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Review Article

Recycling domestic sewage sludge to agricultural and farming areas in line with Sustainable Development Goals (SDG)

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ABSTRACT

Corresponding to the rapid increase in population, the increase in the number of domestic wastewater treatment plants, as well as the increase in domestic sludge levels above acceptable levels, pave the way to utilize sewage sludge in a variety of different applications and usage areas. Using sewage sludge in agriculture, landscape plant cultivation, and other agricultural areas has a number of advantages, including the ability to make rational use of waste without damaging the environment as well as delivering fertilizer benefits to the plant due to the high organic matter content of the wastewater sludge. Aside from these advantages, the most serious drawbacks of waste sewage are pathogenic bacteria, heavy metal contamination, and the presence of potentially hazardous compounds. The use of existing waste in the soil in appropriate proportions and in methods that are compatible with ecological life, on the other hand, will contribute to the fertilization of agricultural areas, providing an alternative to the fertilizer industry. The Sustainable Development Goals (SDGs), also known as the Global Goals, are a global call to action to end poverty, safeguard the environment, and guarantee that everyone lives in peace and prosperity. It is expected that this research will help to promote awareness about the reuse of waste within the context of a sustainable environment, as well as shed light on the application of sewage sludge to agricultural fields in accordance with the Sustainable Development Goals. Furthermore, the support for sewage sludge recycling in agricultural regions for long-term development goals is shown.

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INTRODUCTION

Rapid increases in the world population have expedited the economic and technical advancements taken by human beings, resulting in a rapid depletion of our planet's natural resources. Because our resources are finite, exhaustion and deprivation are unavoidable consequences of our existence. The natural balance of the environment, which humanity uses thoughtlessly and rudely, has deteriorated over time, and this situation has caused irreversible detrimental consequences.

Today, the subject of waste management is a critical concept that is being explored and stressed in a variety of disciplines [1]. Projects and studies on this subject have been increasing, especially recently. The most significant cause for this is a decrease in the ecosystem's tolerance for wastes as a result of climate change. In fact, as a result of the careless release of waste and toxic substances into the environment, the ecological system has begun to worsen significantly around the world [2]. This scenario has developed into a problem that must be addressed at this point, and it has impacted

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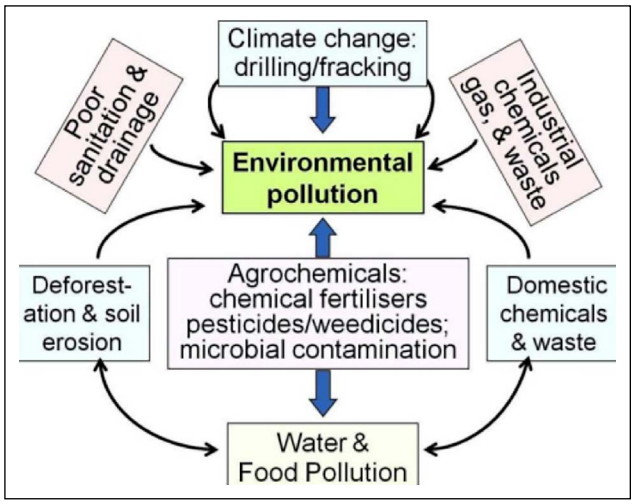

Figure 1. Agrochemical-related environmental pollution [4].

every phase of ecological life as well as the substance of ecosystems in the process. We know that the scenario in which we use our ecological assets carelessly and allow waste to decompose in their natural surroundings without thinking about the harms caused by the waste has extremely negative repercussions for ourselves, our environment, and the entire ecosystem. We started to pay for the price, starting from sea species that are dealing with plastic and other pollution, as well as polar bears that are having difficulties finding a home as a result of global warming in the polar regions, to the plastic in the deepest parts of the oceans and traces of pollution in the most remote places of the earth that have not been touched by humans, as well as the loss of many living species around the world.

