the natural environment, but also improve human health.

This research can be extended by gathering data and creating detailed data sets on economic, social, and demographic aspects. Collecting data on socio-economic indicators would be very helpful in constructing causal models on environmental problems separately. Therefore, the regional degradation extend of the environment due to economic activities can be estimated trough causal model regressions.

Furthermore, the analysis should be applied to the whole island of Cyprus in order to get a big picture regarding the entire island, due to the fact that more or less similar environmental problems are faced in both Northern and Southern Cyprus. In the future, there is a possibility of establishment of a united federal state in Cyprus with the help of a constituent state of EU. If an advanced descriptive and explanatory statistical analysis is conducted with causal models, then legal policies and legislations concerning the environmental issues can be easily investigated and improved in accordance with EU standards.

APPENDIX

I. Plotting of Air Emission Measurements' Time Series and STL Decomposition of Original Time Series

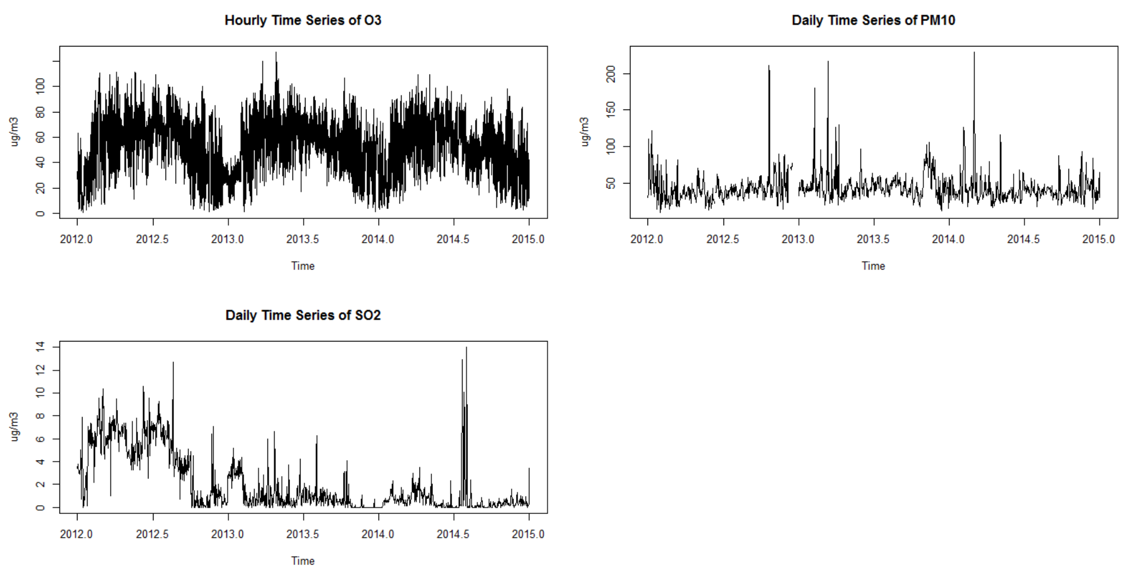


Figure Appendix 1: Famagusta Air Emissions Time Series Plotting

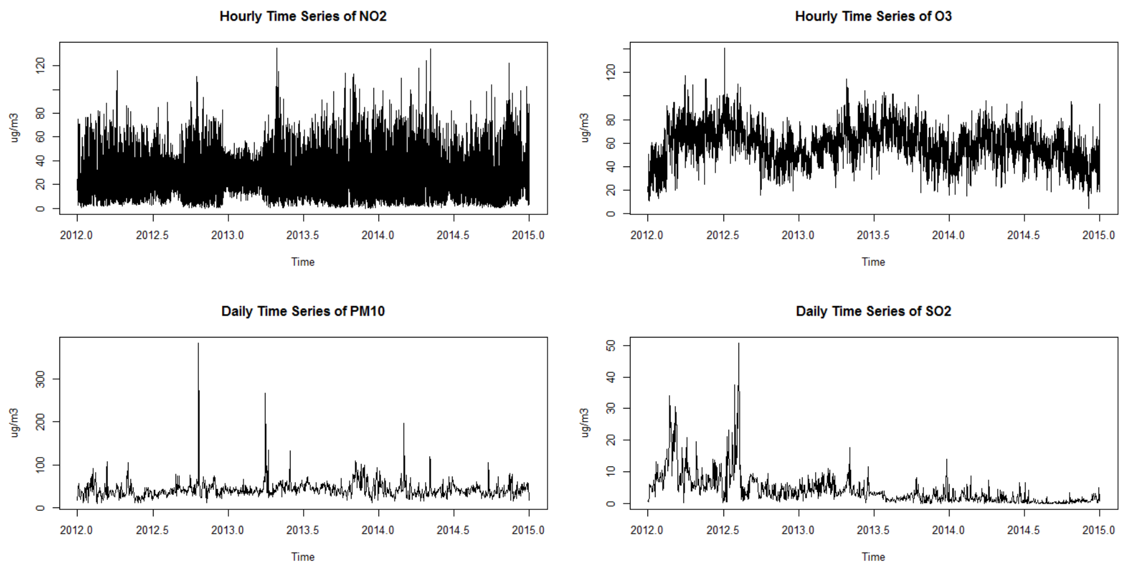


Figure Appendix 2: Kyrenia Air Emissions Time Series Plotting

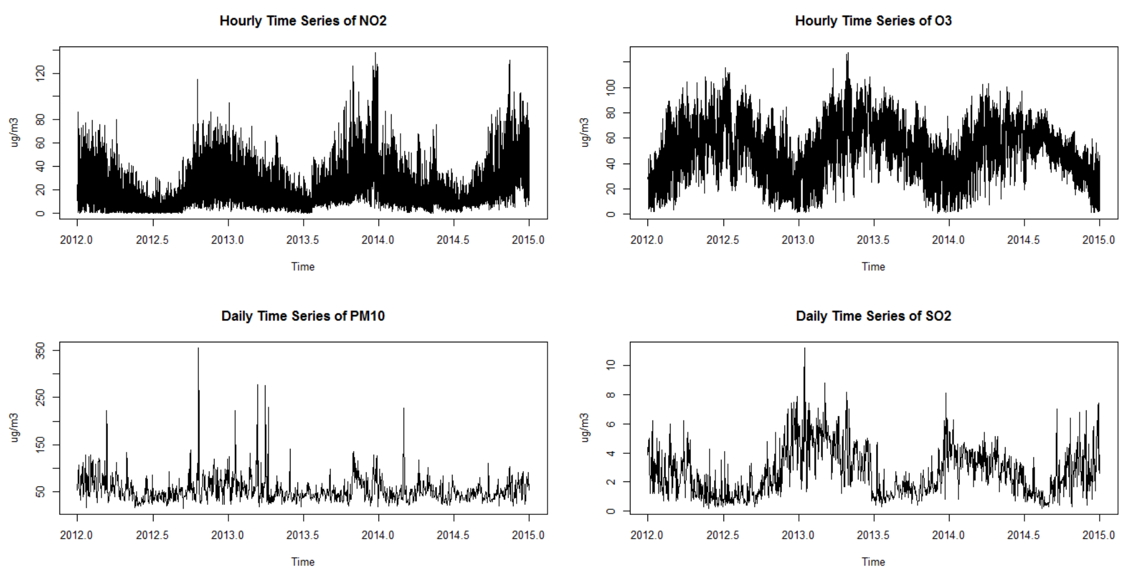


Figure Appendix 3: Nicosia Air Emissions Plotting

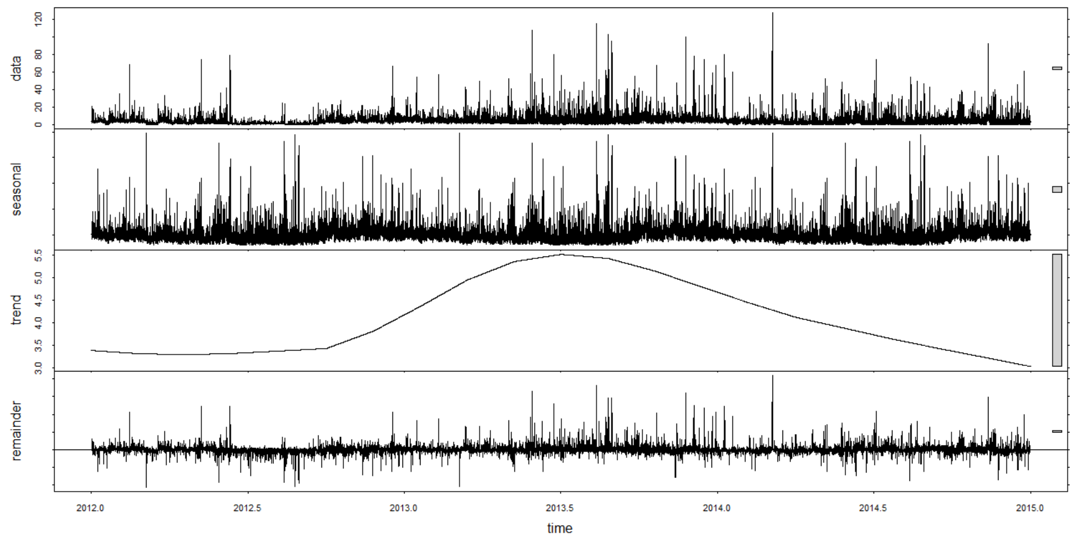


Figure Appendix 4: STL Plot of Teknecik for NO_2 (Hourly)

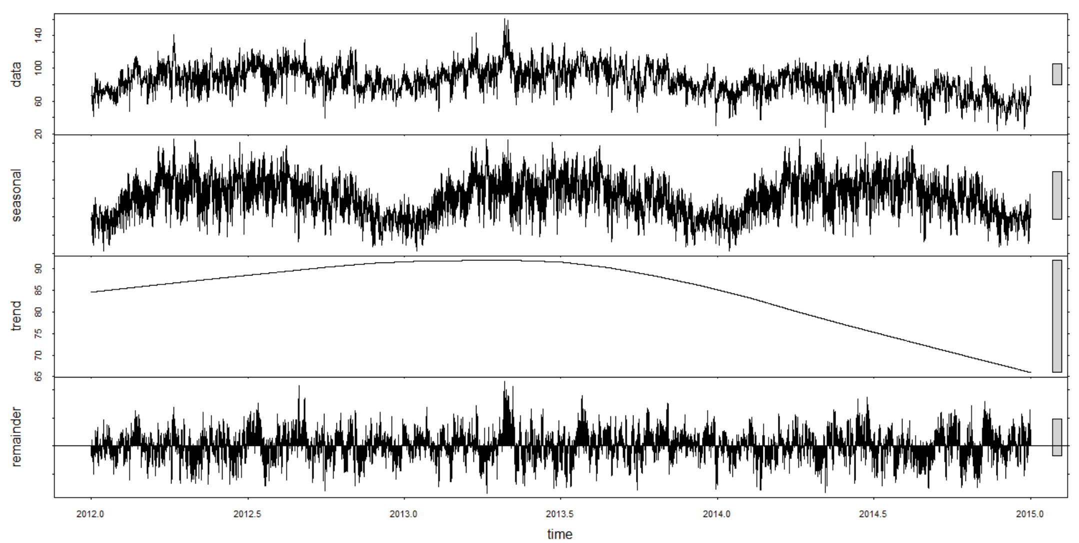


Figure Appendix 5: STL Plot of Teknecik for O_3 (Hourly)

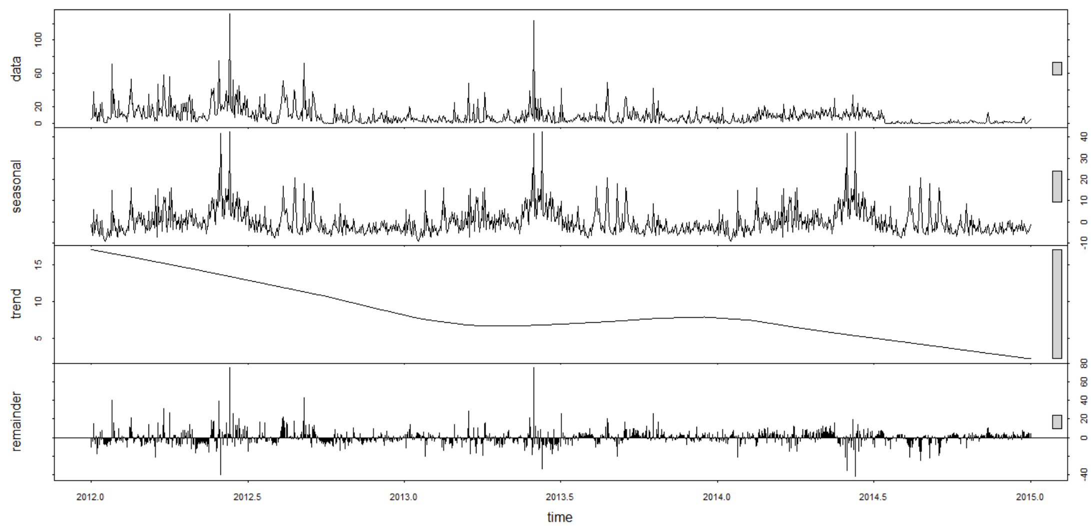


Figure Appendix 6: STL Plot of Teknecik for SO_2 (Daily)

