DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

RECYCLING OF STABILIZED WASTEWATER TREATMENT SLUDGES ON LAND APPLICATION

by
Tutku KURULAR

October, 2019
İZMİR

RECYCLING OF STABILIZED WASTEWATER TREATMENT SLUDGES ON LAND APPLICATION

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"RECYCLING OF STABILIZED WASTEWATER TREATMENT SLUDGES ON LAND APPLICATION"** completed by **TUTKU KURULAR** under supervision of **PROF.DR. AZİZE AYOL** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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RECYCLING OF STABILIZED WASTEWATER TREATMENT SLUDGES ON LAND APPLICATION

ABSTRACT

The conventional recycling and reuse alternatives for sludges produced in domestic/municipal/industrial wastewater treatment plants (WWTPs) are not sufficient to develop a sustainable system including environmental, economical, and social aspects. The recovery of the valuable materials from the sludge and also reuse of it for agricultural purpose are still great concern in this field regarding the possible risks as well as technical limits and requirements based on environmental legislation. Even the sludge processed in WWTPs have enough quality, the agricultural reuse of the sludge strictly depends on the public's acceptance. Also, the farmers' perception was important regarding some factors affecting the attitudes for the crop production, its use, and economic benefits. This thesis investigated the recycling of stabilized wastewater treatment sludges on land application from point view of public perception. For this purpose, a survey study was carried out to determine the public and farmers' perception and awareness for agricultural reuse of treatment plant sludges in Turkey. Approximately 1500 questionnaires designed for public and 400 questionnaires designed for farmers were sent to measure the awareness and acceptance of the public and farmers on the agricultural usage. The return ratios were found as 88% and 58%, respectively. The study showed that the most important issue among the public was found as the health risks associated with the sludge. The farmers were mostly worried about its possible negative effects on the crop quality, food contamination, and sale of the grown crops. The thesis presents the research results in detail and gives the information about current applications and legislation regarding the land application/agricultural usage of sludge in Turkey.

Keywords: Sludge stabilization, public perception, farmers' perception, agricultural usage

STABİLİZE ARITMA ÇAMURLARININ TOPRAK UYGULAMASIYLA GERİ DÖNÜŞÜMÜ

ÖZ

Evsel, kentsel, endüstriyel atıksu arıtma tesislerinde üretilen çamurlar için geleneksel geri dönüşüm ve yeniden kullanım alternatifleri çevresel, ekonomik ve sosyal yönleri içeren sürdürülebilir bir sistem geliştirmek için yeterli değildir. Değerli malzemelerin çamurdan geri kazanılması ve ayrıca tarımsal amaçlarla yeniden kullanılması, bu alandaki olası riskler ve ayrıca çevresel mevzuata dayanan teknik sınırlar ve gereklilikler açısından büyük önem taşımaktadır. Atıksu arıtma tesislerinde işlenen çamurlar yeterli nitelikte olsalar bile, çamurun tarımsal kullanımı kesinlikle halkın kabulüne bağlıdır. Ayrıca çiftçilerin algısı mahsul üretimine, kullanımına ve ekonomik faydalarına yönelik tutumları etkileyen bazı faktörler açısından önemlidir. Bu tez, arazi uygulamasındaki stabilize atıksu arıtma çamurlarının geri dönüşümünü kamu algısı bakış açısıyla incelemiştir. Bu amaçla, Türkiye'deki arıtma tesisi çamurlarının tarımsal yeniden kullanımı konusundaki halkın ve çiftçilerin algı ve farkındalıklarını belirlemek amacıyla bir anket çalışması yapılmıştır. Halk için tasarlanan yaklaşık 1500, halkın ve çiftçilerin tarımsal kullanım konusundaki farkındalığını ve kabulünü ölçmek için çiftçiler için tasarlanan 400 anket gönderildi. Geri dönüş oranları sırasıyla %88 ve %58 olarak bulundu. Çalışma, halk arasında en önemli sorunun çamurla ilişkili sağlık riskleri olarak bulunduğunu göstermiştir. Çiftçiler çoğunlukla ürün kalitesi, gıda kirliliği ve yetiştirilen ürünlerin satışı üzerindeki olası olumsuz etkileri konusunda endişeliydi. Tez, araştırma sonuçlarını ayrıntılı sunmakta ve Türkiye'deki çamurun arazi uygulaması / tarımsal kullanımı ile ilgili güncel uygulamalar ve mevzuat hakkında bilgi vermektedir.

Anahtar Kelimeler: Çamur stabilizasyonu, halkın algısı, çiftçilerin algısı, tarımsal kullanım

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CHAPTER ONE
INTRODUCTION

1.1 Introduction

Beneficial usage of treatment plant sludge addressed in environmental legislation became an essential part of the sustainable sludge management. Land application of sludges for agricultural purpose regarding the regulations was emphasized in many countries in Europe, USA, Canada, etc. (Sanin et al., 2014). Although only stabilized sludge can be used for agricultural purpose depending on the regulations, many precarious parameters including heavy metals, pathogens, and organic contaminants are still great public concern beyond the regulation limits. Sludge contains important amounts of resources like nutrients, organic matter, potassium, and micronutrients, however; the micro contaminants found in the sludge are of growing alarm (Turunen, 2018; Sternbeck, 2011). Due to the presence of these contaminants in stabilized sludge at any concentration, the risks of agricultural application posed to the human and animal health as well as the environment should be attentively determined. There are wide-ranging differences on whether limit values exist for the contaminants in sludge in regulations of European countries, USA, Canada, Japan, and other countries. For example, while concerns about the health effects of the micropollutants strived some European countries like France, Denmark, and Turkey to put regulatory limits, some others like USA and Canada claimed that the potential risks for them are extremely low (Sanin et al., 2014).

Lishan et al. (2018) stated the difficulty for the preparation of effective sludge management plan. Joo et al. (2015) reported that the land application, specifically agricultural, is an alternative for biosolids disposal in addition to the problematic issues like the contaminants available in sludge contaminating soil and crops, soil worms bioaccumulating contaminants from sludge, and also runoff and leachate issues from sludge (Joo et al., 2015). Beyond the some restrictions on land spreading for agricultural purpose, it is still in use. A more regardful management and treatment, disposal and reuse options considering cost, practicability, possible environmental impacts, and public perception are required (Insel et al., 2013).

This thesis investigated the recycling of stabilized wastewater treatment sludges on land application from point view of public and farmers' perception. For this purpose, a survey study was carried out to determine the public and farmers' perception and awareness for agricultural reuse of treatment plant sludges in Turkey. The thesis presents the survey research results in detail and gives the information about current applications and legislation regarding the land application/agricultural usage of sludge in Turkey.

CHAPTER TWO
SCOPE AND OBJECTIVES OF THE THESIS

2.1 Scope of Study

Turkey having about 900 municipal wastewater treatment plants (WWTPs) currently generates around $9x10^5$ tons of sludge, annually (Ayol et al., 2019). In these WWTPs, the most commonly used treatment processes are biological treatment systems which are mainly biological nutrient removal systems (BNR) with respect to total wastewater treated (42% of total wastewater treated) (TUBITAK-KAMAG, 2013). In Turkey, regulation regarding the use of domestic and municipal sludge on land claims that only stabilized sludge can be applied on land (Official Gazette, 27661, 3 August 2010). This regulation was mainly adopted from EU directive-86/278/EEC. Turkey is among the countries applying stringent limit values for a number of organic micro-pollutants based on the limit values given in EU Working Document on Sludge, 3rd Draft (3rd Draft, 2000). Also, regulation regarding soil pollution control and sites polluted by point sources have strict rules to protect the land degradation in Turkey based on the monitoring and risk assessment evaluations (Official Gazette, 27605, 8 June 2010).

Although stabilization units are used in a rather smaller number of treatment plants, the WWTPs have higher treatment capacities located in metropolitans and urban settlements. According to the results of a research project carried out on behalf of Ministry of Environment and Urbanization, Republic of Turkey in 2013, approximately, 25% of the sludge produced is stabilized while aerobic digestion (53%) is the most common type of stabilization process. The other stabilization processes are anaerobic digestion (29%), lime stabilization (16%), and composting (2%) (Insel et al., 2014; TUBITAK-KAMAG, #108G167 project, 2013).

Though the stabilized sludge recycling on land is not widely applied in Turkey, a detailed study on public and farmers' attitudes and risk perception toward agricultural usage of sludge was not carried out, yet. A more efficient sludge management including treatment, disposal, and reuse options should consider the

possible environmental impacts, and public perception. This thesis focused on the public and farmers' perceptions on land application of stabilized sludges in Turkey.

2.2 Objectives of Study

The objectives of the thesis are hence:

- To review the sludge land application in Turkey from view of legislation and practical applications,
- To evaluate gender differences and issue awareness impacts based on the public knowledge and perception of risks related to sludge reuse on land,
- To assess the perceptions of public and farmers associated with agricultural usage of sludge in Turkey.

CHAPTER THREE
LITERATURE REVIEW

3.1 Treatment Plant Sludge Production and Management

Wastewater treatment plants (WWTP) are constructed to eliminate and minimize the environmental impacts of wastewaters into local waterways. While wastewaters are treated in WWTPs by using different treatment techniques, large amounts of sludges have been produced as a by-product. The sludges have different characteristics depending on the treated wastewater properties, applied wastewater and sludge treatment processes. Regarding the ecological sustainability, wastewater treatment processes require energy and resource saving, waste minimization, and materials and energy recovery (Lishan et al., 2018). The appropriate sludge treatment and management are considered as central components of WWTPs (Peccia & Westerhoff, 2015). Recently, much more efforts have been made for sludge resource recovery with enhancement of sustainability of WWTPs (Lishan et al., 2018). Ayol et al. (2019) have pointed out that the sludge production ratio differs from country to country and at different regions in the same country. The estimated sludge production rate was about 13.5 kg/PE/year in Turkey. Although, the wastewater and sludge management vary in different countries, the constant growth of sludge production is a global challenge. In addition to the stricter legislation on wastewater and sludge management, the environmental awareness has increased (Lishan et al., 2018).

Energy and material recovery from sludge and wastewater has become a great concern. The recycling of organic wastes to agriculture has been discussed for decades (Odlare et al, 2011). There are various reasons including the accumulation of pollutants and their possible transmission to crops. Apart from this, energy recovery from sludge during the sludge processing in WWTPs via anaerobic digestion process is crucial regarding the total economic profit.

Especially, biological sludges mainly produced from activated sludge processes include organics, nutrients, and pathogens (Joo et al., 2015). Commonly, sludges

have been handled using supporting treatment processes like thickening, stabilization, and dewatering. Depending on the processed sludge quality, they can be landfilled or used for agricultural purpose. As conventional disposal alternatives, landfilling, incineration, and land application have faced significant hurdles (Joo, Antmann, Chorath & Monako, 2015). Agricultural production by using sludge has been problematic due to the pollutants (Joo et al., 2015).

As another alternative, biological sludges can be converted to a compost material for vegetation growth and for land restoration, and as a soil conditioner (Joo et al., 2015).

Although recent waste management approaches regarded the sludges as biomass (Ayol et al., 2019), nutrient recycling via land application is still in use in different countries. The recovery of nutrients from sludge is seen as an auspicious process. They can be recovered with struvite (Joo, Antmann, Chorath & Monako, 2015), electrodialytic (ED) process, microfiltration, etc. (Joo et al., 2015).

In sludge management, typical sludge disposal methods confront issues of social, environmental, and economic concern (Joo et al., 2015).

3.2 Reuse of Wastewater Treatment Sludges in Different Countries

There are different approaches to reuse of treatment plant sludges in different countries. This sections reviews some applications applied in European countries.

In Denmark, municipal wastewater is processed by centralized WWTPs by using mechanical, biological, or chemical processes. N and especially P-rich sludge is produced in these plants and processed by anaerobic digestion technology (AD) for energy recovery. The sludge is mainly applied to land following stabilization. There is also an important policy interest for sludge recycling (Case et al., 2017).

In Europe, Urban Wastewater Treatment Directive 91/271/EEC and the Water Framework Directive promoted the implementation of WWTPs. Then, sludge production has increased in the European Union by 50% since 2005 (Arias et al., 2007). For the sludge management in Spain, the following pyramid was proposed:

(1) valorization in agriculture, (2) energetic valorization, and (3) landfilling (Arias et al., 2007).

3.3 Environmental Legislation on Land Application of Sludges

Reuse of sewage sludge in agriculture is regulated by environmental directives in different countries. The Directive 86/278/EEC in EU regulated the soil application of sludge (European Commission, 1986). Several member states set national limit values (Kelessidis & Stasinakis, 2012).

Following the prohibition of ocean dumping of wastes in 1990 and establishing the quality standards by the U.S. Clean Water Act, the increased amount of sludge was sent to landfills increased in the United States (Logan, 1995). In addition to this, nutrients availability in sludge led to enhanced handling operations for land application purpose. In 1993, the U.S. EPA published the CFR Title 40 Part 503 on the use or disposal of biosolids: Class A and Class B standards (Arthurson, 2018).