Human beings, who are responsible for an increase in pollutant concentrations around the world, damage the ecosystems in which they live by disposing of their waste in urban areas. As can be seen in Figure 1, the source and focal point of many environmental pollution is human. Chemicals and non-organic products used in agriculture and industry to increase productivity cause environmental pollution and cause serious damage to the ecosystem. Harmful pollutants also clog the pores of the soil that provide water and air permeability. With the effect of water and wind erosion, pollutants cause soil and water pollution by moving from their place to another place. Soil pollutants can be decomposed both chemically and by microorganisms living in the soil and turn them into harmless compounds. The products released as a result of decomposition pollute the water, soil and air by passing from the soil solution to the groundwater by washing and adsorbed in the soil. This situation threatens the health and life of the biological environment [3].

Wastewater is created at a high rate in urban areas with a large number of residents. Water treatment plants for domestic wastewater make sure that the sewage water that we release into rivers, lakes, and seas is treated under the standards set forth in the regulations and that it is released into these environments in a manner that does not harm the ecological life that exists therein. This is very important for the sustainability of the environment. There is, however, a significant amount of waste created at the facility's outflow, and the treatment and disposal of this waste is a significant challenge.

Increasing the number of treatment facilities has become more important in recent years in order to mitigate the environmental harm caused by domestic and industrial waste. A growing number of people are opting to transfer domestic waste to the soil environment that is utilized for farming and agricultural purposes in order to prevent re-pollution and manage the nutritional content of these wastes.

In order to properly define the outputs created as a consequence of industrial and domestic activities as "waste," it is necessary to first determine whether they can be used as an input element in another process or production. Utilizing waste as an input to another business allows the waste to serve as a resource for the other business and to be recycled back into the system.

The move from an unsustainable linear economy to a circular economy, which we might define as sustainable and environmentally friendly, has accelerated in recent years around the world. Taking this into consideration, it has now been widely accepted around the world to include all types of waste into the economy, both in the form of a symbiotic relationship and through recycling.

The use of biological treatment sludge, which is a byproduct of a domestic treatment plant, in agricultural regions helps to the formation of living spaces on land by promoting the goals of responsible production and consumption, which is in line with sustainable development goals. The aim of our study; It is the disposal of the waste sludge, which is a waste and formed at the exit of the wastewater treatment plant, without harming the nature. While doing this, it is to be able to use it safely in agricultural areas by making use of the rich organic content and fertilizer feature of the waste sludge. The use of a waste element for the purpose of benefiting the nature again and moreover, serves the concept of sustainability. The contribution of this situation to all SDGs related to the environment is discussed one by one.

SUSTAINABLE DEVELOPMENT GOALS (SDG)

Sustainability Concept

Sustainability is one of the most widely used concepts today, owing to the high demand for raw resources and the ongoing quest for answers to the massive growth in the volume of environmental waste that has occurred in recent years all over the world. Although the word "sustainability," which has been used especially since the 1980s and comes from the Latin word "Sustinere," has different meanings in dictionaries yet, essentially, it means to provide, maintain, keep, support [5].

One can state that in the early periods of the 19th century, the sustainability concept was expressed perceptibly in the literature, and it emerged about renewable resources such as agriculture, forests, and fisheries as a specific notion [6].