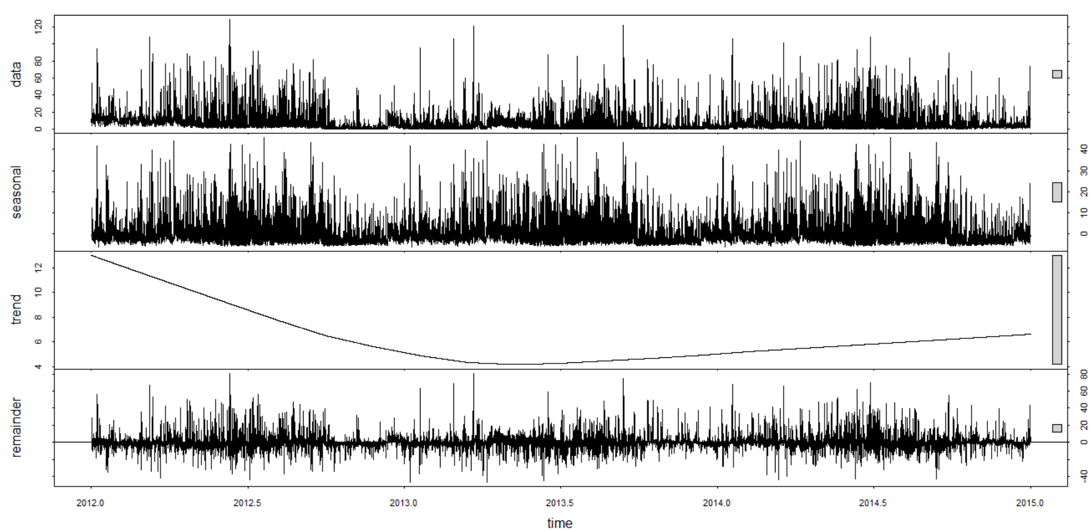


Figure Appendix 7: STL Plot of Kalecik for NO_2 (Hourly)

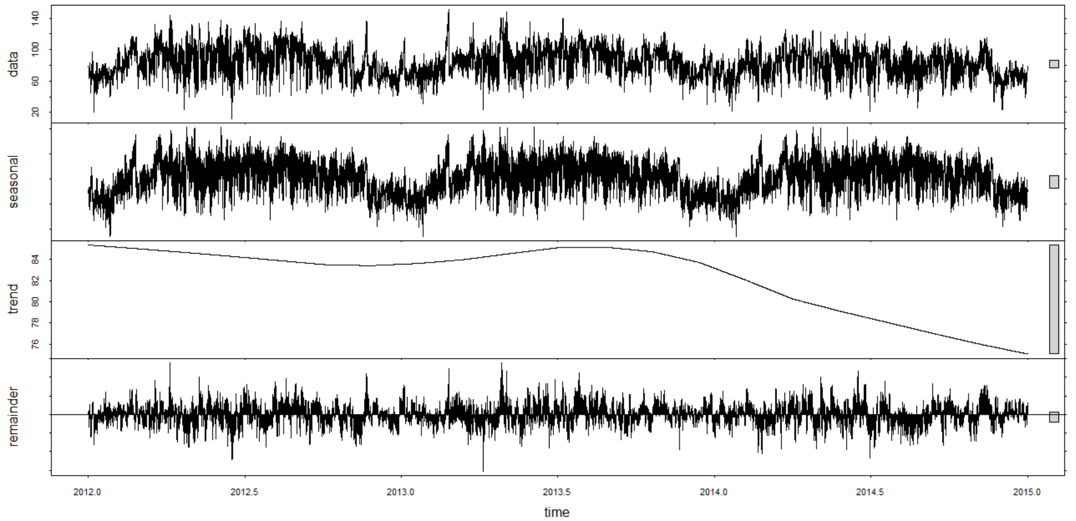


Figure Appendix 8: STL Plot of Kalecik for O_3 (Hourly)

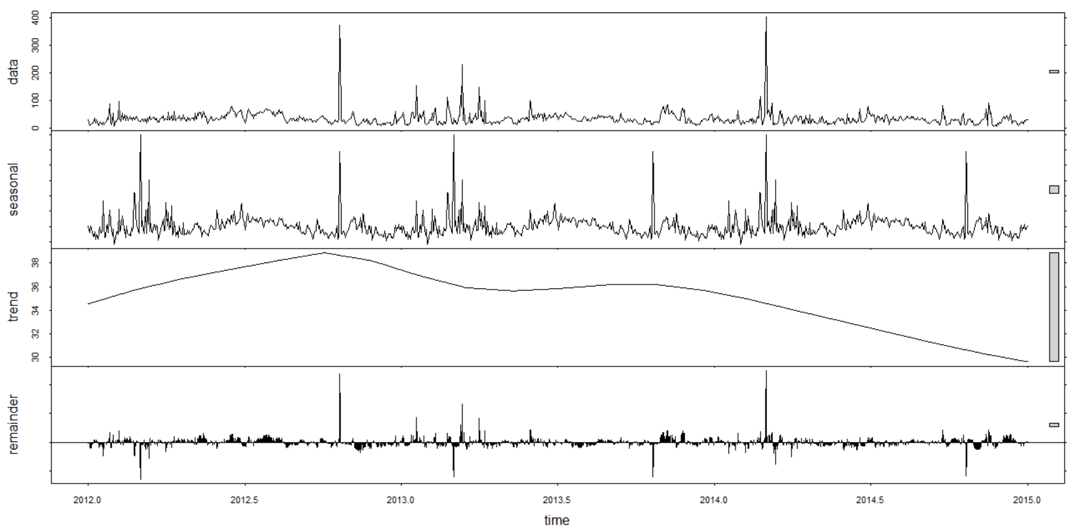


Figure Appendix 9: STL Plot of Kalecik for PM10 (Daily)

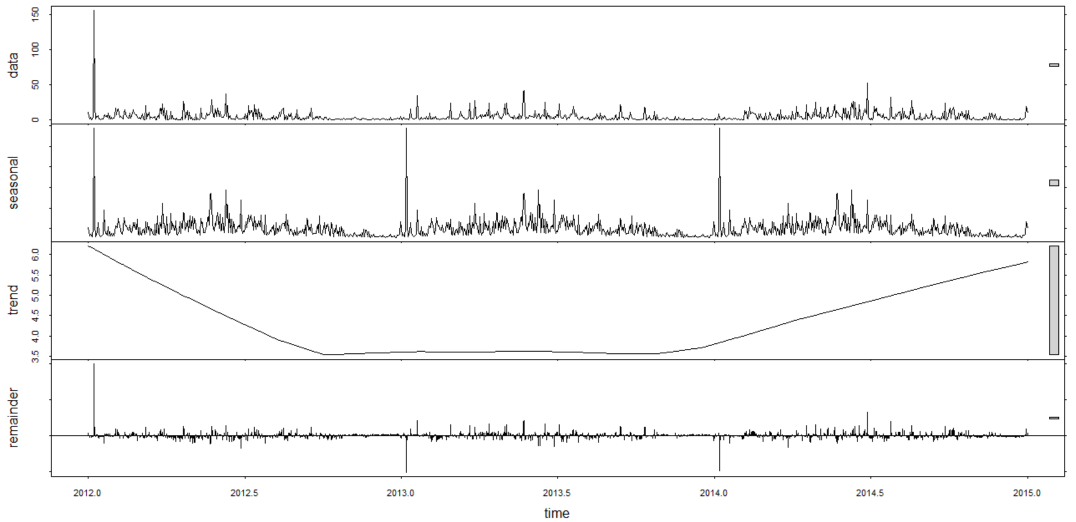


Figure Appendix 10: STL Plot of Kalecik for SO_2 (Daily)

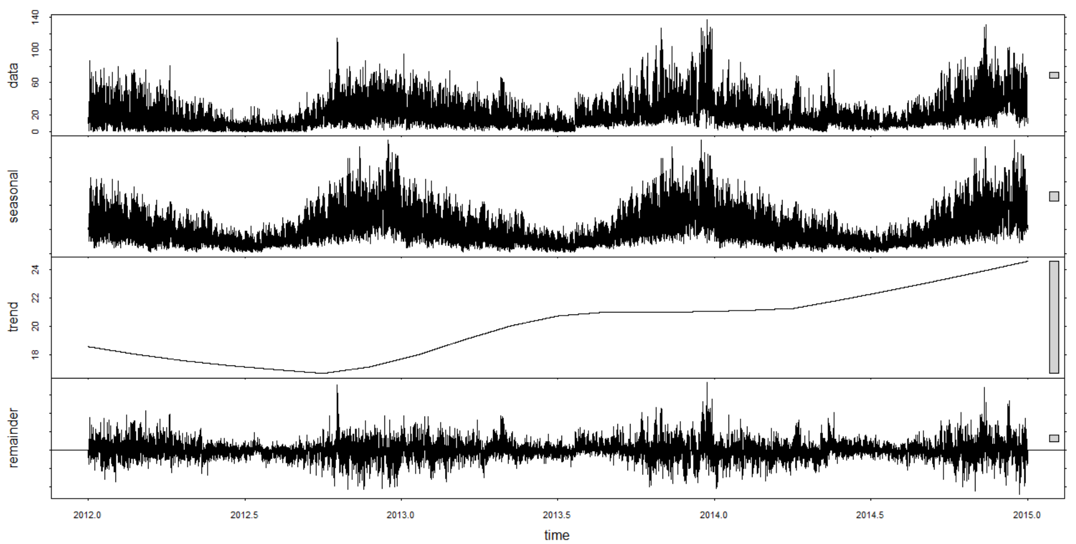


Figure Appendix 11: STL Decomposition for Nicosia NO_2 (Hourly)

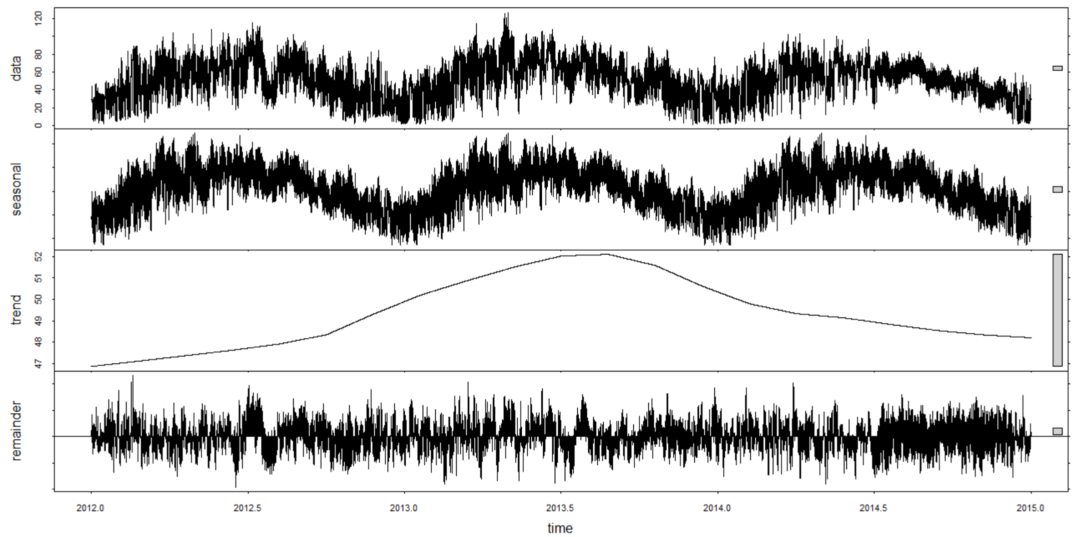


Figure Appendix 12: STL Decomposition of Nicosia O_3 (Hourly)

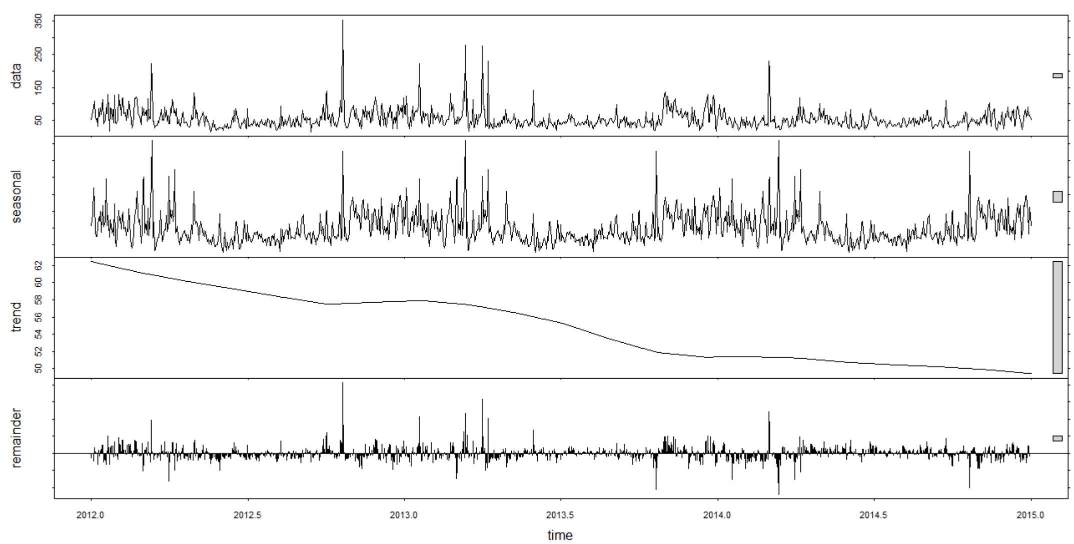


Figure Appendix 13: STL Decomposition of Nicosia PM10 (Daily)