In Turkey, two separate regulations have come into force as Soil pollution control and contaminated site with point sources regulation (Official Gazette, 27605, 8 June 2010) and Use of stabilized domestic and urban sludges on land (Official Gazette, 27661, 3 August 2010). The second regulation regulates stabilized sludge applications for the agricultural and/or land application purpose. This regulation includes the heavy metal concentration limits, adsorbable organic halogens (AOX), linear alklybenzin sulfonate (LAS), Diphtalat (2-ethylhexyl) (DEPHP), NPE, PAH, PCBs, PCDD/F, and also microbiological parameters. It covers the technical and administrative principles regarding the controlled use of treatment sludges that will not harm the soil, plants, animals, and human beings. The application of stabilized sludge is subject to authorization. It has stricter limit values for micro pollutants than those in the EU Directive (86-278EEC).

3.4 Benefits of Using Sludge in Agriculture

Sludge is known as a proper component for soil amendment (Krzyzanowski et al., 2016). The use of sludge in agriculture is useful for many reasons including water holding capacity and infiltration, soil aeration, macronutrients, and micronutrients

(Cofie et al., 2010). Sludge enhance the physical and chemical properties of soils, forests and home gardens (Dessalew et al., 2018).

3.5 Some Studies on Public Health and Perception Related to the Sludge Land Application

Sludge management has many environmental, technical, financial, and regulatory challenges such as the minimization of health risks and increase of agricultural productivity. So, it is necessary to consider farmers' socio-cultural case, public perception, economic benefits, and restrictions of its use.

Although sludge usage in agriculture is well-known, some issues regarding its quality and impact on human health must be taken into account, like pathogens. Some reports were published about the epidemics associated with vegetable consumption and *Salmonella spp.* (Krzyzanowski et al., 2016). Moya et al. (2019) indicated that the perception is one of the main challenges with food products derived from sewage sludge in accordance with the Global Good Agricultural Practices (GAP, 2011). They have pointed out that while the farmers do not consider the origin of organic amendments if they have a helpful effect on soil (Moya et al., 2019). Especially, perception issues led to develop assertion models in different countries (Moya et al., 2019). A research to evaluate the perception of farmers and economic benefits of excreta use in southern Ghana was conducted by Cofie et al. (2010). They got the information on the use of excreta for cultivation was greatest disseminated through the farmers. They indicated that the farmers disagreed that it causes food contamination. The results of these studies and surveys remarked that the socio-economic and environmental factors are critical in perceptions of agricultural application of sludge.

CHAPTER FOUR
MATERIALS AND METHODS

4.1 Survey Study and Its Evaluation

Two surveys were developed regarding the public and farmers' perceptions based on environmental and health criteria. The surveys to measure the public and farmers' perceptions were given in Appendixes I and II, respectively.

Surveys were designed as in the form of open-ended and multiple choice questionnaire-type and the statements for each group –public and farmers- were introduced with a short information explaining the aim of the study.

Both surveys divided to the three parts. The first part of each survey was constituted to have socio-demographic information. While the second part of the public survey asked the questions to evaluate the common awareness of sludge including definition of sludge, characteristics, disposal alternatives, and agricultural usage, the second part of the farmers' survey asked the questions to gather the information on the farmers' attitudes concerning growing crops, fertilizers, and agricultural usage of sludge. Third parts of the surveys questioned the inquiries related to the environmental and health risks of the agricultural usage of sludge. The survey prepared for the public perception consisted of 26 questions while the survey designed for farmers' perception had 29 questions.

The surveys were conducted via online, face-to-face interview, or post. More than 1500 questionnaires for public and 400 questionnaires for farmers were distributed throughout Turkey. 1323 of them were completely answered by public while 233 of them were replied by farmers. The locations of the respondents in Turkey were shown in Figure 4.1.

Figure 4.1 The locations of the respondents in Turkey

The return rates of the questionnaires for public and farmers were 88% and 58%, respectively. Each responded spent approximately fifteen minutes for the survey. The survey responses were entered directly into a spreadsheet developed in MS Excel for further evaluation. The socio-demographic characteristics of the respondents were also determined based on the frequency analysis related to respondents' ages, genders, educations, and incomes.

CHAPTER FIVE
RESULTS AND DISCUSSION

5.1 Socio-economic Characteristics of Respondents

The socio-economic characteristics of farmers and public who attend the survey were summarized in Table 5.1. The mean ages for farmers and public respondents, which were less than 55 years, indicated that the farmers were mostly active in the work-life in terms of economic gain while the public respondents paid more attention to the survey related to the food safety, environmental and human health risks. The number of female farmers as compared to the male was very low. However, there are too much women laborers who live in rural areas and do farming activities. The gender distribution of the public respondents was almost equal to each other.

The mean education level of the farmers was mostly primary and secondary schools; however, the percentage of them who took the high school education was also noticeable level. Most of the public respondents had university and high school education. The incomes varied for each group.

Table 5.1 The socio-economic characteristics of respondents'

Socio-economic characteristics		Farmers (%)	Public (%)
Gender	Female	8	46
	Male	92	54
Age	10-15	-	1
	16-25	13	57
	26-40	24	28
	41-55	37	12
	>55	26	2
Education	Primary school	22	1.9
	Middle school	33	1.4
	High school	38	18
	University	7	68
	MSc	-	9
	PhD	-	1
	Post PhD	-	0.7
Income	<175 €/month	-	16
	175-345 €/month	8	20
	345-520 €/month	17	15.5
	520-850 €/month	53	22
	850-1380 €/month	20	19
	>1380 €/month	2	7.5

5.2 The Farmers' Perceptions Based on the Survey Results

The farmers' perceptions in the case of recycling of the stabilized sludge for agricultural purpose were asked depending on some important factors affecting the attitudes for the crop production in Turkey. The respondents' answers for the questions were depicted in between Figure 5.2-5.15. First question focused on the variety of the growing crops in the fields. Mostly, the farmers grow the green leafy

vegetables/ fruits while the production of the corn, wheat, etc., which are very important crops in Turkish people' food habits, were the second rank. The production ratio of the commercially inedible plants such as cotton, canola, safflower was about 9% in the total production. The farmers can harvest a few times in a year in some part of Turkey like western part of the country. 85.8% of the respondents answered the question on how many times per year they plant in the fields as only one. However, 13.8% of the farmers mentioned that they could plant twice. The farmers (99%) agreed on the organic amendments positively affecting the soil. While they claimed that the source of the fertilizer is not a great concern, most of them (67%) preferred the chemical fertilizers. However, organic farming activities are a growing issue in Turkey. Therefore, 32% of the farmers doing organic farming are used to apply organic manure. It was mentioned that they accessed to the animal manure primarily from their own livestock farms. The use of other agrochemicals (i.e. pesticides and herbicides) are recently on a very limited scale in Turkey. 47% of the farmer respondents said that they paid up to 175€ for the fertilizer annually, while 35% of them claimed the price was between 175 € and 345 €. The larger landowners expressed the fertilizer costs was higher than 500 €.

Regarding the environmental conscious, the first two questions were asked to learn whether the farmers were aware of wastewater treatment topic and sludge production. The majority of the farmers had the knowledge about the wastewater treatment (69%) and sludge production from the wastewater treatment plants (65%). Only 20% of the respondents are aware of using the stabilized sludges in the soil as a fertilizer. Most of them declared that they learned this information from radio-television and internet-social media. The distribution of the learning sources was also given in Figure 5.7. Most participants (96%) were unaware that the effects of the use of sewage sludge on the crops' quality as a fertilizer while very small group declared that they used the stabilized sludge for agricultural purpose. Mostly, the reason was its positive impact on product quality (76%). Oppositely, the farmers who do not prefer to use sludge for growing the crops were mainly worried about its possible negative effects on the product quality (77%). However, 29% of the farmers claimed the agronomic benefits of sludge reuse on soil.

Although, the farmers disagree that sludge application on land causes food contamination as also reported in Coffie et al. (2010), they claimed the usage of sludge for agricultural purpose could make a negative effect on the sale of the grown crops.

They were in doubt whether the public accepts to buy the crops especially vegetables/fruits grown by sludge addition. Moya et al. (2019) have pointed out that the use of biosolids directly onto fields growing vegetables was still controversial and not accepted at present. Similar concerns were also observed in this study. While the most of the farmers were unaware the other land application alternatives of sludges, 16% of them answered the question as the rehabilitation of the closed mining areas (41%), forest areas (22%), green areas on highway edges (16%), barren soil (16%), and other (5%). Majority of the respondents (97%) were unaware the availability of the Turkish regulation on land application of stabilized domestic/urban sludge regarding the agricultural usage of sludges.

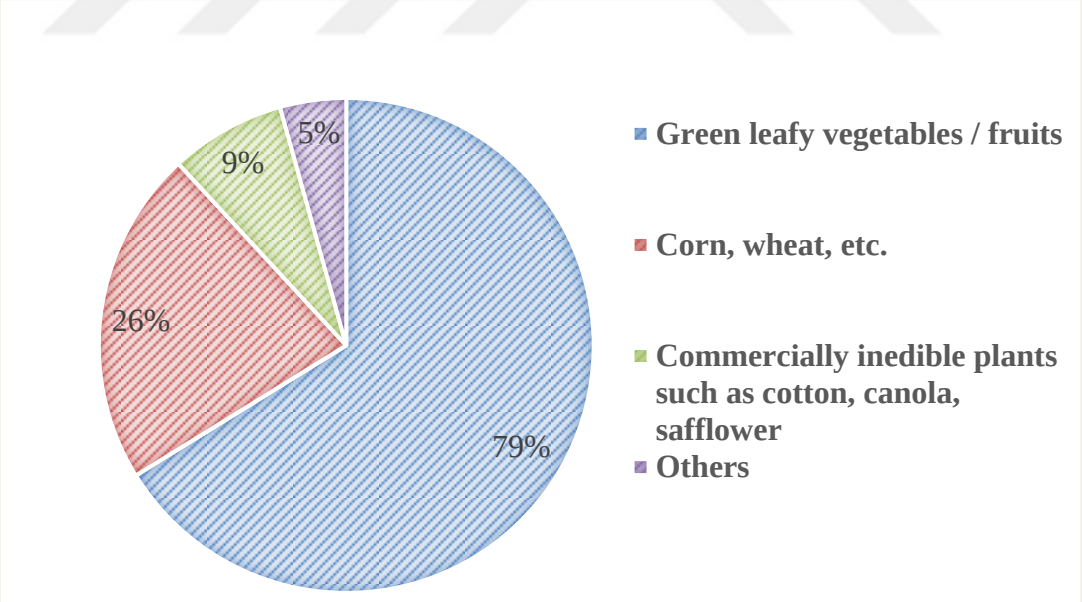

Figure 5.1 What kind of products do you grow in your field

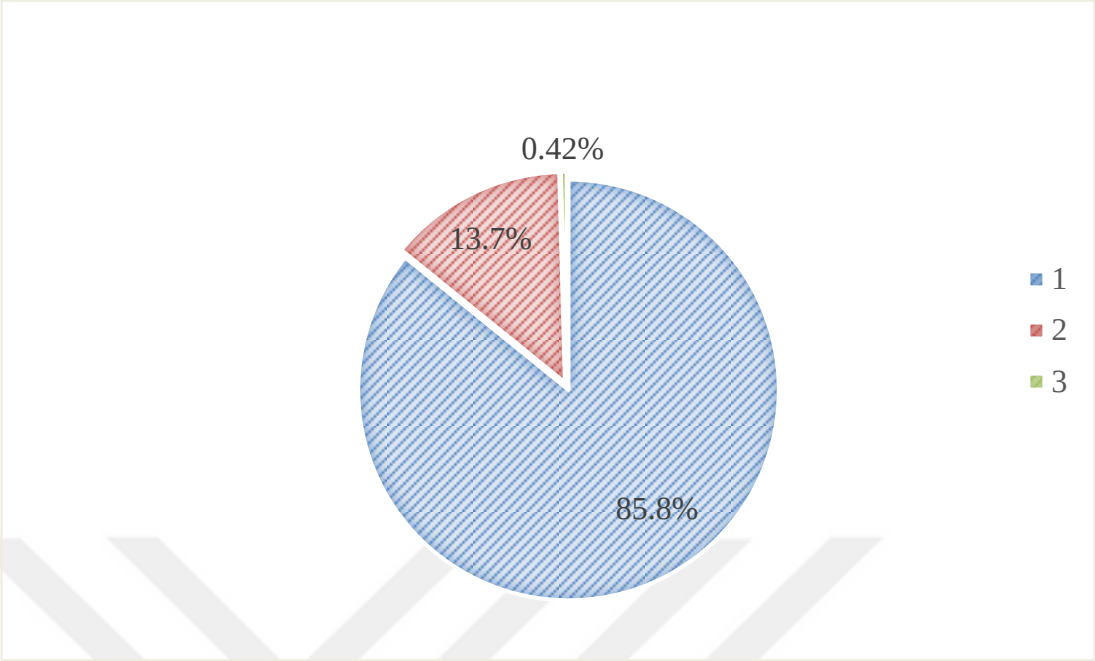

Figure 5.2 How many times per year do you plant in your farm

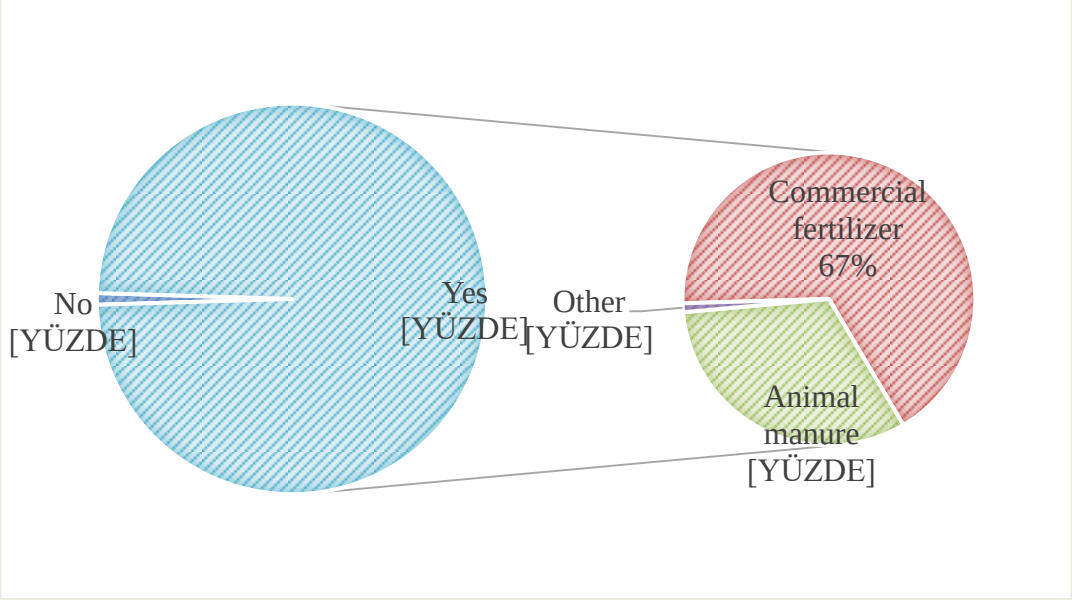

Figure 5.3 Do you use fertilizers to increase yield in the field? What kind of fertilizer do you use