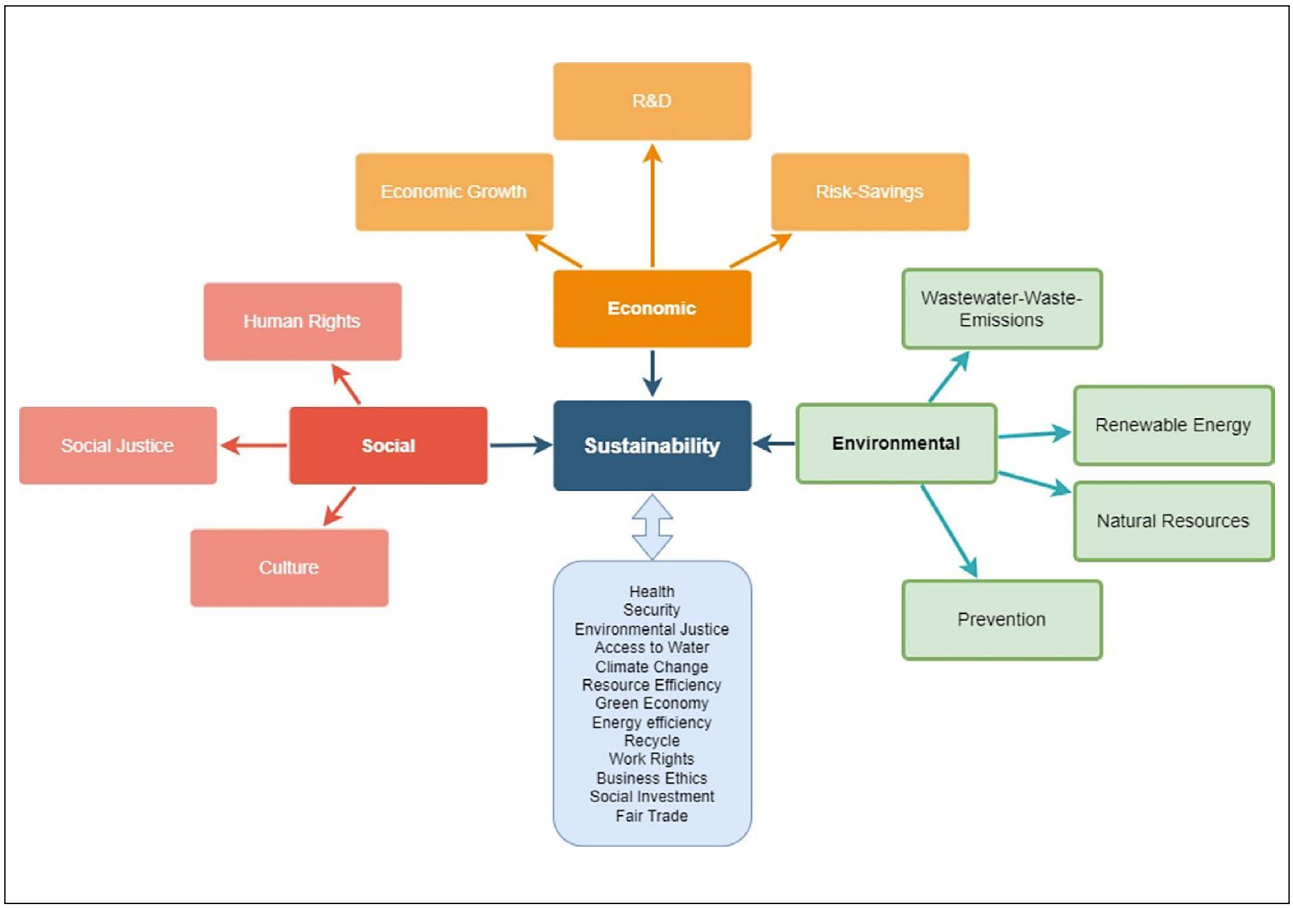

Figure 2. The concept of sustainability and its components.

The sustainability of something can mean its current state of existence or capacity to renew itself. Based on this definition of the word, the notion of sustainability has been applied in the sense of leaving future generations with a world that is sustainable in terms of environmental, economic, and social conditions (Fig. 2).

As can be seen in Figure 2, it is clear that the concept of sustainability is closely tied to economic, social and environmental factors. In order to achieve sustainability, each element supports each other. According to the sustainable development approach, if a coordination between the environment and economic policies is ensured, an improvement in the social structure will also occur. In this context, it is possible to talk about three dimensions of sustainable development that can be defined as economic sustainability, social sustainability and environmental sustainability. The first of these dimensions includes participation and a strong civil society, the second includes the stability of economic capital, and the third includes meeting human needs, conserving natural resources and promoting human well-being [7].