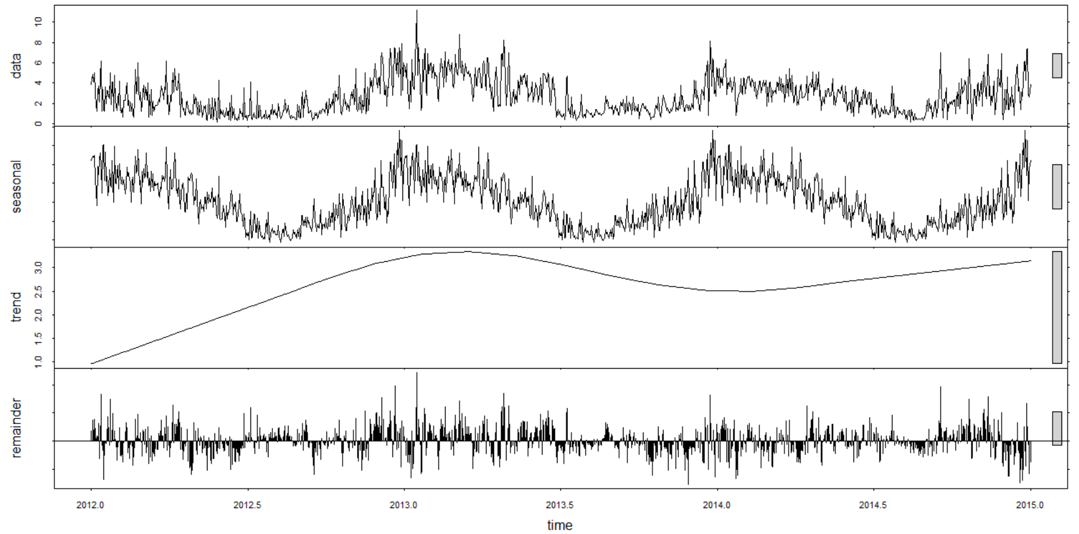


Figure Appendix 14: STL Decomposition of Nicosia SO_2 (Daily)

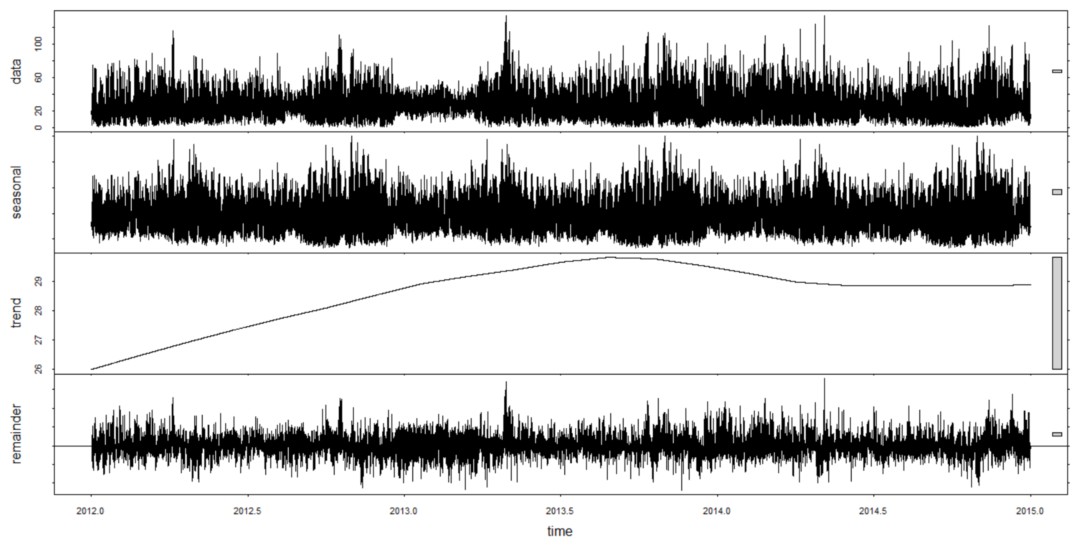


Figure Appendix 15: STL Decomposition of Kyrenia NO_2 (Hourly)

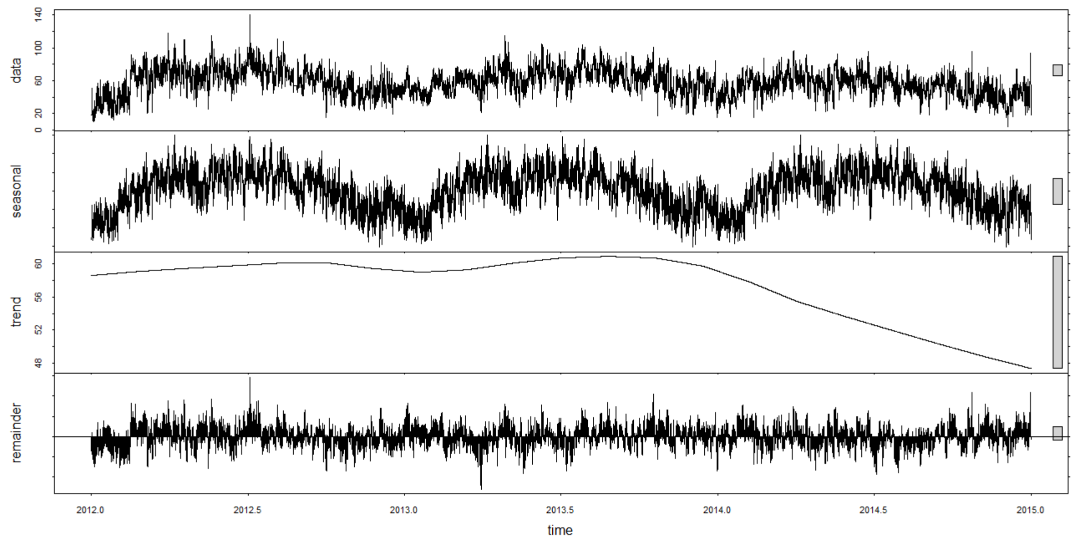


Figure Appendix 16: STL Decomposition of Kyrenia O_3 (Hourly)

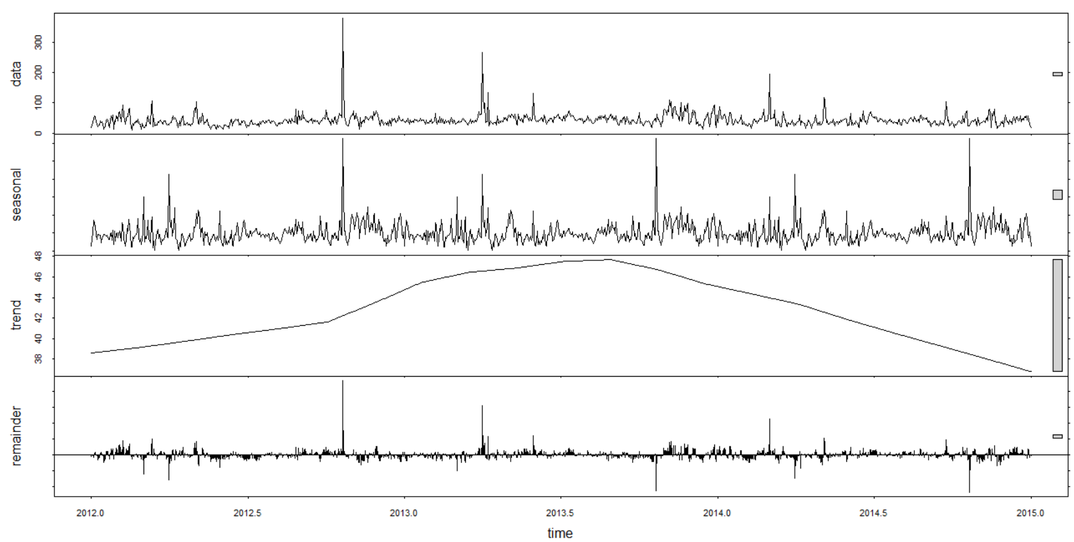


Figure Appendix 17: STL Decomposition of Kyrenia PM10 (Daily)

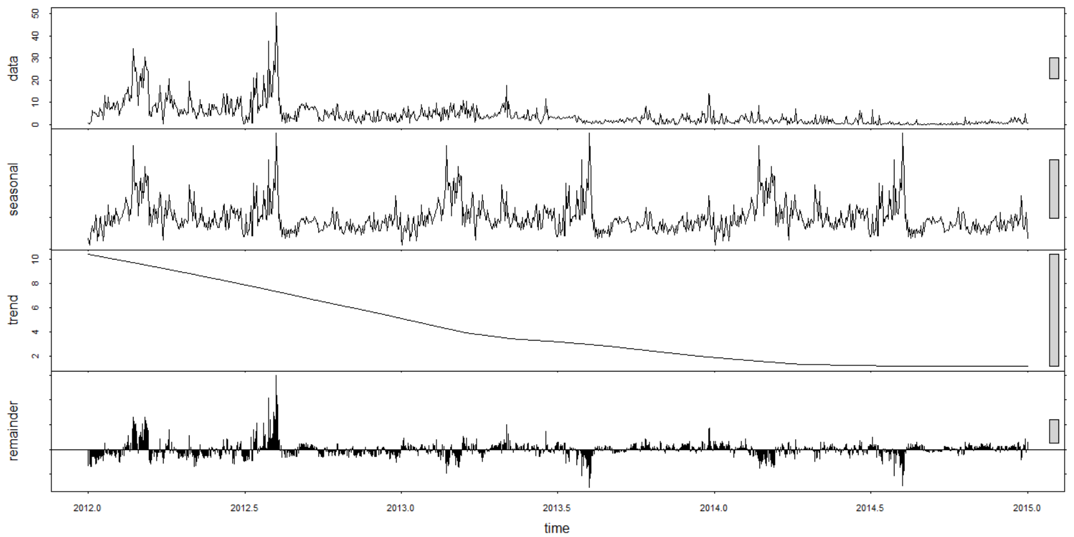


Figure Appendix 18: STL Decomposition of Kyrenia SO_2 (Daily)

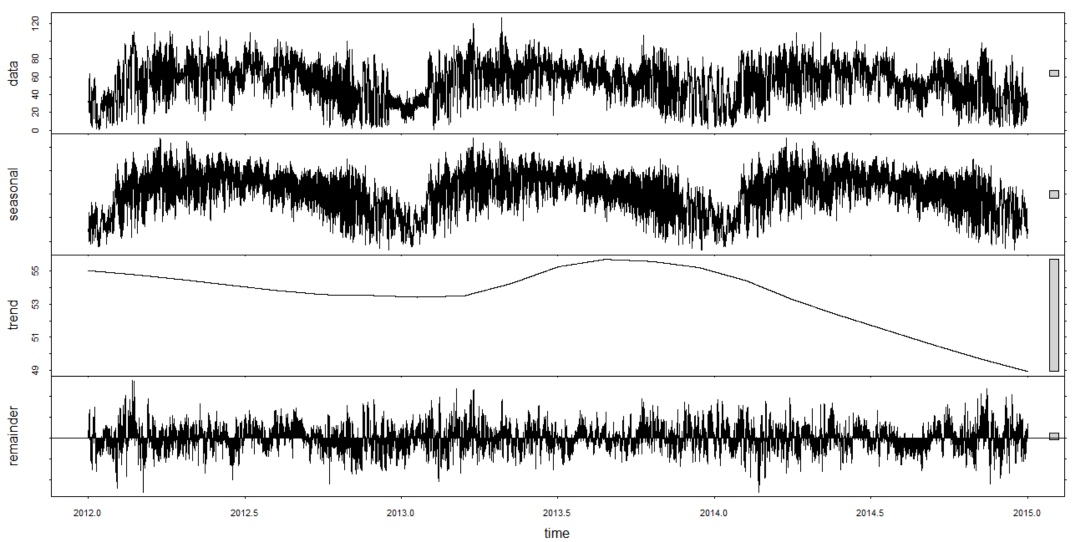


Figure Appendix 19: STL Decomposition of Famagusta O_3 (Hourly)