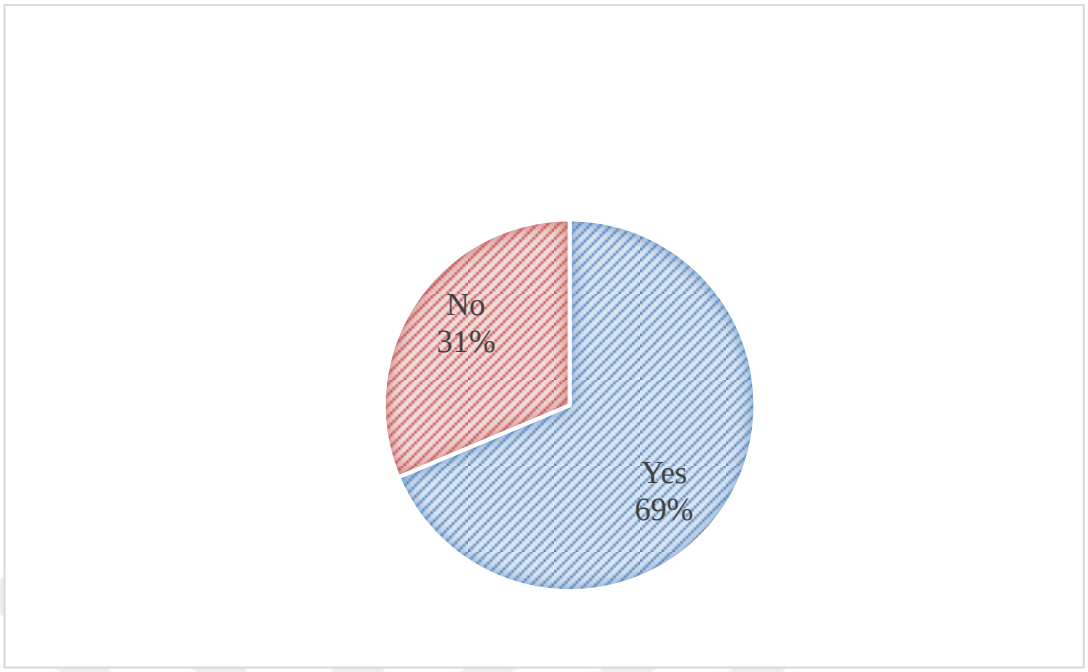

Figure 5.4 Do you know that wastewaters from domestic, urban and industrial water use are treated to prevent environmental pollution

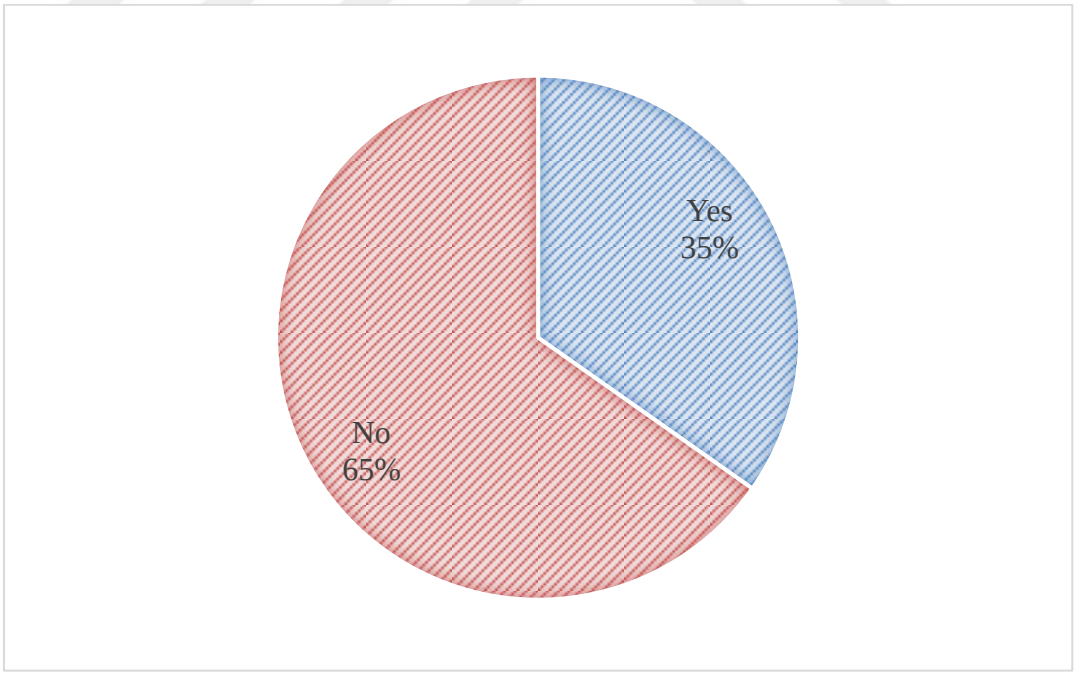

Figure 5.5 Do you know that wastewater treatment plants produce sewage sludge that can be harmful to the environment while treating wastewaters

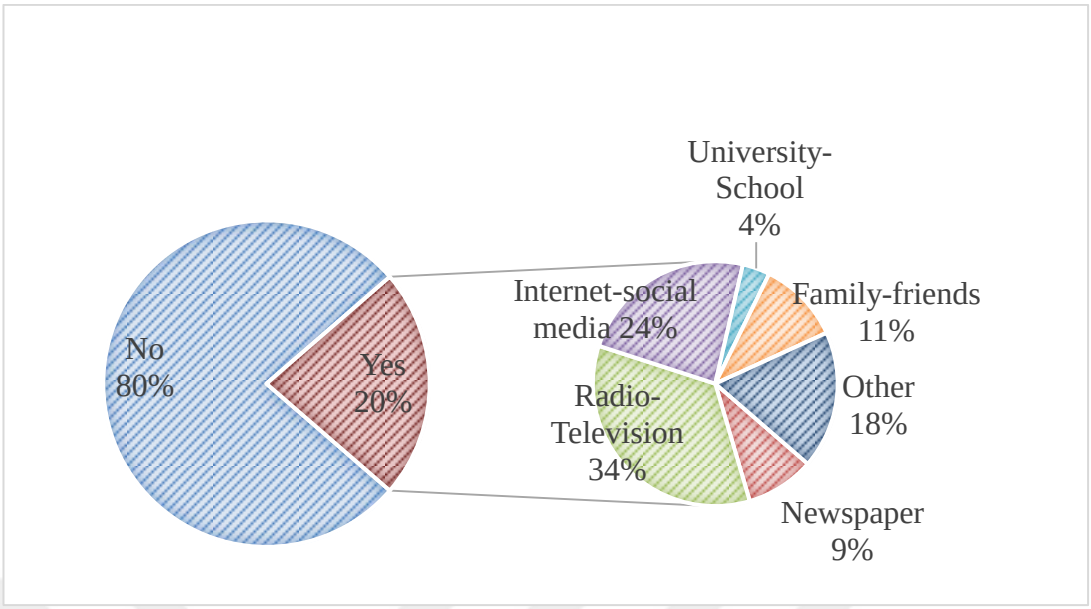

Figure 5.6 Do you know that stabilized sewage sludges are used in the soil as fertilizer for agricultural purpose

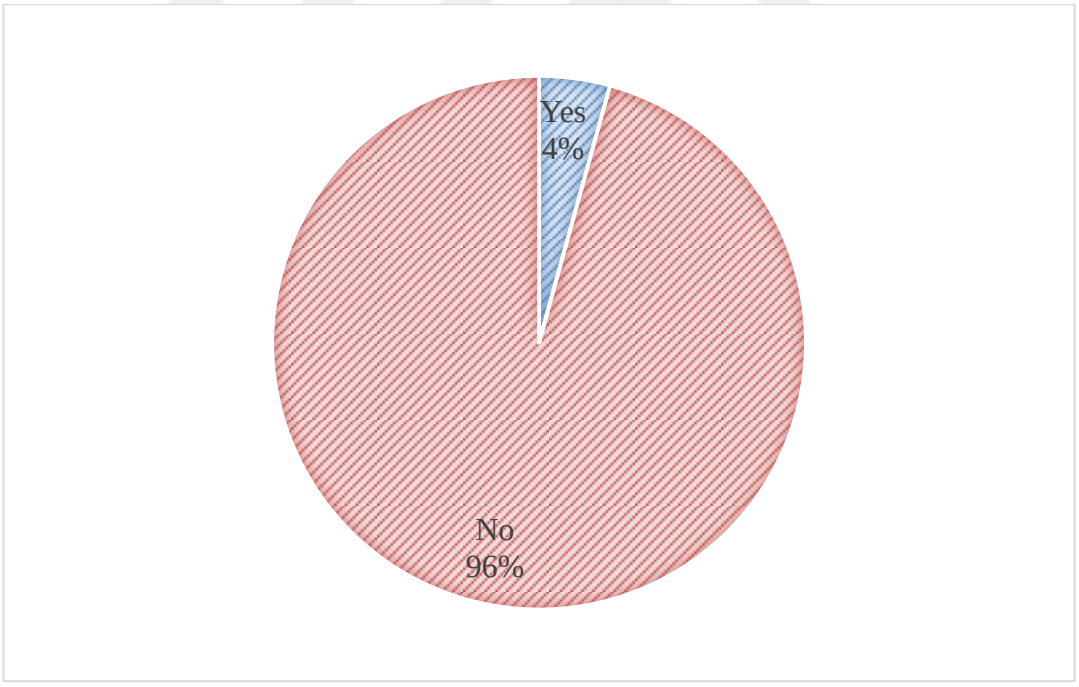

Figure 5.7 Do you have any information about the effect of the use of sewage sludge on the quality of crops in agriculture

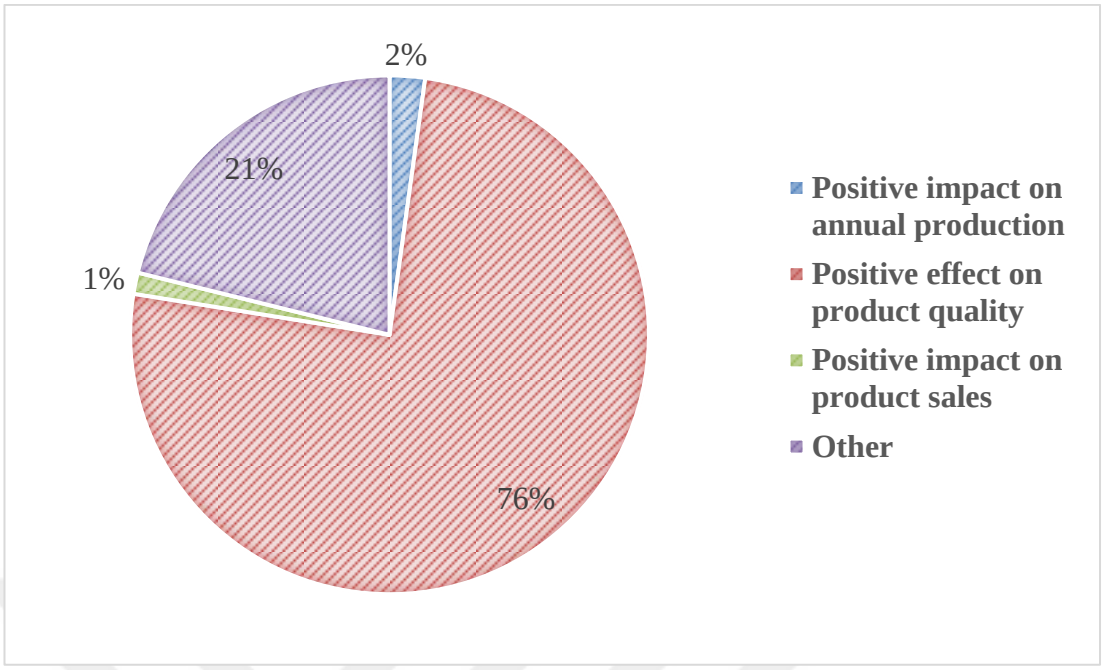

Figure 5.8 If you use sewage sludge while growing your products, what is your primary reason for choosing this