The United Nations' report Our Common Future, issued in 1983, had a significant impact on the definition of the word sustainability. According to the research, sustainability is defined as meeting our daily requirements and developing without jeopardizing nature's and future generations' capacity to meet their own needs.

Sustainability Concept

The problem of sustainable development and sustainability is a critical one on the academic and policy agendas today. It is well known that the subject of sustainable development and sustainability has an interdisciplinary structure that encompasses a broad range of issues in terms of environmental, economic, and social dimensions, as well as pragmatic and political aspects that are accompanied by a solution-oriented standpoint.

The term sustainability has been defined by different sources since its inception. However, due to the fact that this phenomenon is multifaceted, comprehensive and holistic; It is obvious that it is a complex concept that is not easily understood and needs to be explored and developed in depth.

The most common definition of sustainable development is the one by the World Commission on Environment and Development in 1987. According to this definition, development is about 'meeting the needs of the present without compromising the ability of future generations to meet their own needs' [8].

The approach to sustainable development emphasizes the need for increasing economic growth while also taking a protective stance against environmental degradation by placing a high priority on environmental concerns. In brief, for the last quarter-century, efforts have been made to balance the negative consequences of expanding economic ac-

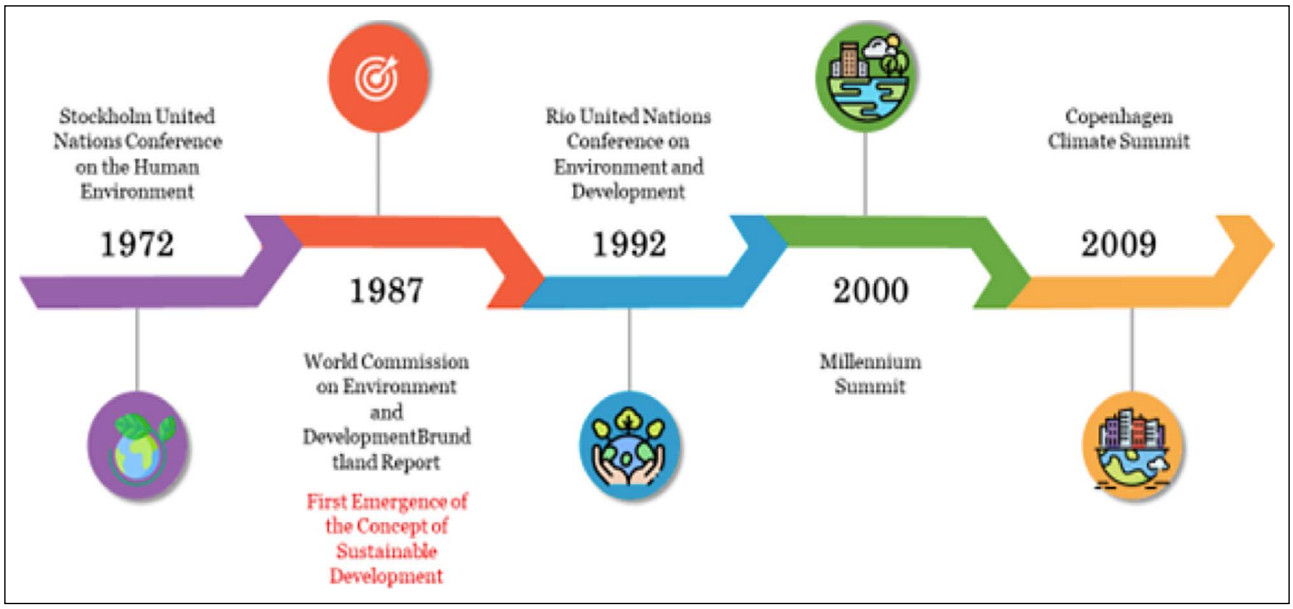

Figure 3. Chronology of agreements on the environment and the first emergence of the concept of sustainable development.

tivity on the environment throughout the world with the "sustainable development" model of growth. As a result of the fact that "we do not have a spare planet" and that yet another planet where humans may dwell has not yet been located. According to the data of the International Energy Agency (IEA), in 2013, the fact that renewable energy sources such as wind and solar surpassed natural gas assets while becoming the world's second-largest natural resource for electricity generation after coal, and the decrease in the average amount of greenhouse gas emissions per capita by 15% in all OECD countries and 26% in EU countries during the 1990-2016 period (OECD STATEUROSTAT, 2018) were two serious examples of the steps taken towards sustainable development [9].