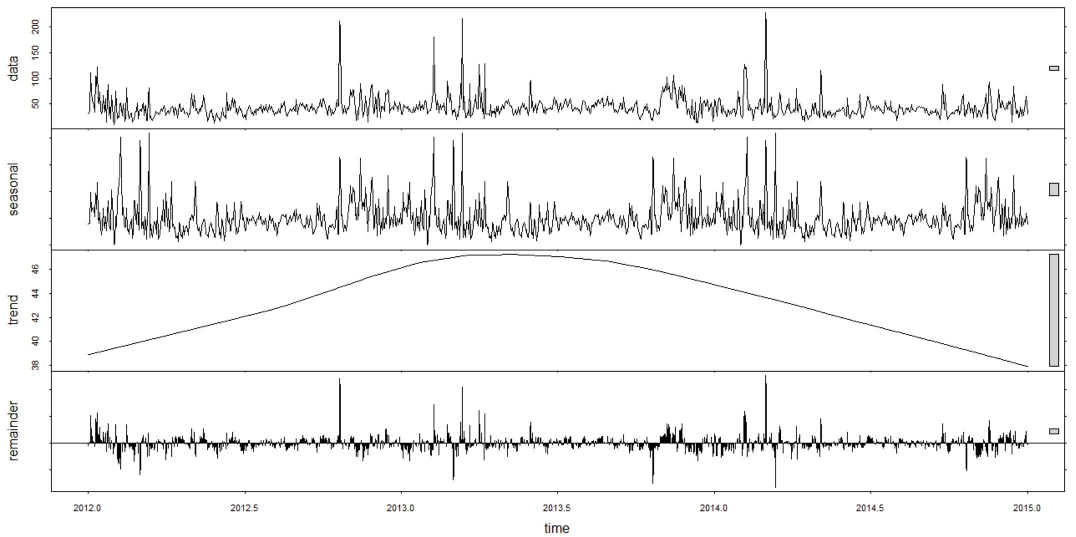


Figure Appendix 20: STL Decomposition of Famagusta PM10 (Daily)

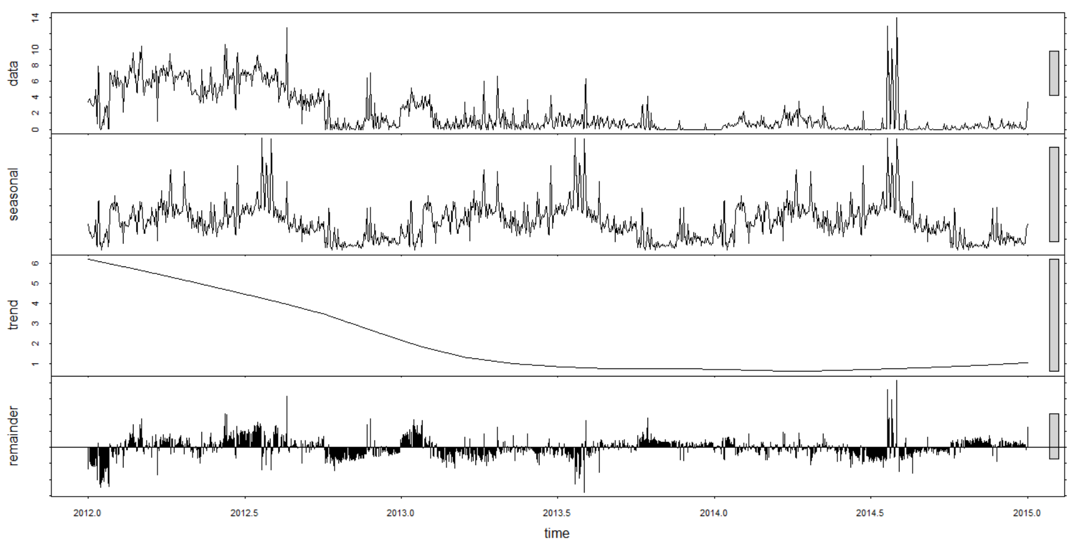


Figure Appendix 21: STL Decomposition of Famagusta SO_2 (Daily)

II. STL Decomposition of Original Time Series

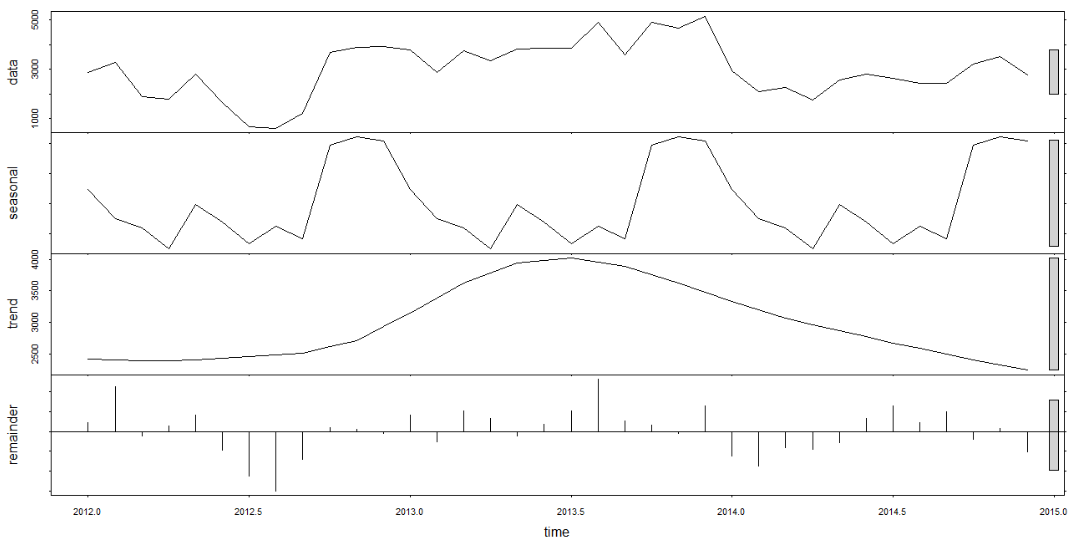


Figure Appendix 22: STL Decomposition of Teknecik NO_2 (Monthly)

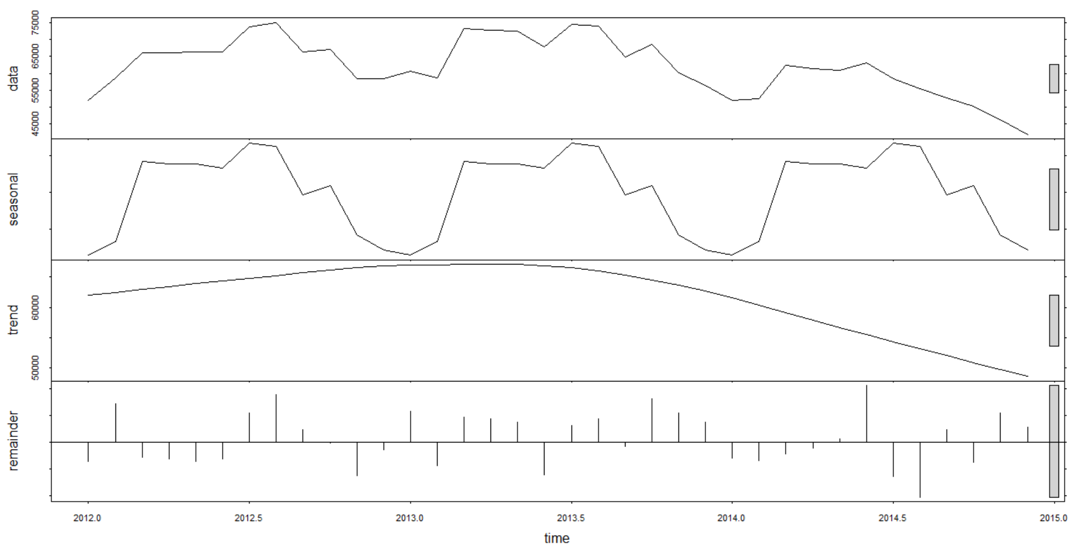


Figure Appendix 23: STL Decomposition of Teknecik O_3 (Monthly)

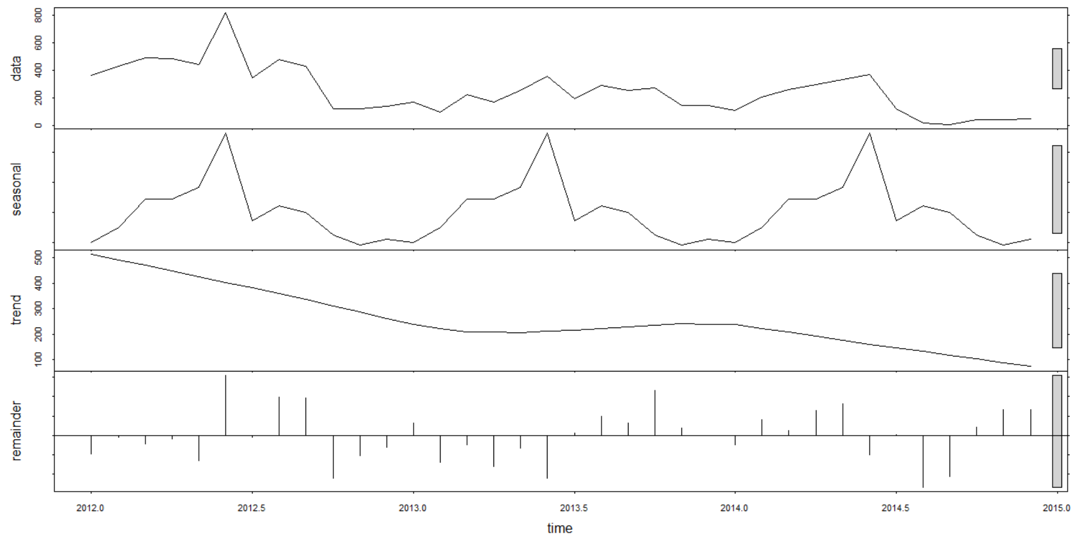


Figure Appendix 24: STL Decomposition of Teknecik SO_2 (Monthly)

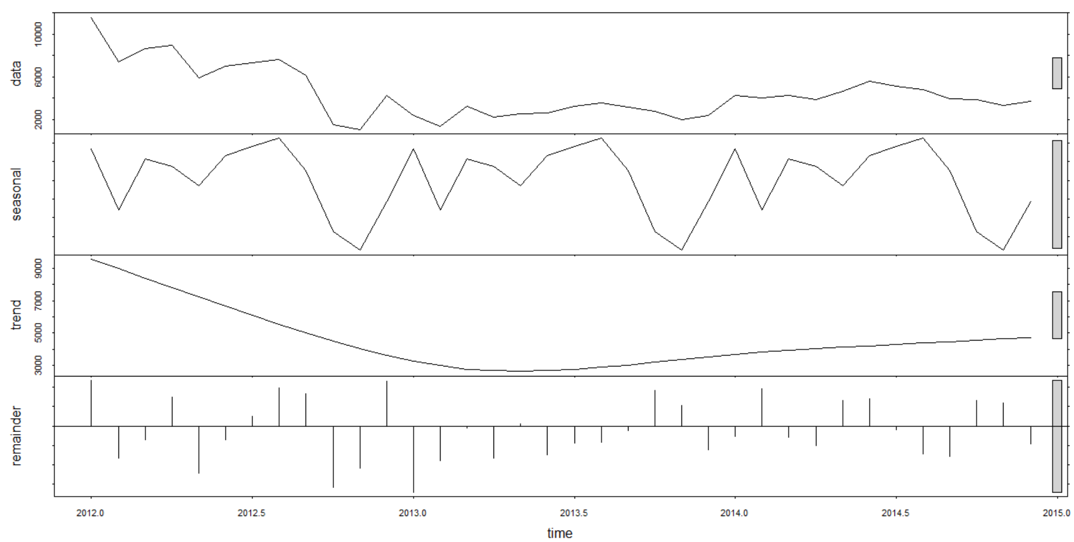


Figure Appendix 25: STL Decomposition of Kalecik NO_2 (Monthly)

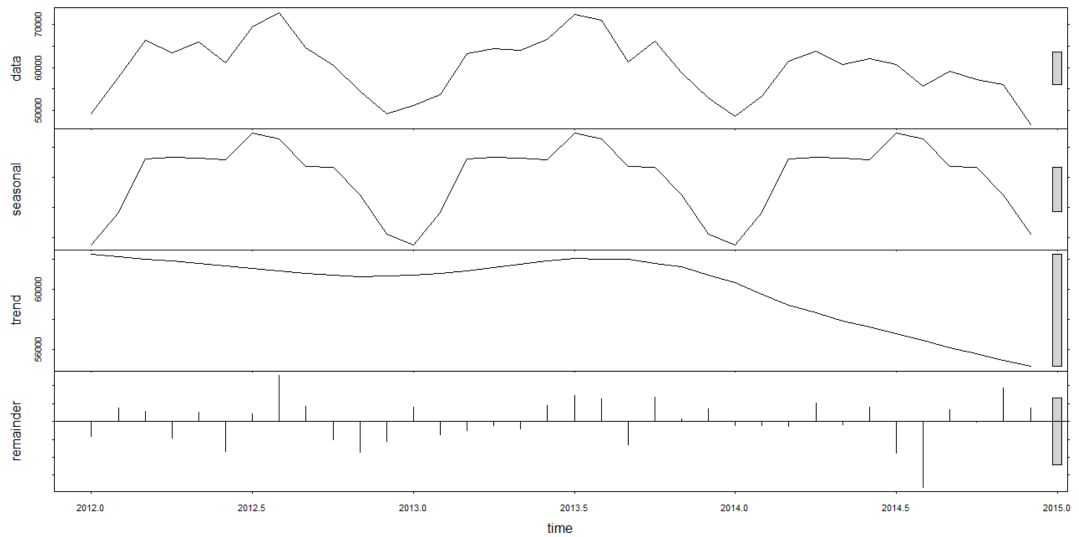


Figure Appendix 26: STL Decomposition of Kalecik O_3 (Monthly)