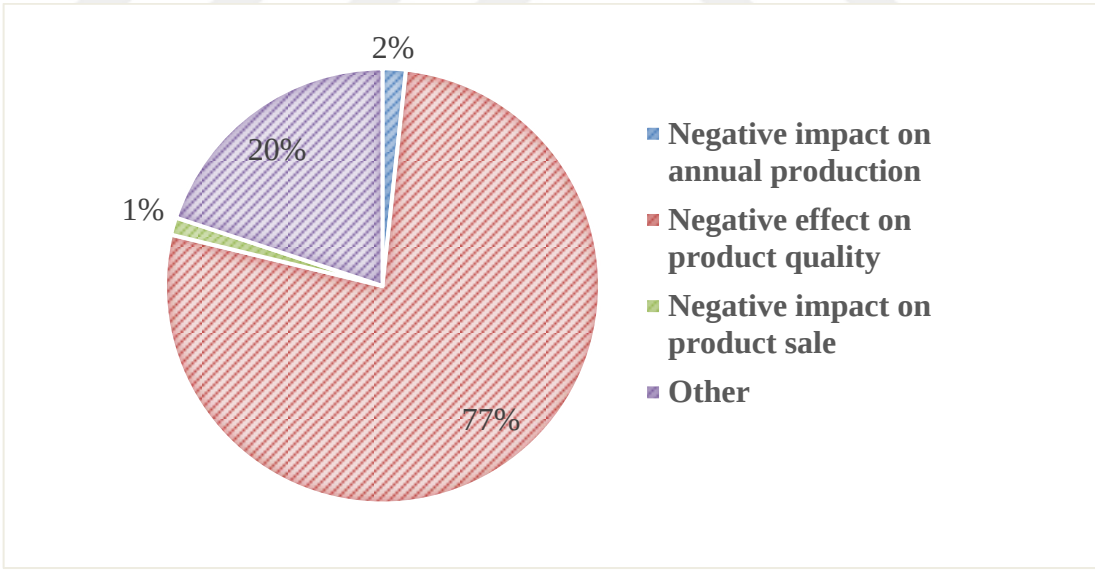

Figure 5.9 What is the primary reason you don't want to use sewage sludge while growing your products

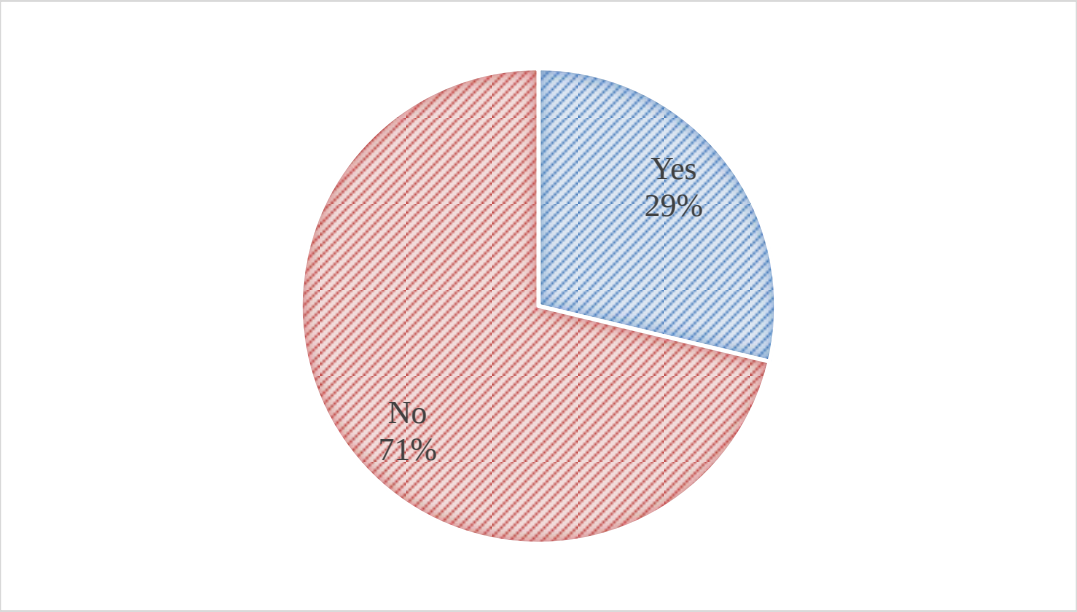

Figure 5.10 Do you think the use of sewage sludge will make the soil productive

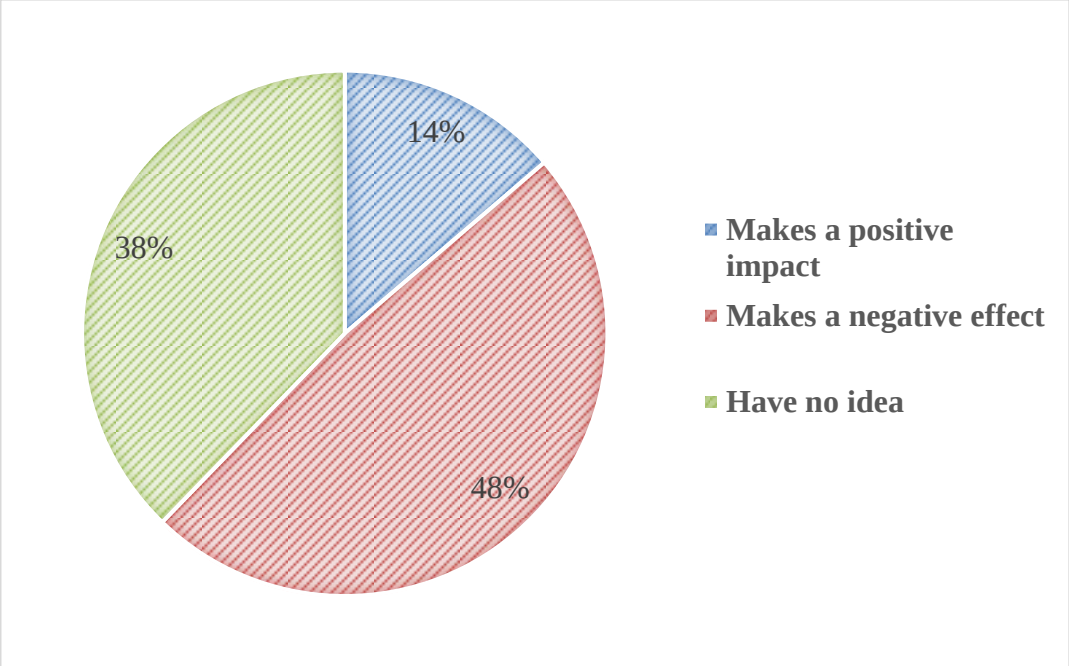

Figure 5.11 What do you think about the sale of the products you have grown by using sewage sludge

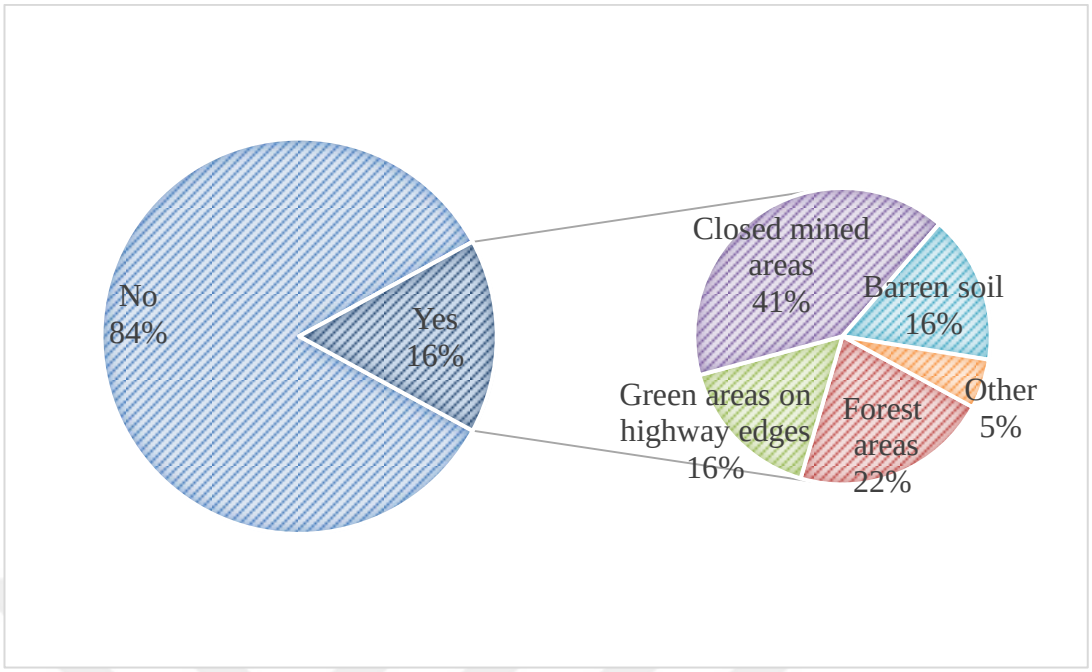

Figure 5.12 Do you know in which areas sewage sludge can be used except for agricultural purpose

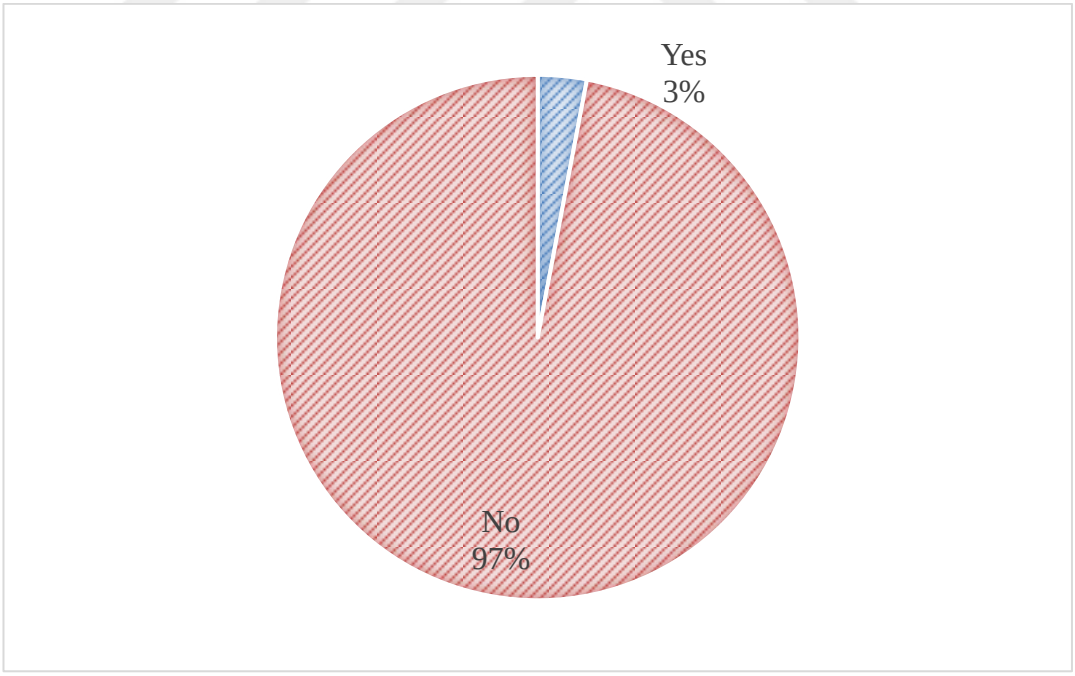

Figure 5.13 Are you aware of the regulations on the agricultural use of sewage sludge by the directive of the use of stabilized domestic / urban treatment sludges in soil

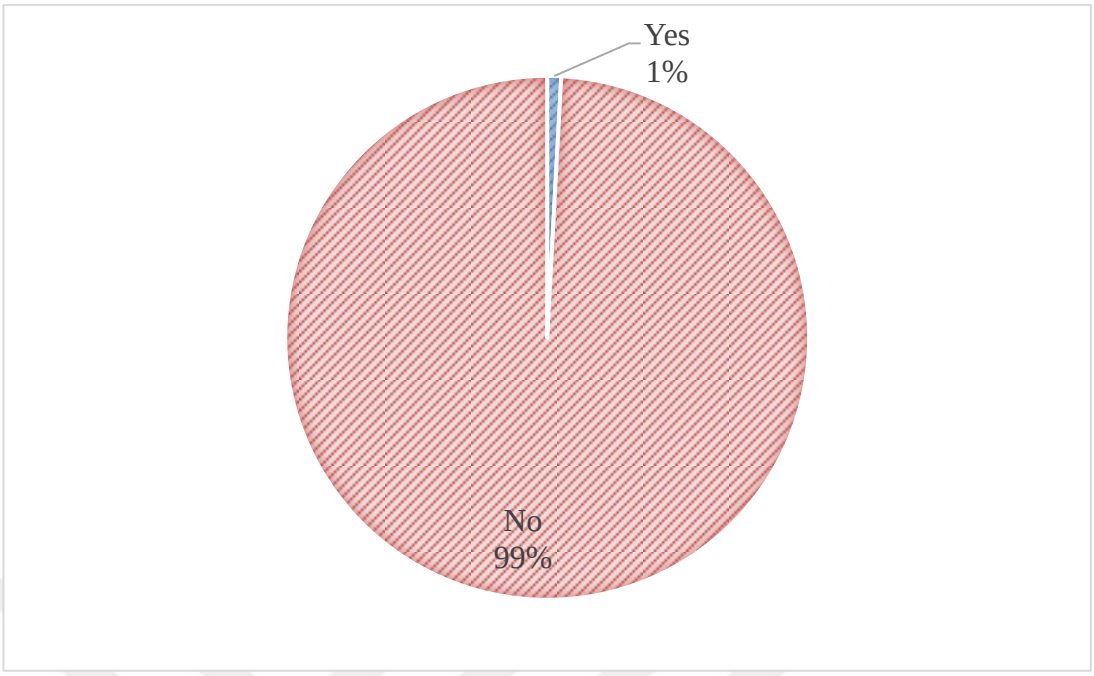

Figure 5.14 Do you think that the institutions / organizations responsible for water, wastewater and sewage sludge management in our country give enough information to farmers about the use of processed sludge in soil

They all agreed that the institutions/organizations and authorities, which are responsible for water/ wastewater treatment and sludge management, did not give a detailed information on the usage of processed sludges in soil. They also stated that the information about the application of the sludge as a fertilizer, the health risks associated with sludge on land, precautions to be taken during the application should be given to the farmers by the authorities. Beyond this, the necessity of the certification of sludge to be applied to the soil and the crops grown by using the stabilized sludge was remarked by the farmers having long experience with farming activities, especially for the food retailers and consumers. Similar doubts and worries were also obtained in different studies (Coffie et al., 2010; Joo et al., 2015; Moya et al., 2019).

The farmers' perception from the study showed that the challenging issues related to the sludge application on land should be assessed in details in Turkey since this

application, specifically agricultural, is still regarded as a beneficial usage alternative.

5.3 The Public Perception Based on the Survey Results

The first a few questions of the survey, which was prepared to determine the public perception, were about the environmental conscious on wastewater treatment and sludge production. While 83% of the respondents were aware of the wastewater treatment, 50% of them were aware of sludge production from the WWTPs. However, surprisingly 88% of the participants expressed the opinion that treatment plant sludges had pollutants and toxic pollutants including mostly heavy metals (41%) and pathogens (33%). Also, 63% of them had the knowledge on the nutrients availability in sludge as organic matter (37%), Nitrogen (35%), and Phosphorus (28%). When comparing to the responses of the farmers for the same questions, the awareness of the public was clearly quite high. The respondents aware of the sludge production, its properties, and usage of sludge as a fertilizer in many countries were also asked about the main sources for obtaining information. Among the information sources options given in the survey, they chose one or more options. The respondents stated that the internet-social media (35%), university-school (24%), and newspaper (13%) as their main learning sources while the most prevalent answers were radio-television and internet-social media for the farmer respondents. It can be said the internet-social media is the superior for the dissemination of the knowledge. However, the other sources can differ depending on the age and education of the both respondent groups.

In another study evaluating the public perception of water reuse alternatives in Turkey, it was also reported that the media was the dominant way of informing a community (Buyukkamaci and Alkan, 2013). Figure 20 shows the percentages of the responses given to the public survey.

While 79% of the respondents considered the agricultural use of stabilized sludge coming from domestic/urban WWTPs as suitable, the use of industrial sludge for this purpose was also highly accepted. Most of them (77%) expressed that the quality of the treated sludge should have been certificated by an accredited institution. Those

were also asked about the crop types. The commercial products (cotton, canola, safflower, etc.) were the widely accepted crops as 54%. However, in the case of eating the fruits and vegetables grown with stabilized sludge, a majority of the respondents (65%) refused the use of the sludge as a fertilizer on soil. Moreover, most of them did not support the use of floor, which is very important food material in Turkish people food habits, if it was obtained from the wheat or corn grown by using sludge as a fertilizer on soil. As mentioned by the farmers (48%) who remarked the negative impacts on the sale of the food products, the public respondents oppose the use of sludge for the growing of food crops, and fruits/vegetables. The responses of the question about using the textile products from the cotton grown the soil, which the sludge was applied as a fertilizer, was highly positive (70%).

A challenging concern is the appropriateness of the using processed sludges to grow grass or flowers in the playgrounds where the children could play due to the most of the people are very sensitive to the children. Unexpectedly, almost the half of the respondents (46%) were positive for this question. However, they claimed the sludge's quality should be guaranteed in terms of pathogens, toxic substances, and other pollutants to minimize the health risks. Especially, they focused on the long term unknown health effects.

Apart from the agricultural usage, the respondents answered the question on the other fields where the sludge could be applied as green areas in highway edges (27%), rehabilitation of closed mining areas (27%), barren soil (22%), and forest areas (21%) while the majority of the farmers answered this question as green areas in highway edges (41%). Most of the respondents (70%) were also unaware of the environmental regulation on the land application of stabilized domestic/urban sludge usage came into force in Turkey as in farmers' perception survey. However, the percentage ratio was lower than that in the farmers' survey. Almost the same percentage of the participants worried about whether the regulation would be enough to provide the safe food or not. As in the farmers' survey, the respondents (93%) claimed the lack of a detailed information on the land application of the sludge from

the institutions/organizations and authorities, which are responsible for water/ wastewater treatment and sludge management.

The public perception results regarding the sludge application for agricultural purpose showed that the female participants responded with mostly negative attitudes than males and they were more sensitive. It was observed that the amount of the positive responses was consistent with the increased education level. It was not found a certain link between the responses and age and income level. Similar results were also obtained in a study on the water reuse perception in Turkey (Buyukkamaci and Alkan, 2013).

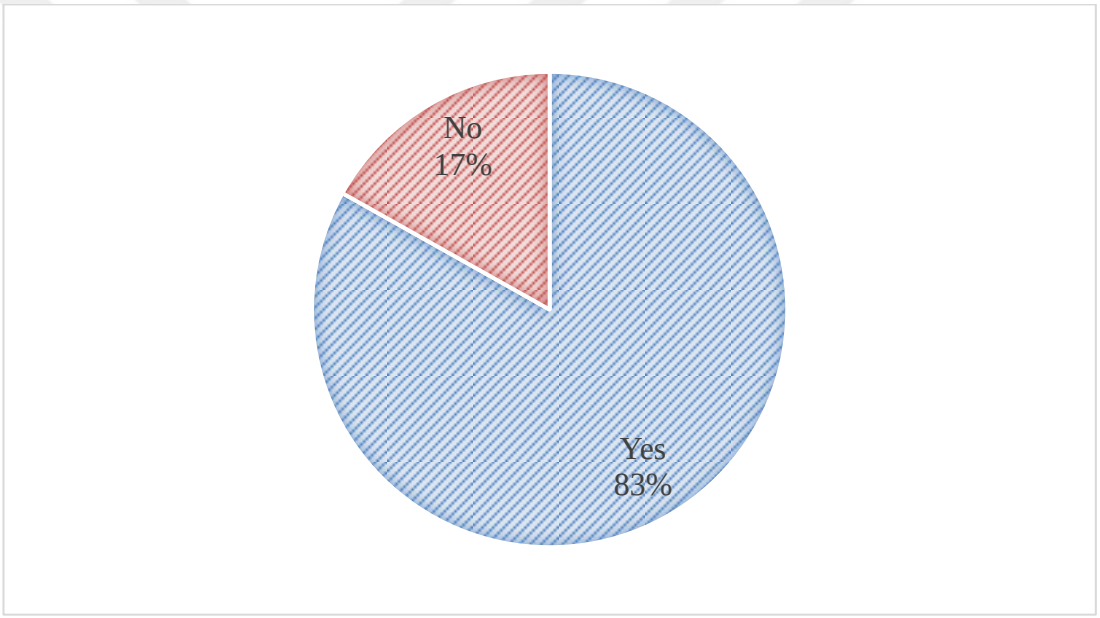

Figure 5.15 Do you know that wastewaters caused by domestic/municipal or industrial water usage are treated to protect environment

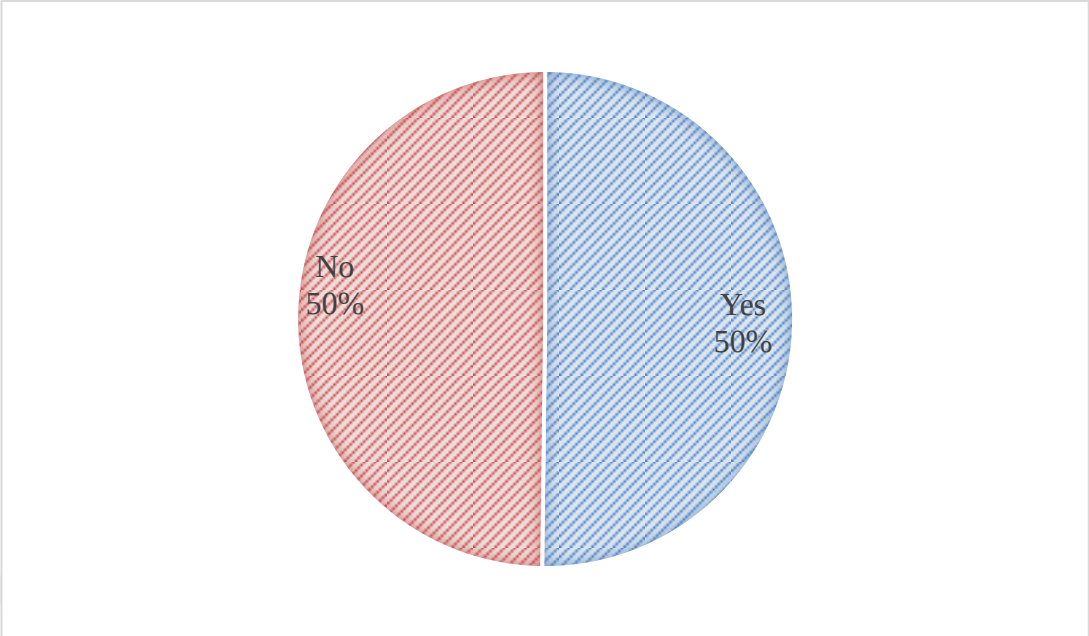

Figure 5.16 Are you aware of whether treatment plant sludges are produced as by-product in wastewater treatment plants during wastewater treatment processes

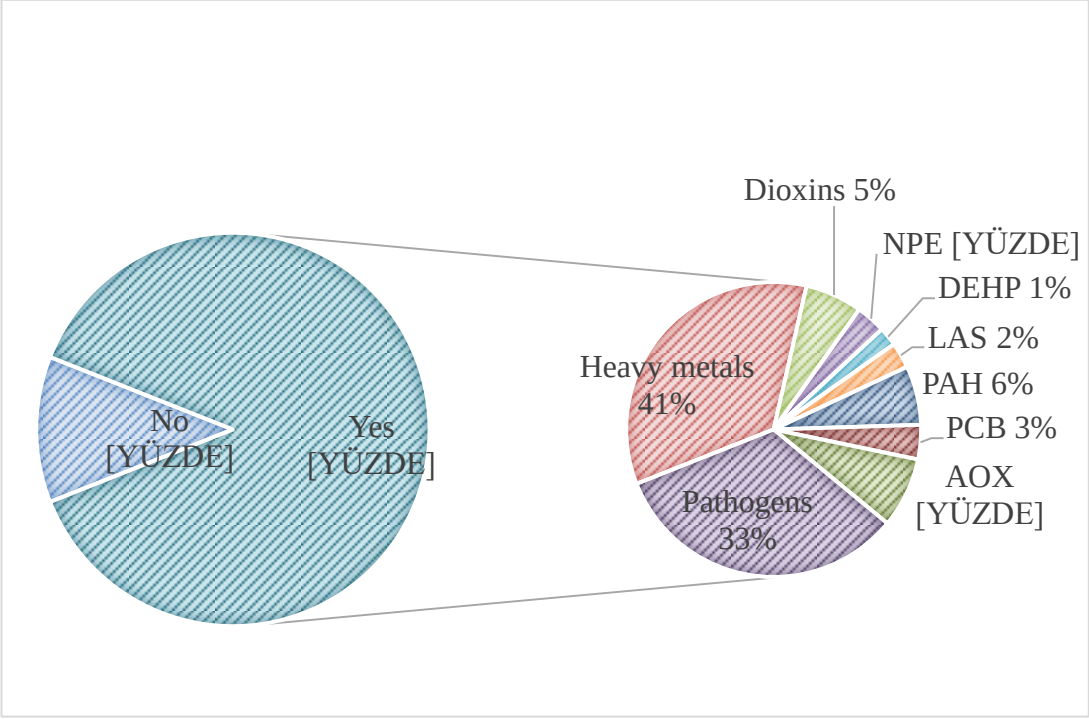

Figure 5.17 Do you think whether treatment plant sludges have pollutants/ toxic components