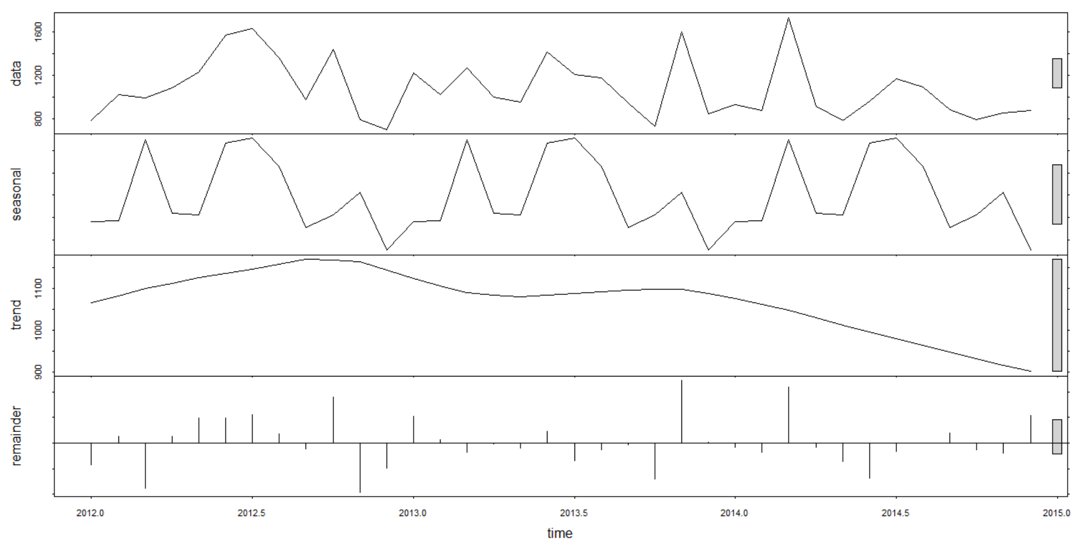


Figure Appendix 27: STL Decomposition of Kalecik PM_{10} (Monthly)

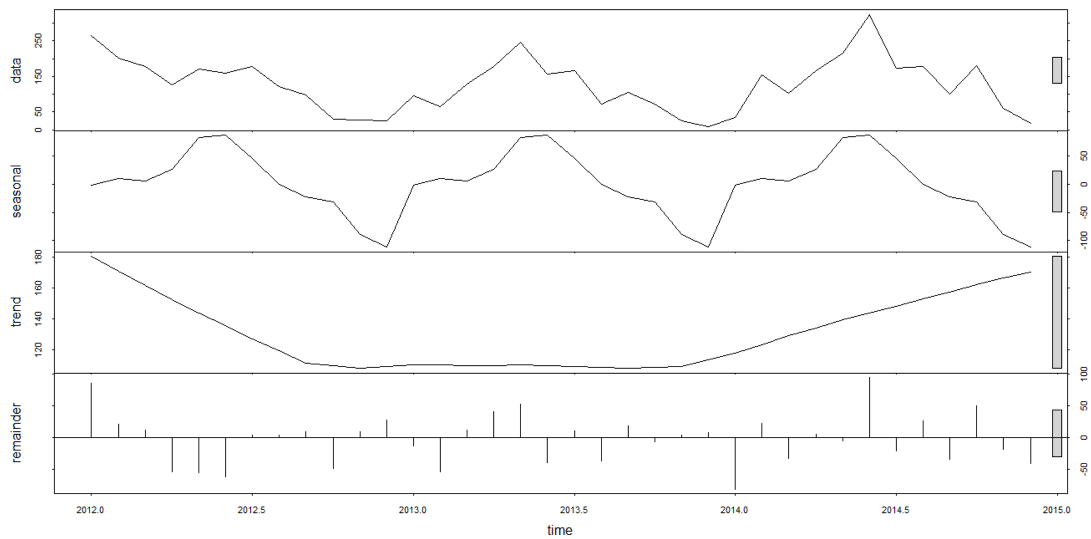


Figure Appendix 28: STL Decomposition of Kalecik SO_2 (Monthly)

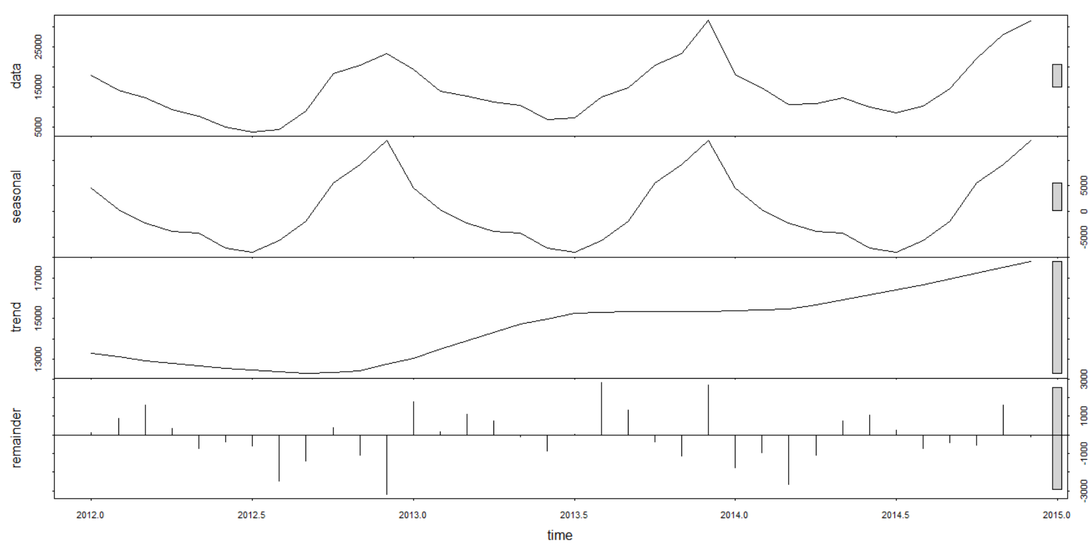


Figure Appendix 29: STL Decomposition of Nicosia NO_2 (Monthly)

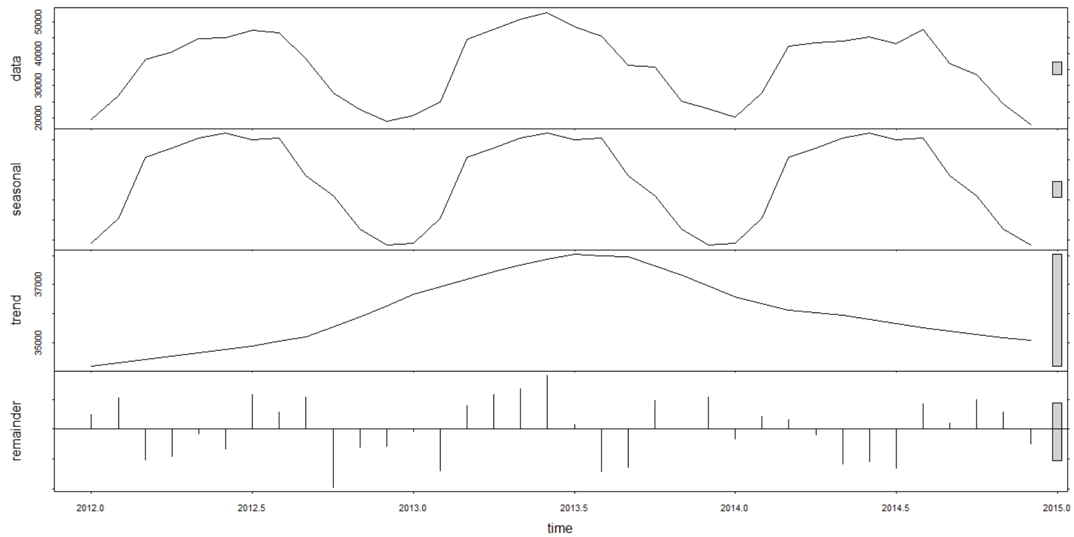


Figure Appendix 30: STL Decomposition of Nicosia O_3 (Monthly)

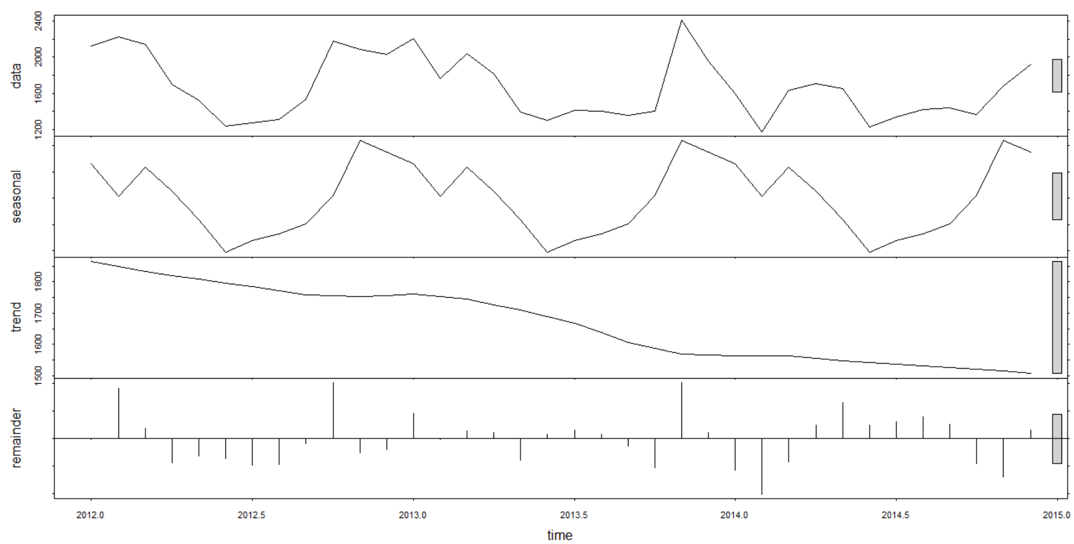


Figure Appendix 31: STL Decomposition of Nicosia PM_{10} (Monthly)

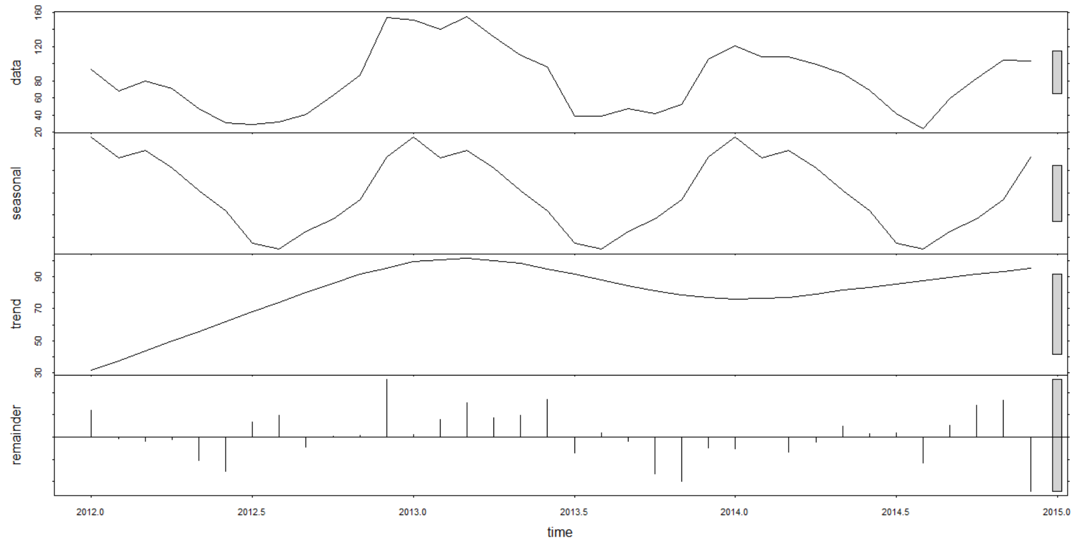


Figure Appendix 32: STL Decomposition of Nicosia SO_2 (Monthly)