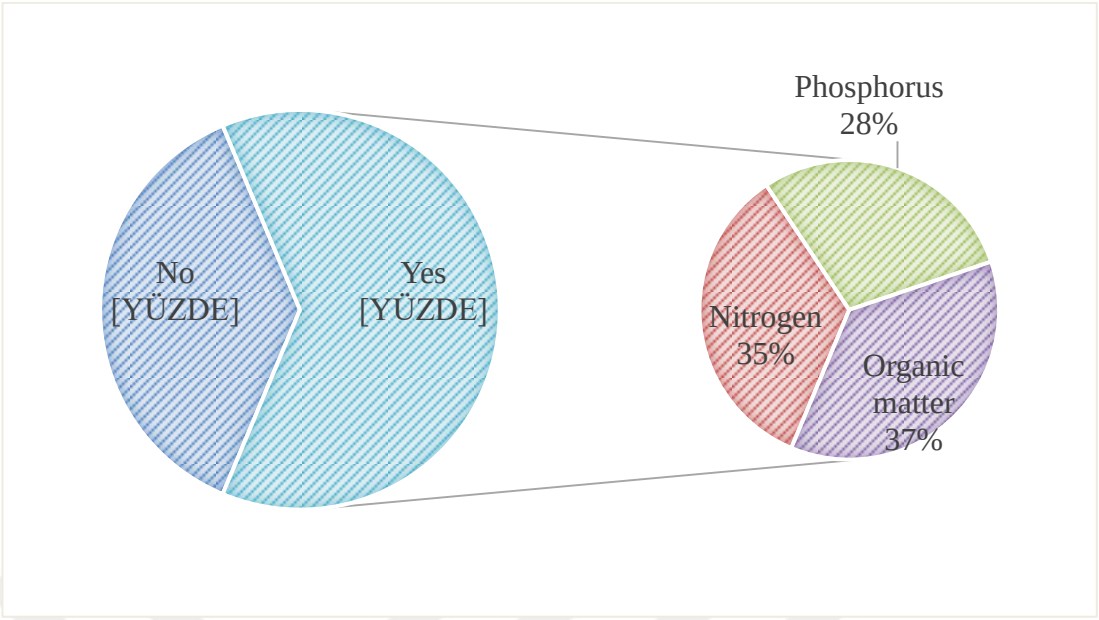

Figure 5.18 Do you know whether treatment plant sludges have nutrients used as a fertilizer

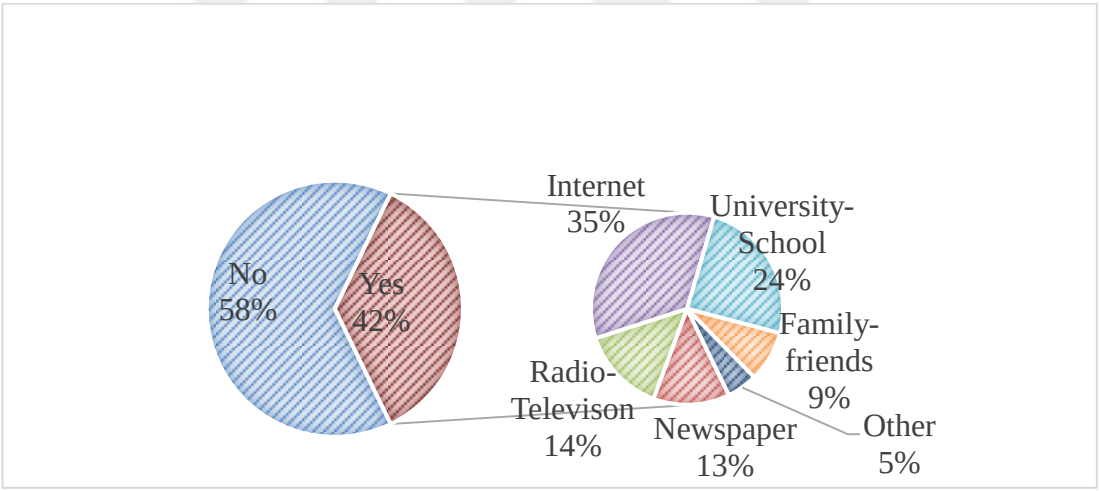

Figure 5.19 Do you know that treatment plant sludges have been used as a fertilizer in many countries if yes, how did you learn

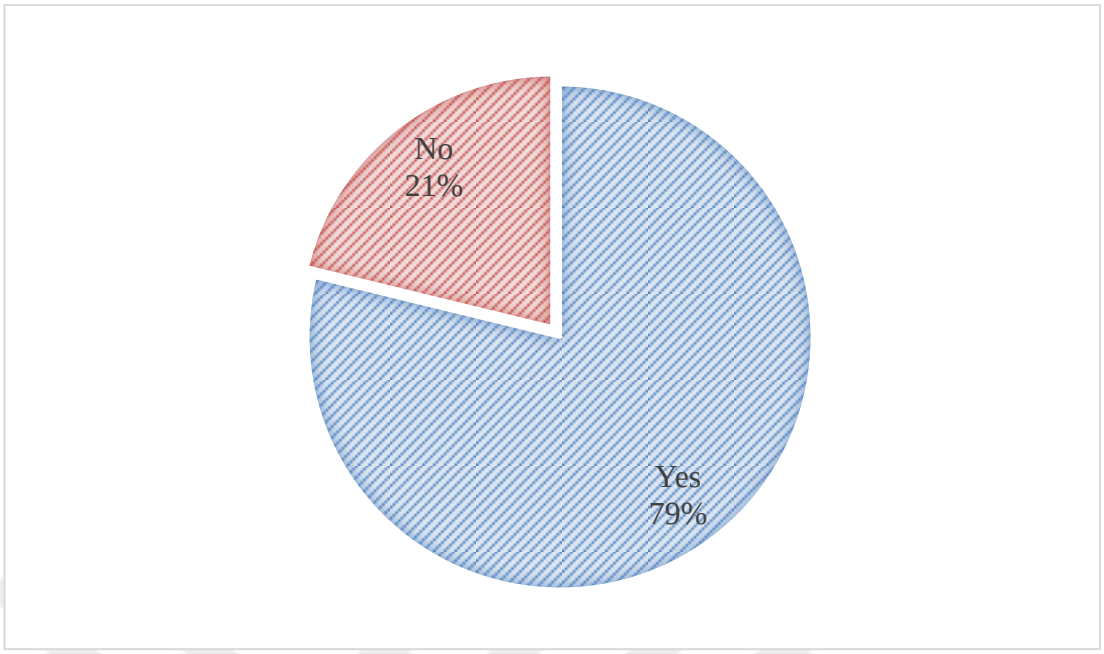

Figure 5.20 Is it appropriate that stabilized treatment plant sludges could be applied to the land for agricultural purpose

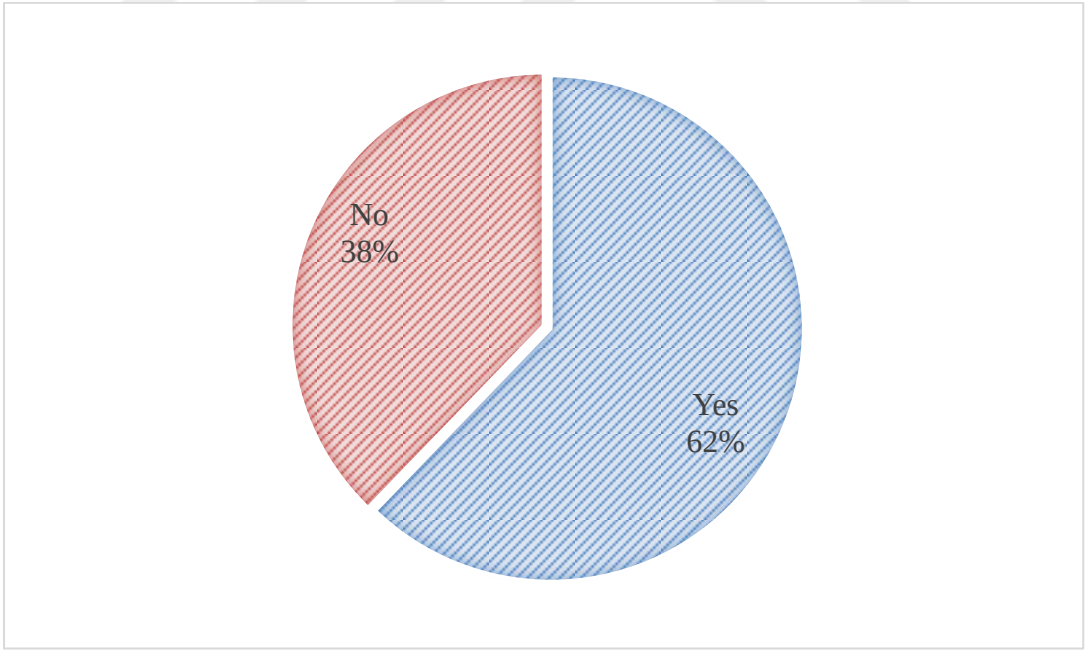

Figure 5.21 Is it appropriate that stabilized treatment plant sludges produced at industrial wastewater treatment plants could be applied to the land for agricultural purpos

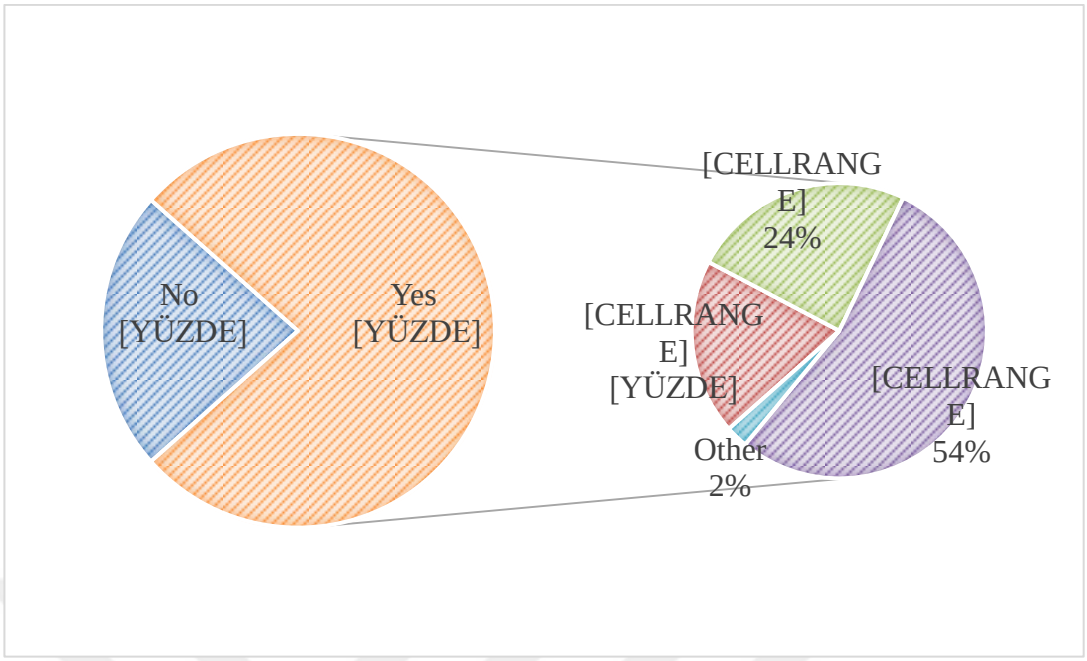

Figure 5.22 If the quality of the treated sludge is assured by an accredited institution, do you think that this sludge could be applied to the land for agricultural purpose if yes, which products can be grown by using this sludge as a fertilizer

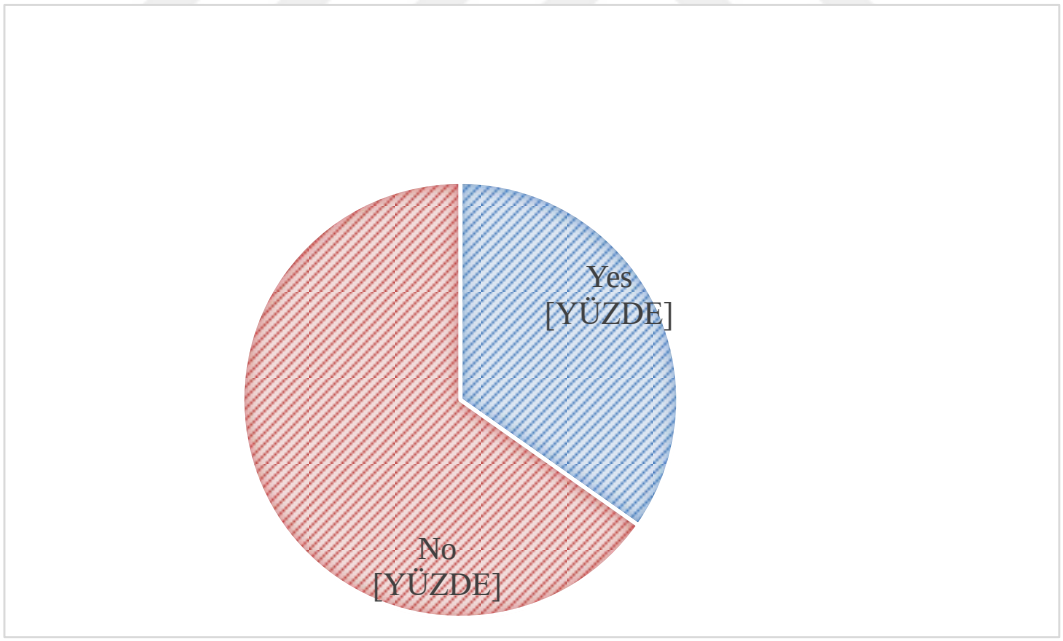

Figure 5.23 Do you accept to eat vegatables and fruits grown by using treatment plant sludge as a fertilizer

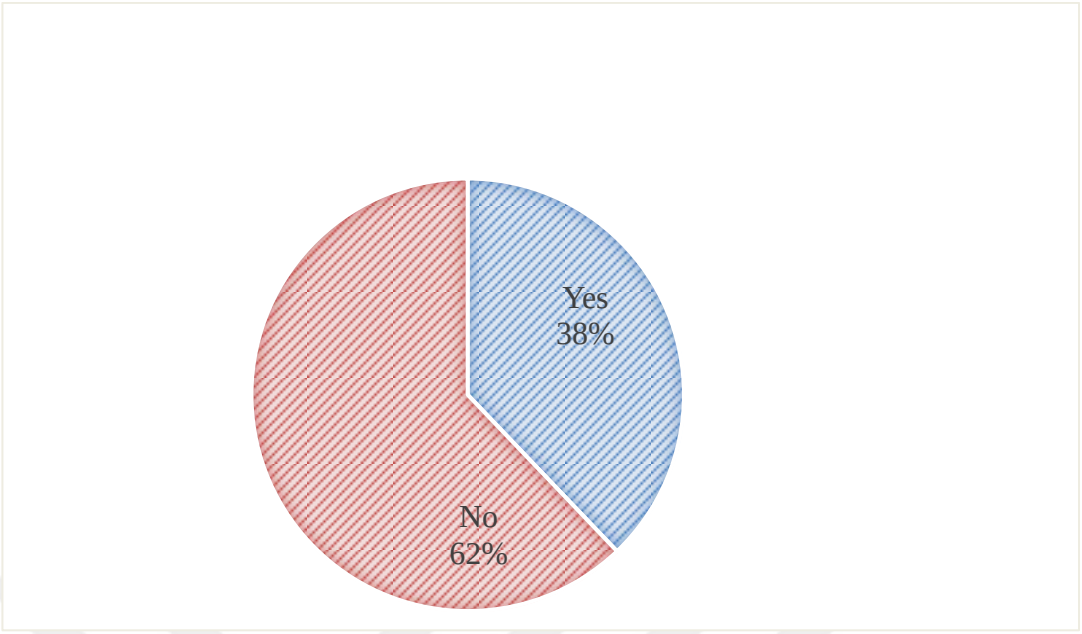

Figure 5.24 Do you accept to use floor obtianed by processing of wheat or corn grown by using treatment plant sludge as a fertilizer for your family

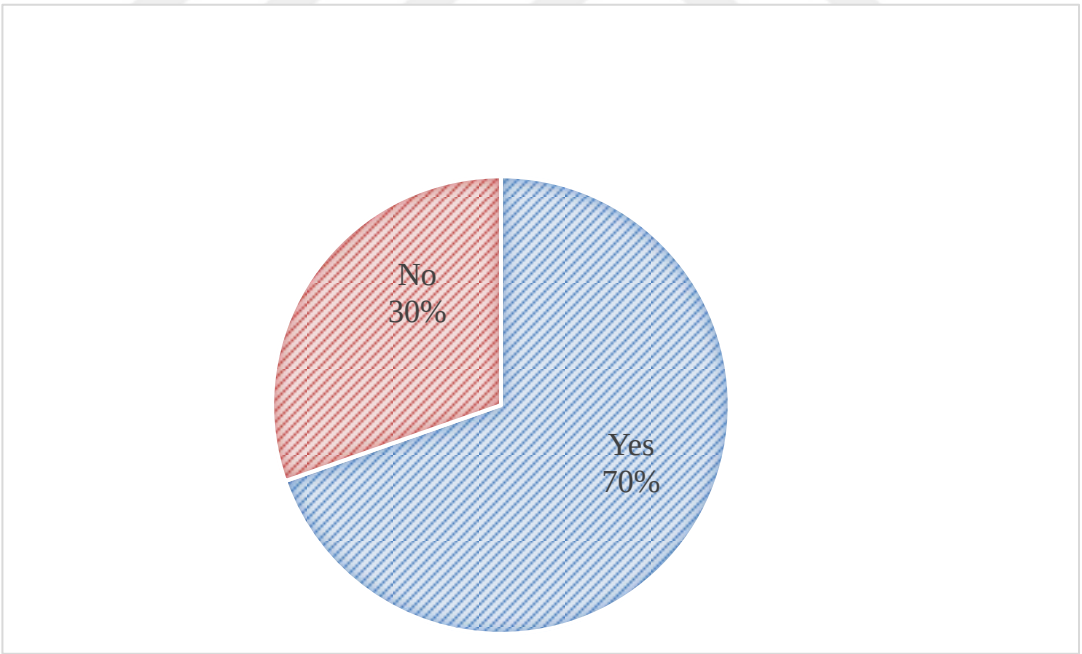

Figure 5.25 Do you accept to use textile products obtianed by processing of cotton grown by using treatment plant sludge as a fertilizer for your family

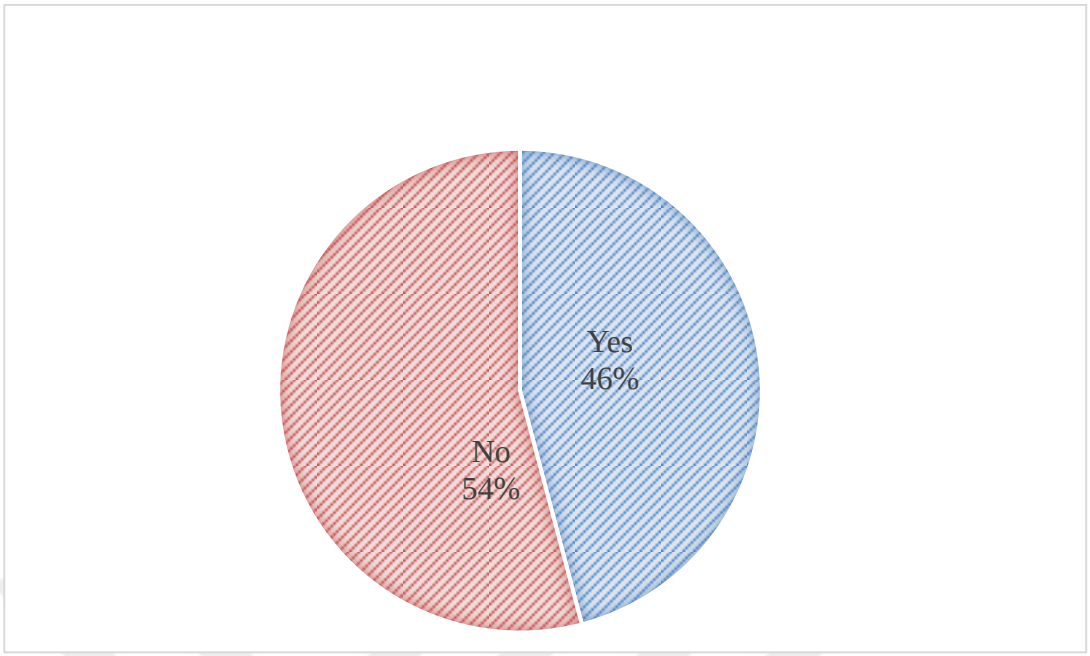

Figure 5.26 Is it appropriate to use treated sludges for grass or flowers in the playgrounds where the children can play

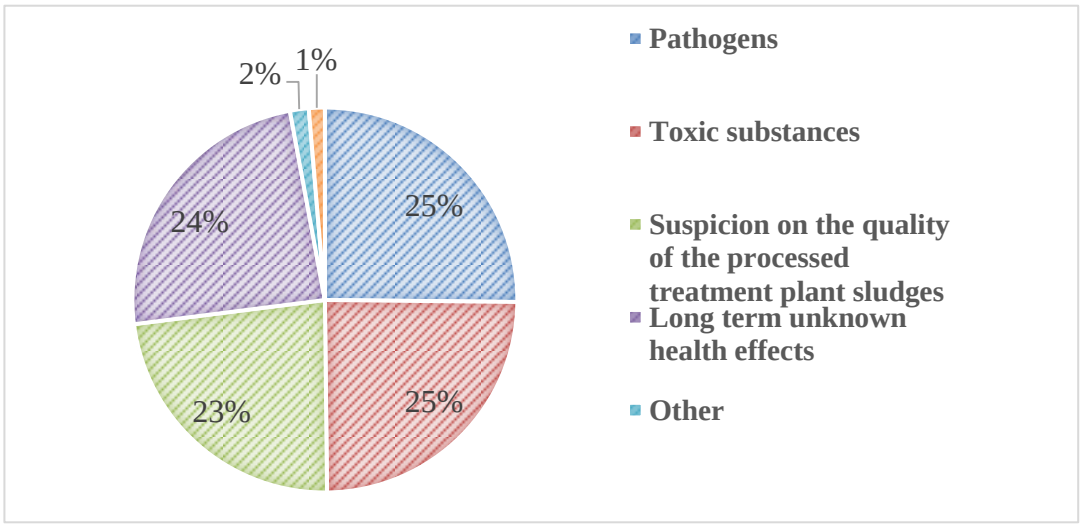

Figure 5.27 Do you have any suspicion about agricultural usage of treated sludges

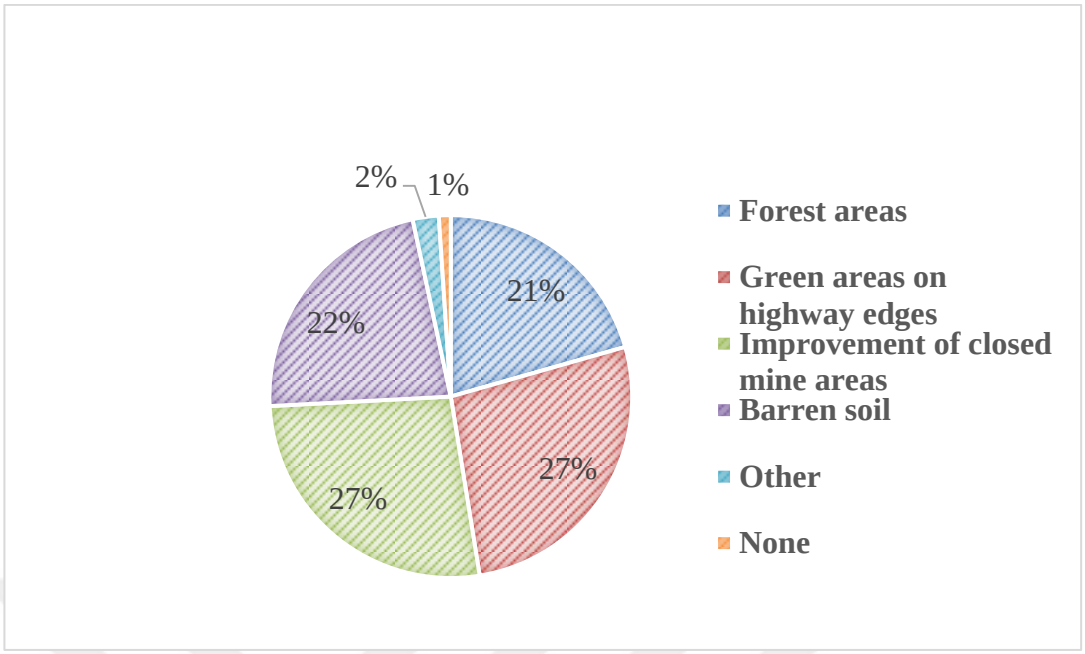

Figure 5.28 Except for agricultural usage of stabilized treatment plant sludges, do you think that it could be applied for another field

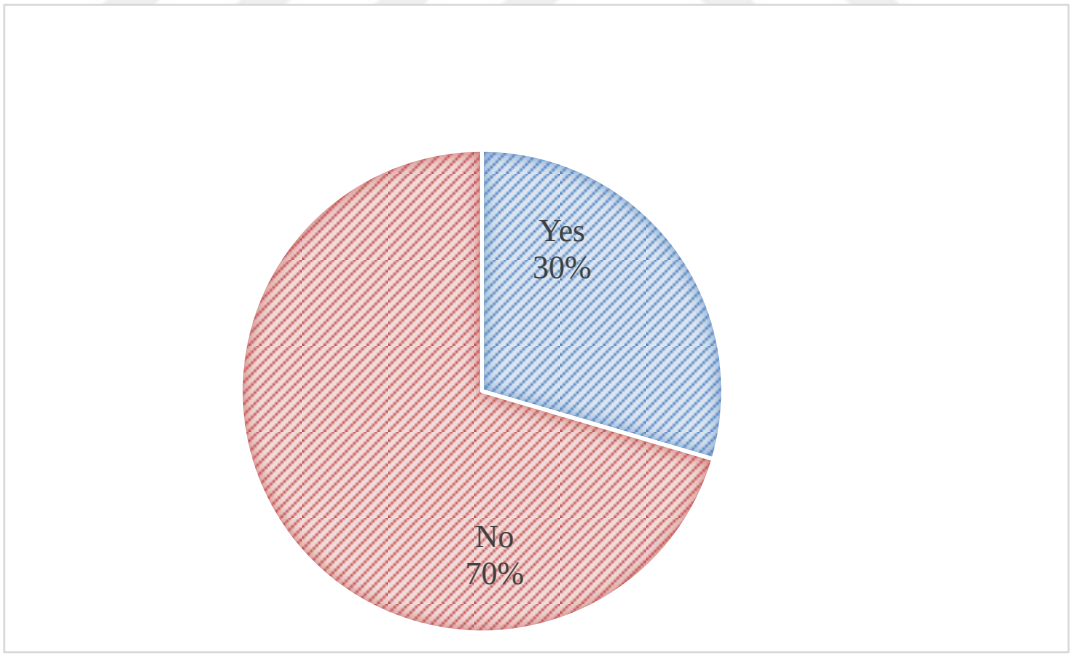

Figure 5.29 Do you know whether our country has a regulation or guideline for agricultural usage of treatment plant sludges