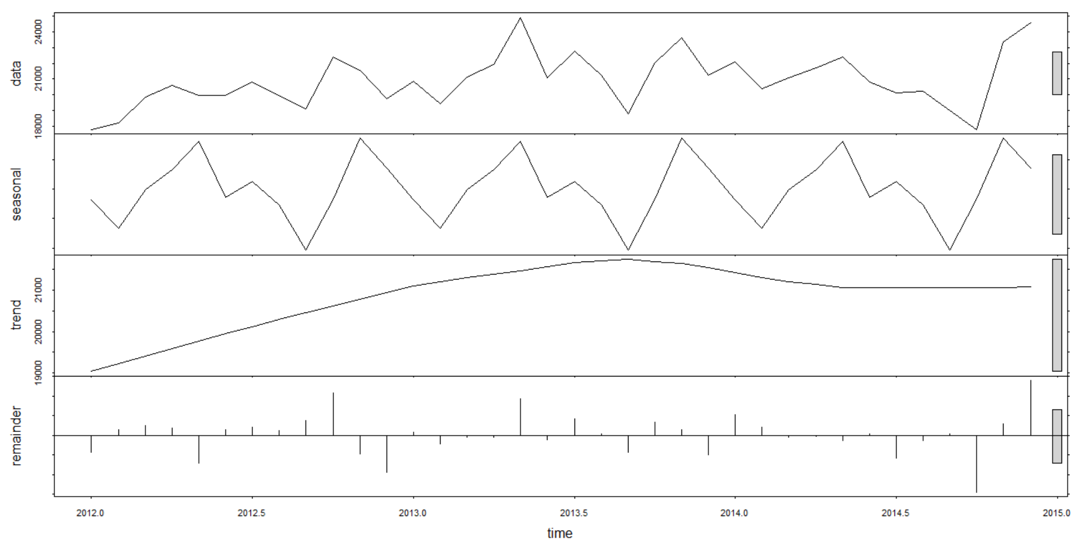


Figure Appendix 33: STL Decomposition of Kyrenia NO_2 (Monthly)

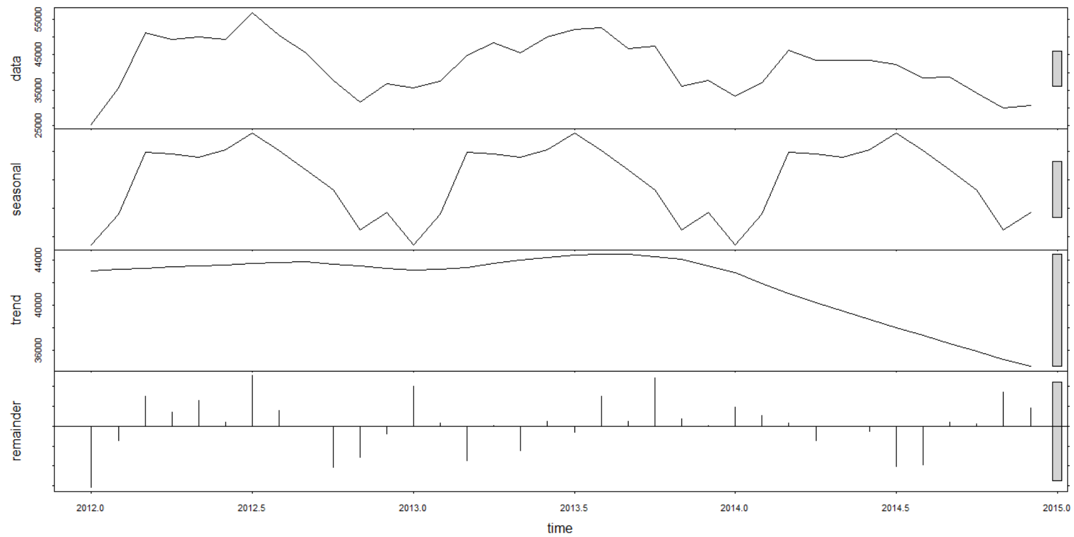


Figure Appendix 34: STL Decomposition of Kyrenia O_3 (Monthly)

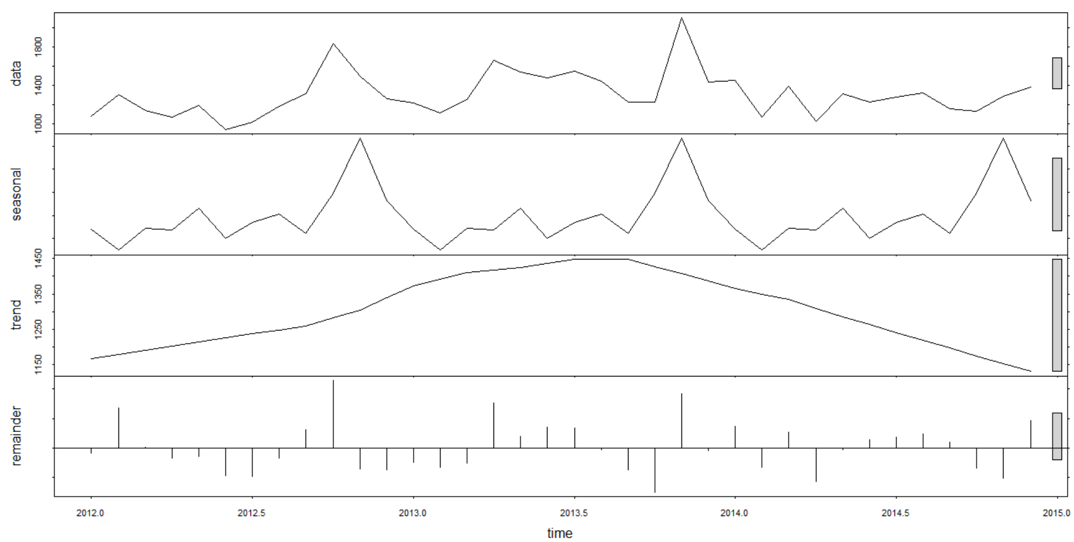


Figure Appendix 35: STL Decomposition of Kyrenia PM_{10} (Monthly)

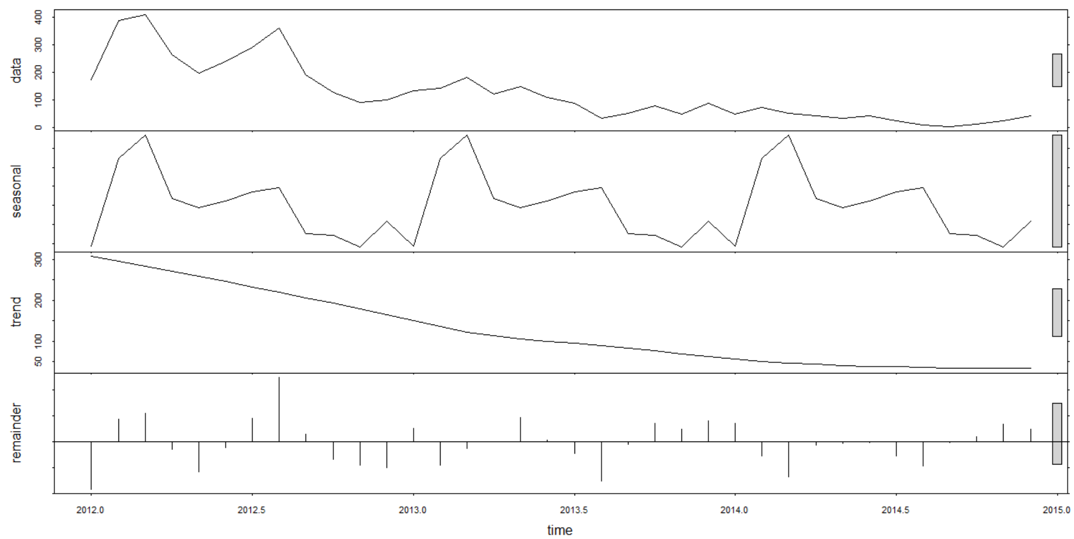


Figure Appendix 36: STL Decomposition of Kyrenia SO_2 (Monthly)

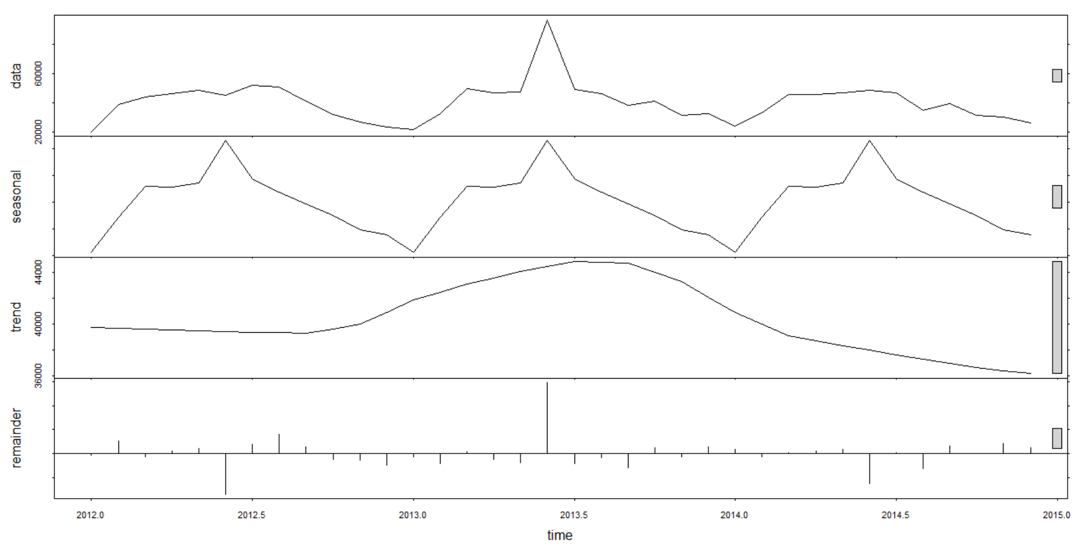


Figure Appendix 37: STL Decomposition of Famagusta O_3 (Monthly)

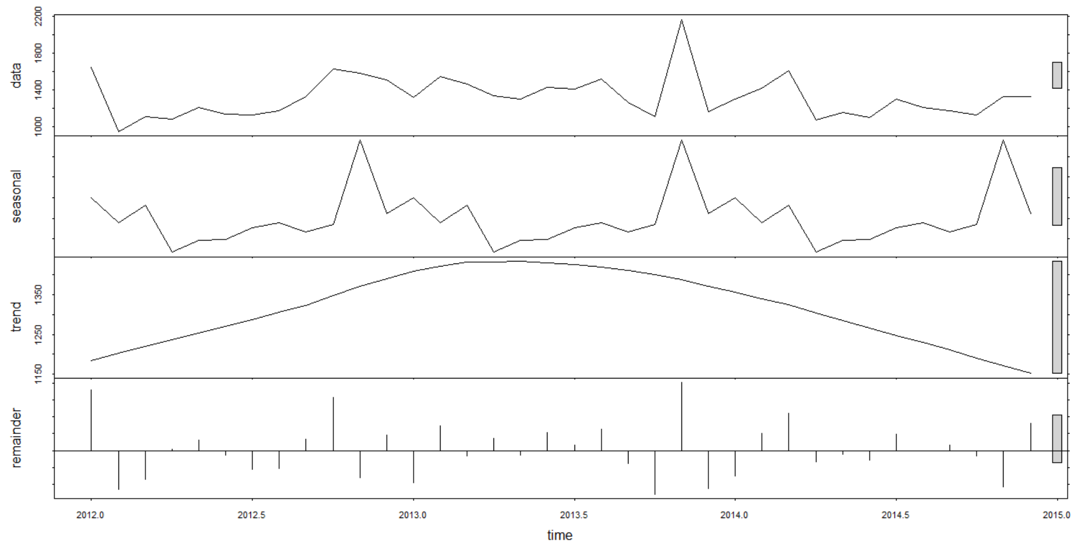


Figure Appendix 38: STL Decomposition of Famagusta PM_{10} (Monthly)

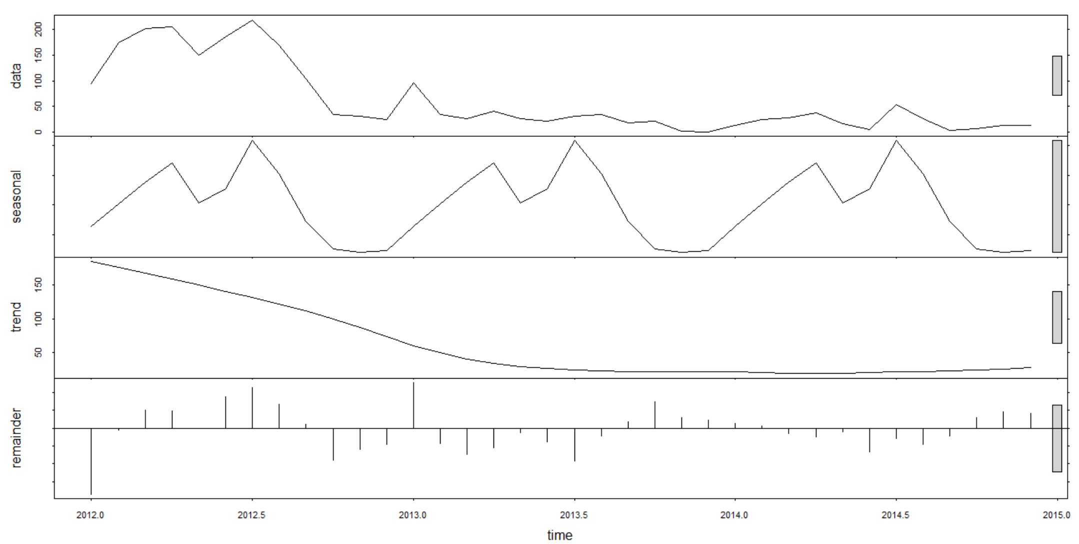


Figure Appendix 39: STL Decomposition of Famagusta SO_2 (Monthly)