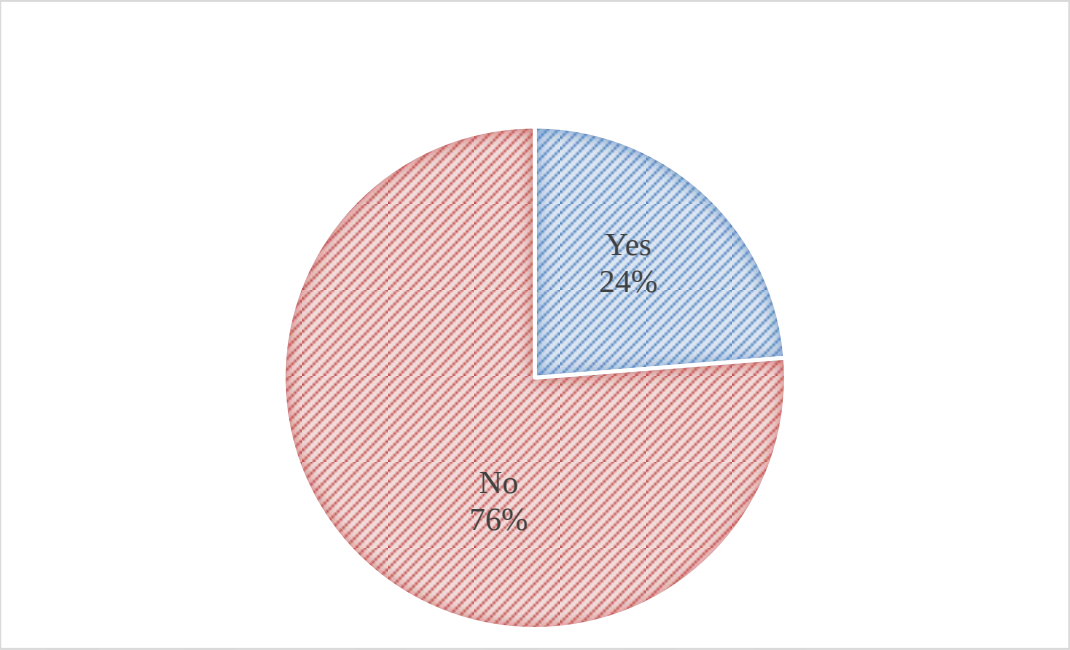

Figure 5.30 Do you think the environmental regulation on agricultural usage of treatment plant sludges would be enough regarding the safe food

CHAPTER SIX
CONCLUSIONS

6.1 Conclusions

The recycling of the sludge for use in agriculture are still in great concern in many undeveloped and developed countries for many reasons including providing a cost effective disposal method, meeting the organic matter need of soil, and also adding the nutrients to the plants. However, the challenges were identified regarding the public and farmers' perception in this study. The specific concluding remarks from this thesis were as follows:

- The farmers agreed on the organic amendments positively affecting the soil and the source of the fertilizer is not a great concern. However, they were mostly worried about its possible negative effects on the crop quality, food contamination, and the sale of the grown crops. The necessity of the certification of sludge to be applied to the soil and the crops grown by using the stabilized sludge was remarked by the farmers having long experience with farming activities, especially for the food retailers and consumers.

- Majority of the farmer respondents were unaware the availability of the Turkish regulation on land application of stabilized domestic/urban sludge regarding the agricultural usage of sludges.

- Most of the public participants claimed the opinion that treatment plant sludges had pollutants and toxic pollutants like heavy metals and pathogens in addition to the valuable nutrients and organic matter in sludge. The agricultural use of industrial sludges as well as the stabilized sludge coming from domestic/urban WWTPs was found as appropriate.

- The public respondents opposed the use of sludge for the growing of food crops, and fruits/vegetables although the textile products from the cotton grown the soil, which the sludge was applied as a fertilizer, was considered as highly positive.

- The quality of the treated sludge was found a critical issue in terms of its certification by an accredited institution. They insisted on the guaranteed sludge quality regarding the pathogens, toxic substances, and other pollutants to minimize the health risks. Especially, they focused on the long term unknown health effects.

- The public respondents stated that the internet-social media and university-school as their main learning sources while the most prevalent answers were radio-television and internet-social media for the farmer respondents. The internet-social media was found as the superior for the dissemination of the knowledge. However, the other sources can differ depending on the age and education of the both respondent groups.

- The both groups agreed that the governmental authorities, which are responsible for water/ wastewater treatment and sludge management did not give enough information on the land application of sludge. While the farmers mentioned that the unsatisfactory information on the application of the sludge as a fertilizer, the health risks associated with sludge on land, precautions to be taken during the application, the public participants focused on the health, food safety, and environmental risks.

- It was not found a certain link between the responses and age and income level. However, the more positive responses were taken depending on the increased education level.

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APPENDICES

Appendix 1:

A Survey on Farmer Perception of Treatment Plant Sludge Reuse for Agricultural Purpose

1- Age

☐ 10-15 ☐ 16-25 ☐26-40 ☐ 40-55 ☐ 55 >

2- Gender

☐ Female ☐ Male

3- Education

☐Primary School ☐Secondary School ☐High School ☐ BSc ☐Master MSc

☐ PhD ☐ PostDoct

4- City and Country

5- Please remark your income range (optional)

☐ < 175 € ☐175-345 € ☐ 345-520 € ☐ 520-850 € ☐ 850-1380 € ☐ >1380 €

6- What kind of products do you grow in your field ?

☐ Green leafy vegetables / fruits ☐ Corn, wheat etc.

☐ Commercial inedible plants such as cotton, canola and saffflower ☐ Other

7- How many times a year do you plant in your field? Is there a different breeding situation? Inform please.

8- Do you use fertilizer to increase yield in the field?

☐ Yes ☐ No

9- If yes, what kind of fertilizer do you use?

☐ Commercial fertilizer ☐ Animal fertilizer

☐ Other

10- What is the price of the fertilizer you use?

11- If there was a cheaper fertilizer option, would you try it ?

☐ Yes ☐ No

12- Do you know that wastewaters caused by domestic/municipal or industrial water usage are treated to protect environment?

☐ Yes ☐ No

13- Are you aware of whether treatment plant sludges are produced as by-product in wastewater treatment plants during wastewater treatment processes?

☐ Yes ☐ No

14- Do you know that treatment plant sludges have been used as a fertilizer in many countries (e.g USA, Germany, France)?

☐ Yes ☐ No

15- If your answer for the above question is yes, please explain how you learned them. You can choose one or more items given below.

☐Journal, newspaper ☐ Radio-TV ☐ Internet sources

☐ University-school ☐ Family or Friends ☐ Other

16- Is it appropriate that stabilized treatment plant sludges could be applied to the land for agricultural purpose?

☐ Yes ☐ No

17- Are there people around you who use sewage sludge as fertilizer in agriculture ?

☐ Yes ☐ No

18- Do you know about the effect of sludge treatment on the quality products?

☐ Yes ☐ No

19- Have you ever used sewage sludge when growing your crops?

☐ Yes ☐ No

20- If you use sewage sludge when growing your products, what is the

primary reason for choosing this?

☐ Positive impact on annual production ☐ Positive effect on product quality

☐ Positive effect on product sales ☐ Other

21- What is the primary reason for not wanting to use sewage sludge when growing your products?

☐ Negative effect on annual production ☐ Negative effect on product quality

☐ Negative impact on product sales ☐ Other

22- Do you think the use of sewage sludge will make the soil fertile?

☐ Yes ☐ No

23- What do you think about the sale of products you grow using sewage sludge?

☐ Positive effect ☐ Negative effect

☐ I have no idea

24- Do you know in which areas the sludge is used other tha agricultural?

☐ Yes ☐ No

25- If yes, in which areas would it be appropriate to use it?

☐ Forest areas

☐ Highway in green spaces

☐ Improvement of closed mining areas

☐ Barren lands

☐ Other

☐ None

26- Do you have any informatşon about the legal use of sewage sludge in our country?

☐ Yes ☐ No

27- Do you know whether your country has a regulation or guideline for agricultural usage of treatment plant sludges?

☐ Yes ☐ No

28- Do you have any information about the stages of treatment sludge until it reaches the agricultural use stage?

☐ Yes ☐ No

29- Do you think that the authorities which are responsible for water/ wastewater/ sludge management transfer enough information on the land/agricultural application of treated sludges to the farmer?

☐ Yes ☐ No

Appendix 2:

A Survey on Public Perception of Treatment Plant Sludge Reuse for Agricultural Purpose

1- Age

☐ 10-15 ☐ 16-25 ☐ 26-40 ☐ 40-55 ☐ (>55)

2- Gender

☐ Female ☐ Male

3- Education

☐Primary School ☐Secondary School ☐ High School ☐ BSc ☐ MSc

☐ PhD ☐ PostDoct

4- City and Country

5- Please remark your income range (optional)

☐ < 175 € ☐ 175-345 € ☐ 345-520 € ☐ 520-580 € ☐ 850-1380 € ☐ > 1380 €

6- Do you know that wastewaters caused by domestic/municipal or industrial water usage are treated to protect environment?

☐ Yes ☐ No

7- Are you aware of whether treatment plant sludges are produced as by-product in wastewater treatment plants during wastewater treatment processes?

☐ Yes ☐ No

8- Do you think whether treatment plant sludges have pollutants/ toxic components?

☐ Yes ☐ No

9- If your answer for the above question is yes, please choose the pollutants that you know from the list below.

☐ Heavy metals (Lead, Cadmium, Zinc, Nickel, Cupper, Mercury, Chromium)

☐ AOX (Adsorbable organic halogens)

☐ LAS (Linear alkylbenzene sulphonates)

☐ DEHP (Di (2-ethylhexyl) phthalate)

☐ NPE (Nonylphenol and nonylphenol ethoxylates with one or two ethoxy groups)

☐ PAHs (Polycyclic Aromatic Hydrocarbons)

☐ PCBs (Polychlorinated biphenyls)

☐ Dioxins (PCDD/F Polychlorinated dibenzodioxin / dibenzofuran)

☐ Pathogens

10- Do you know whether treatment plant sludges have nutrients (nitrogent and phosphorus) used as a fertilizer?

☐ Yes ☐ No

11- If your answer for the above question is yes, which one of them from the list below is known by you?

☐ Nitrogen

☐ Phosphorus

☐ Organic matter

12- Do you know that treatment plant sludges have been used as a fertilizer in many countries (e.g USA, Germany, France)?

☐ Yes ☐ No

13- If your answer for the above question is yes, please explain how you learned them. You can choose one or more items given below.

☐Journal, newspaper ☐ Radio-TV ☐ Internet sources

☐ University-school ☐ Family or Friends ☐ Other

14- Is it appropriate that stabilized treatment plant sludges could be applied to the land for agricultural purpose?

☐ Yes ☐ No

15- Is it appropriate that stabilized treatment plant sludges produced at industrial wastewater treatment plants could be applied to the

land for agricultural purpose?

☐ Yes ☐ No

16- If the quality of the treated sludge is assured by an accredited institution, do you think that this sludge could be applied to the land for agricultural purpose?

☐ Yes ☐ No

17- If your answer for the above question is yes, which products can be grown by using this sludge as a fertilizer. Please choose them from the list below.

☐ Vegetables and fruits

☐ Corn, wheat, peanut etc.

☐ Commercial products like cotton, canola, safflower

☐ Other

18- Do you accept to eat vegetables and fruits grown by using treatment plant sludge as a fertilizer?

☐ Yes ☐ No

19- Do you accept to use floor obtianed by processing of wheat or corn grown by using treatment plant sludge as a fertilizer for your familiy?

☐ Yes ☐ No

20- Do you accept to use textile products obtianed by processing of cotton grown by using treatment plant sludge as a fertilizer for your familiy?

☐ Yes ☐ No

21- Is it appropriate to use treated sludges for grass or flowers in the playgrounds where the children can play?

☐ Yes ☐ No

22- Except for agricultural usage of stabilized treatment plant sludges, do you think that it could be applied for another field? Please choose one or more alternatives from the list below.

☐ Forest areas

☐ Highway in green spaces

☐ Improvement of closed minig areas

☐ Barren lands

☐ Other

☐ None

23- Do you know whether your country has a regulation or guideline for agricultural usage of treatment plant sludges?

☐ Yes ☐ No

24- Do you think the environmental regulation on agricultural usage of treatment plant sludges would be enough regarding the safe food?

☐ Yes ☐ No

25- Do you have any suspicion about agricultural usage of treated sludges? If yes, you can choose one or more items below.

☐ Pathogens

☐ Toxic substances

☐ Suspicion on the quality of the treatment plant sludges processed

☐ Long

term unknown health effects

☐ Other (please specify it)

☐ There is no risk.

26- Do you think that the authorities which are responsible for water/ wastewater/ sludge management transfer enough information on the land/agricultural application of treated sludges to the public?

☐ Yes ☐ No