III. Assumptions of Simple Linear Regression Model

General assumptions of Simple Linear Regression Model listed below are implemented for regression imputation. (R. Carter, Hill, Griffiths, 2011)

i- The expected value of y for each value of x is a linear regression function,

$$E(y/x) = \beta_1 + \beta_2 x$$

ii- The error term, ε, is random and its expected value is,

$$E(\varepsilon) = 0$$

Its well-matched expression as function is,

$$E(y) = \beta_1 + \beta_2 x$$

iii- The variance of random error is,

$$var(\varepsilon) = \sigma^2 = var(y)$$

In other words, the variance of y and error term are equal to each other and it is a constant which means that variance is homoscedastic.

iv- The covariance of two neighbor observation error terms is,

$$cov(\varepsilon_i, \varepsilon_j) = cov(y_i, y_j) = 0$$

Since the solid waste data set is composed of univariate time series variables, then it is associated with autocorrelation. If this assumption does not hold, no autocorrelation exists between two random errors. Furthermore, the assumption indicates that both random errors ε's and dependent variable y are statistically dependent.

v- The explanatory variable of x is nonrandom and it has to have at least two dissimilar values.

vi- This last assumption is especially assigned to small sample size data sets, that is; the values of random error terms have normal distribution around their mean,

$$\varepsilon \sim N(0, \sigma^2)$$

Because of the Central Limit Theorem this assumption is already hold for large sample cases, and thereby, data sets have normalized distribution.

IV. Figures of Solid Waste Analysis

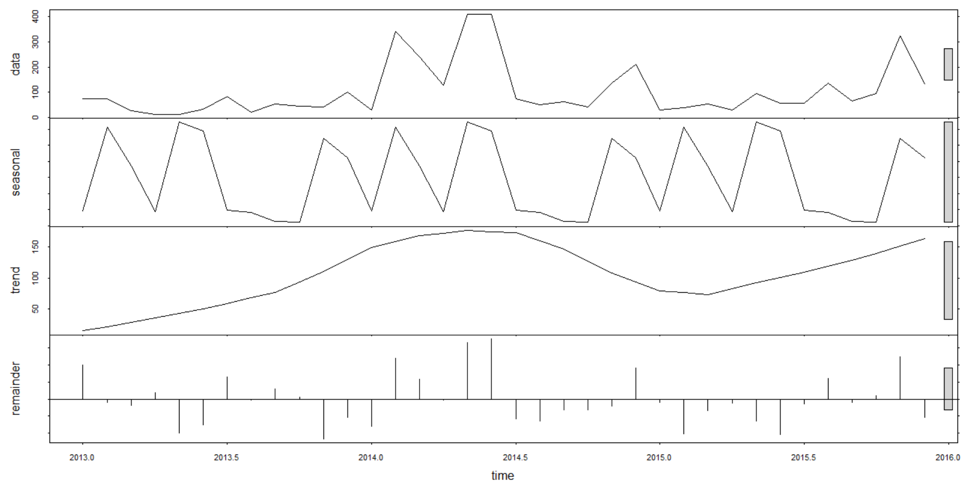


Figure Appendix 40: Decomposition of Disposal Waste Sample

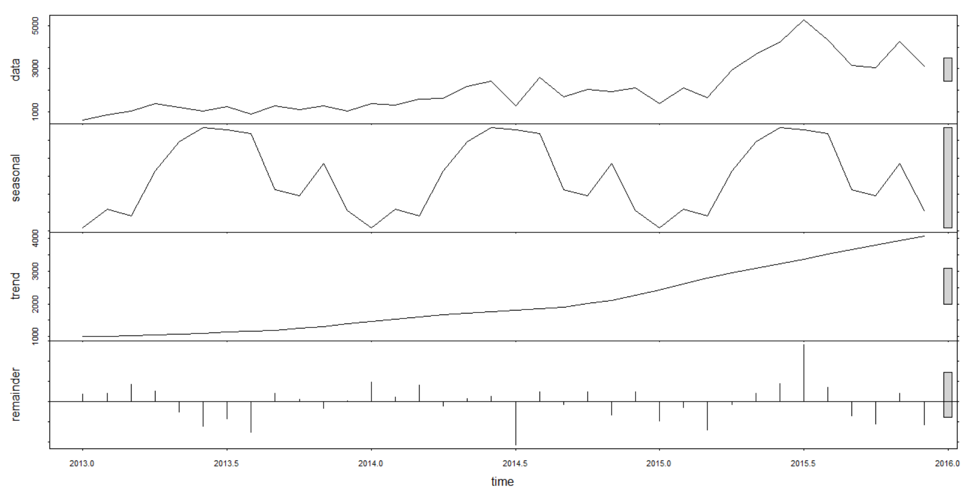


Figure Appendix 41: Decomposition of Garbage and Construction Waste Sample

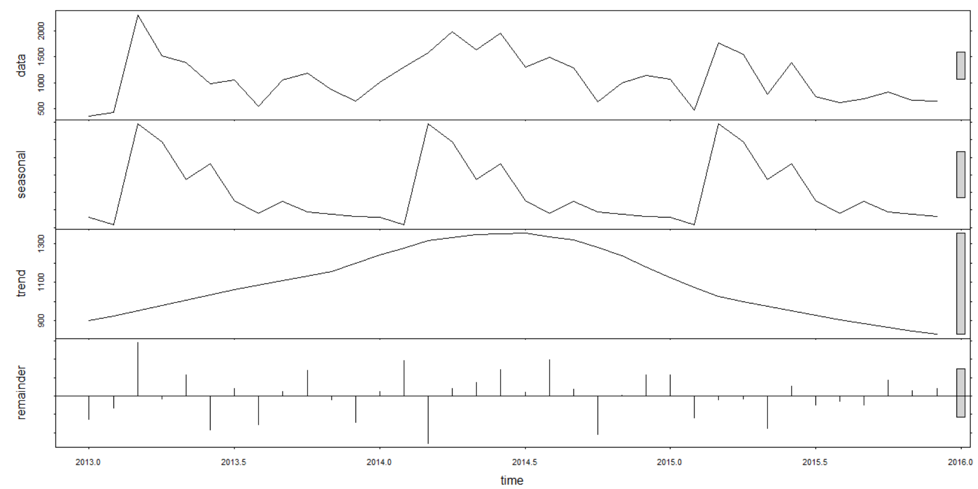


Figure Appendix 42: Decomposition of Industrial and Commercial Waste Sample

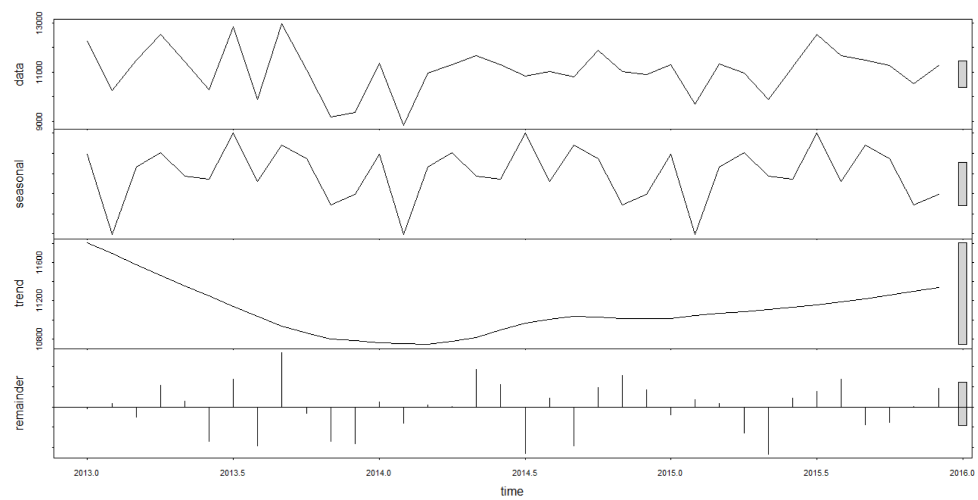


Figure Appendix 43: Decomposition of Household Waste Sample

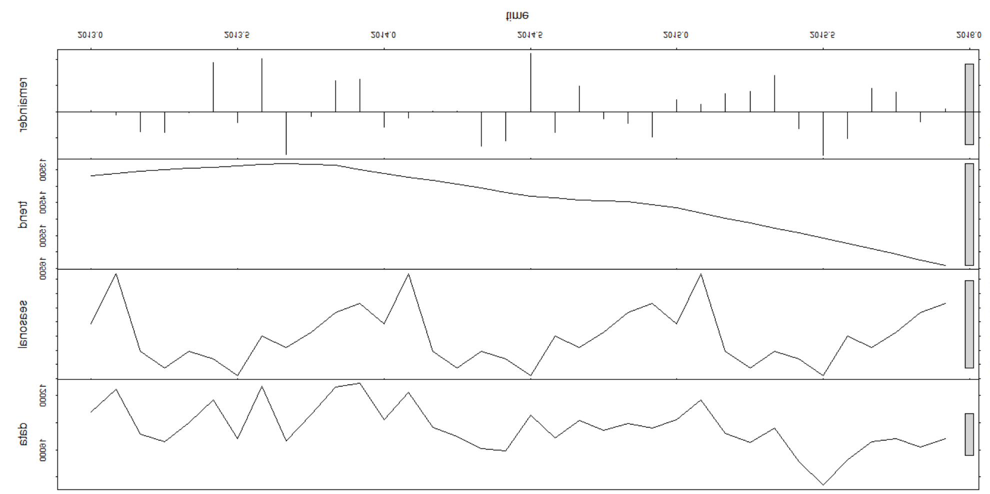


Figure Appendix 44: Decomposition of Total Solid Waste

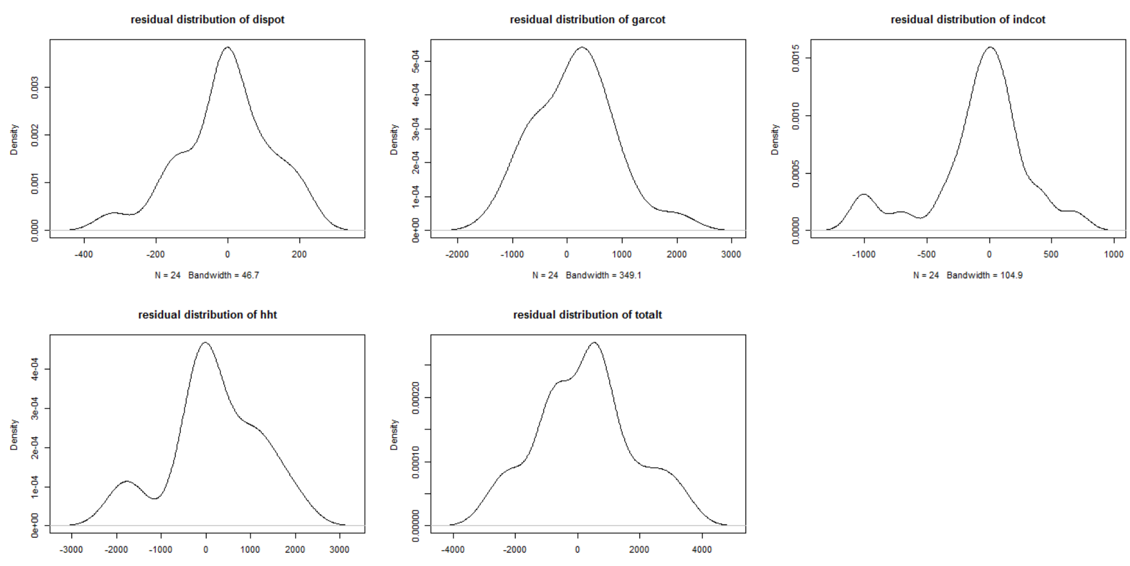
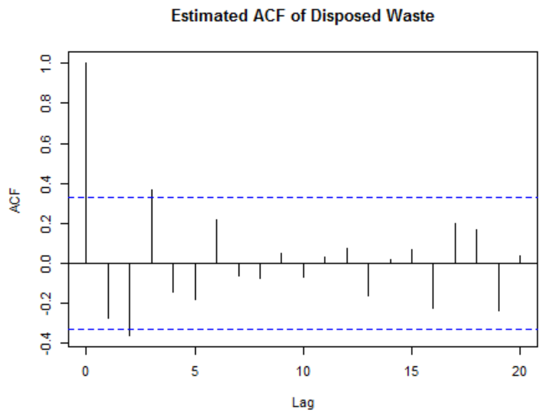
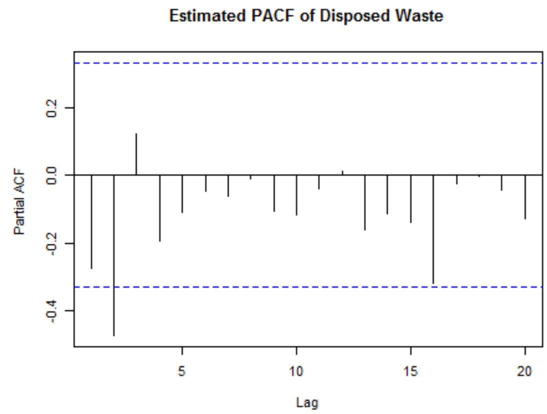
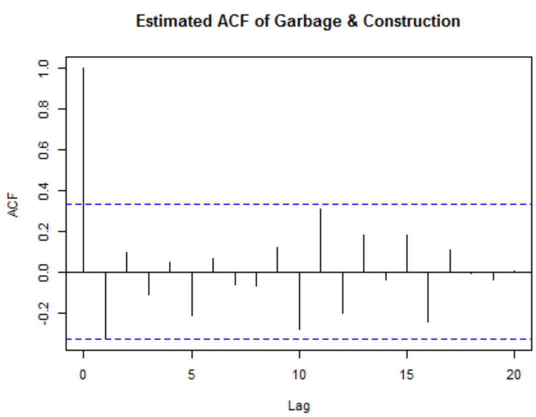
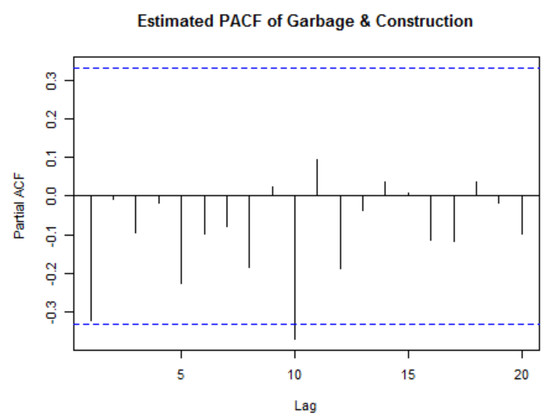


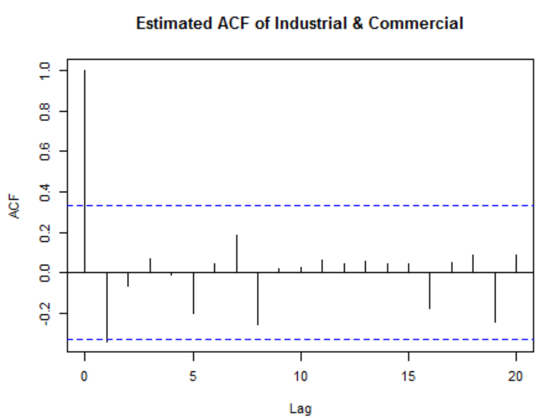
Figure Appendix 45: Distribution of Residuals after Holt Winters Forecasting

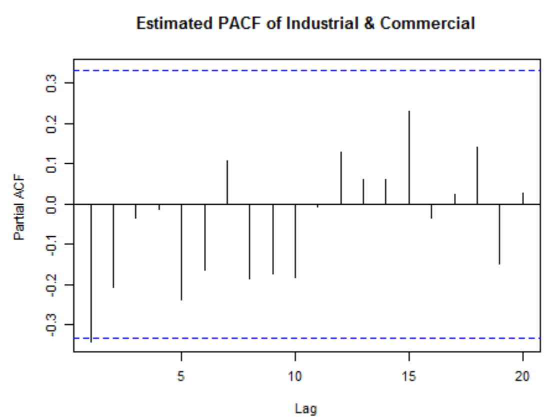

Estimated ACF of Disposed Waste
ACF
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
-0.4
0
5
10
15
20
Lag


Estimated PACF of Disposed Waste
Partial ACF
0.2
0.0
-0.2
-0.4
5
10
15
20
Lag


Estimated ACF of Garbage & Construction
ACF
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0
5
10
15
20
Lag


Estimated PACF of Garbage & Construction
Partial ACF
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
5
10
15
20
Lag


Estimated ACF of Industrial & Commercial
ACF
1.0
0.8
0.6
0.4
0.2
0.0
-0.2
0
5
10
15
20
Lag


Estimated PACF of Industrial & Commercial
Partial ACF
0.3
0.2
0.1
0.0
-0.1
-0.2
-0.3
5
10
15
20
Lag

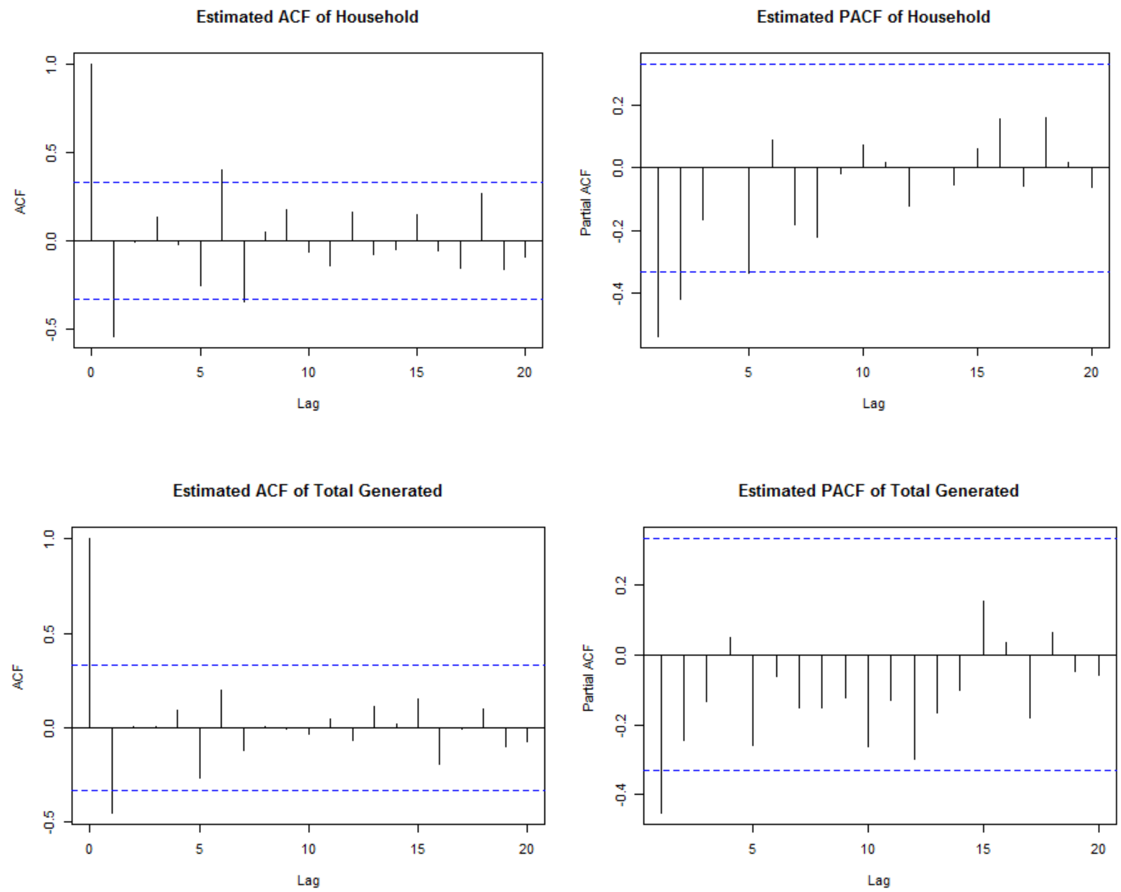


Figure Appendix 46: The estimated ACF and PACF correlogram of solid waste time series.

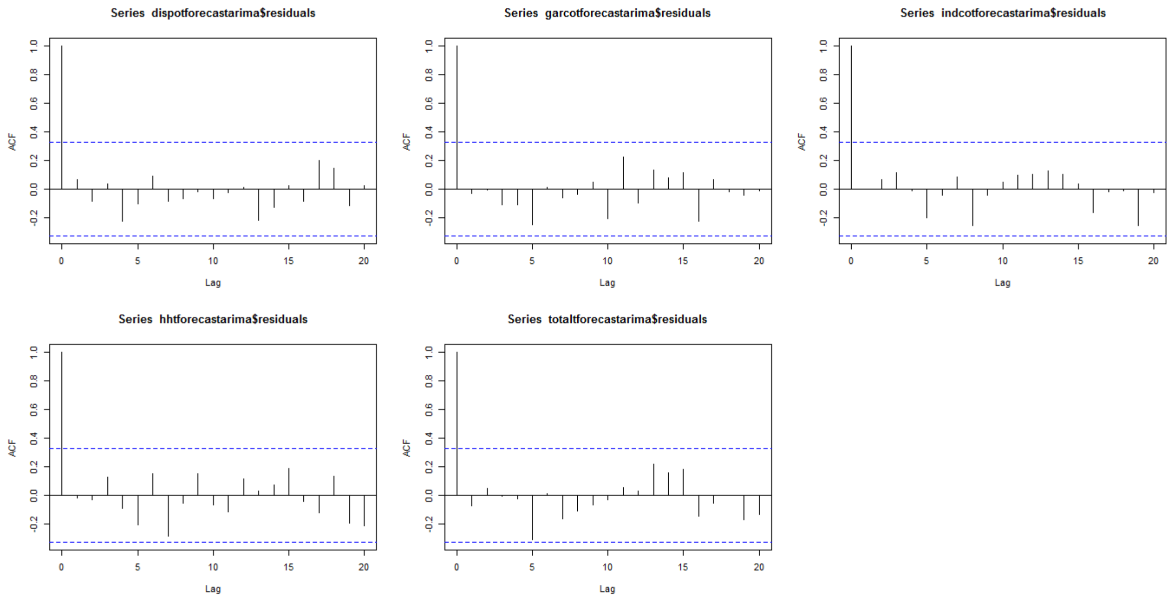


Figure Appendix 47: Correlogram of standard residuals of fitted ARIMA's (p, d, q)

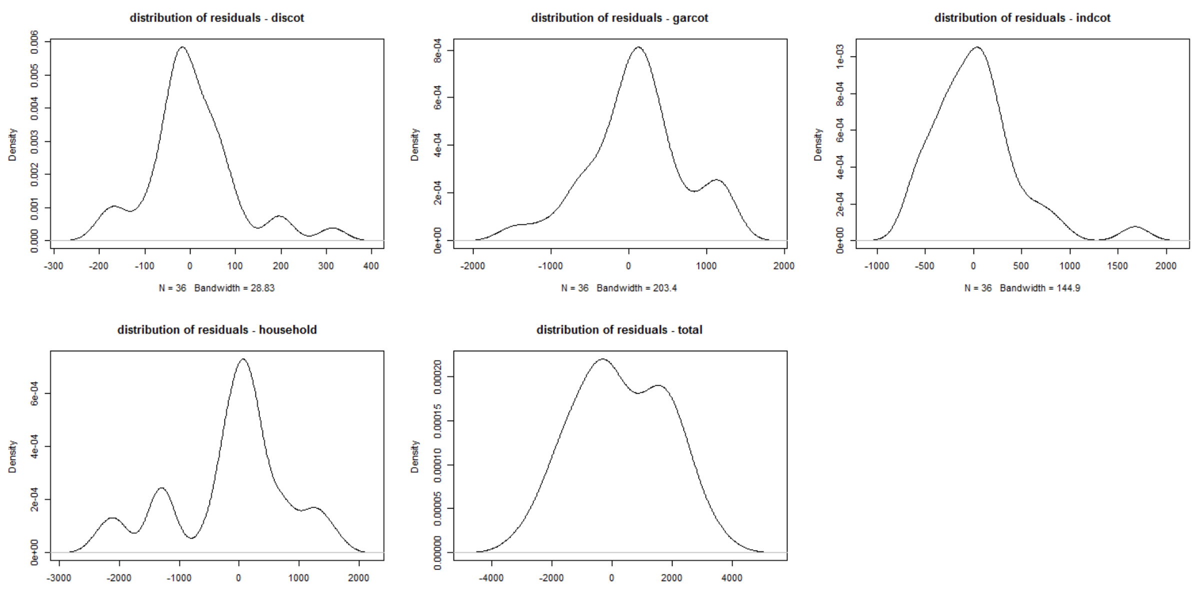


Figure Appendix 48: Distributions of residuals of fitted ARIMA's (p, d, q)

V. R Software Program

In the statistical analysis parts of this study, R programming language is used. R Studio is an integrated dependent environment, and R is an open and a free source of software environment where statistical computing is executed, and visual representations of graphics and figures are obtained. R comprises a wide range of packages (9202 packages at the present time) for applying different statistical techniques and graphical tools. (R, 2008) In this study, the installed and used packages are as follows:

fBasics, forecast, fUnitRoots, ggplot2, imputeTS, lattice, mice, readxl, tseries, urca, vars, VIM.

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