In order to guarantee that human activities do not destroy the earth's land, air, and water resources, the concept of ecological integrity must be adhered to. Ecosystems are presumed to have a limited regeneration capacity as well as a carrying capacity. When combined with population expansion, overconsumption, increasing pollution, and depletion of natural resources, it poses a threat to the integrity of the ecosystem. Human actions have the potential to have substantial negative consequences for the natural environment, including, but not limited to, destruction of biodiversity, depletion of the ozone layer, accumulation of greenhouse gases, waste management, and deforestation, among other things. If the natural environment is threatened, important and necessary resources for human survival such as air, water, and food will be jeopardized as well [10]. With this approach, it is important to protect ecosystem integrity through efficient natural resource management, to use non-renewable resources efficiently, to respect nature and biological diversity, to prioritize global environmental commitment, to prioritize recycling, and to avoid the release of dangerous and polluting substances into the environment.

History And Scope Of Sustainable Development Goals

The concept of sustainable development, which is defined as a "development model that meets current needs without jeopardizing future generations' ability to meet their own needs," was made popular by the World Commission on Environment and Development's Our Common Future report, also known as the Brundtland Report, published in 1987. The Sustainable Development Goals (SDGs), in other words, the Global Goals, are a global call to action to end poverty, safeguard the environment, and guarantee that everyone lives in peace and prosperity (Fig. 3).

The Sustainable Development Goals (SDGs) are moving forward in a spirit of cooperation and pragmatism in order to sustainably enhance living for future generations by making the right decisions now. All countries are given clear advice and objectives to implement in accordance with their priorities and the global environmental issues they face. The Sustainable Development Goals has an inclusive agenda. It addresses the root causes of poverty and unites us to make positive changes for both people and our planet [11].

UNDP Administrator Helen Clark said that supporting the 2030 Agenda is UNDP's top priority and also declared the following "The Sustainable Development Goals provide us with a mutual plan and agenda to address some of the heavy challenges our world is facing, such as poverty, climate change, and conflict (Fig. 4). UNDP has the experience and expertise to help countries make progress and achieve sustainable development." A road map for sustainable development has been established up to the current day as a result of various world summits conducted in the previous 30 years, countless researches, and action plans [12].

Türkiye put the concept of sustainable development on its agenda in 1996, following the United Nations (UN) Conference on Environment and Development in Rio in 1992, and incorporated it in its Development Plans and several

Figure 4. Sustainable development goals [13].

policy documents in the years that followed. Besides the Development Plans, Türkiye's sustainable development agenda now includes sectoral global and thematic national policy and strategy papers that incorporate the notion of sustainability. After all of these, Sustainability in the 10th Development Plan has been one of the key concepts shaping this development plan and also became the dominant theme. The 2030 Agenda for Sustainable Development, which was agreed upon by world leaders and signed by 193 nations, was adopted at the United Nations (UN) Sustainable Development Summit in September 2015. The 2030 Agenda, which accepts the eradication of poverty in all of its forms as an integral part of sustainable development and brings together efforts to tackle climate change with economic and social development issues, was developed as a follow-up to the Millennium Development Goals (MDGs) set in 2000, as well as goals that are even more ambitious. The 2030 Agenda aims to include all societies in efforts to decrease poverty and improve wellbeing throughout the world, safeguard cultural and social values, and avoid or even prevent environmental degradation. Social and environmental issues like gender equality, observing the needs of disadvantaged groups, limiting food waste, trying to combat desertification and drought, and protecting biodiversity, as well as economic problems like economic growth, technological development, employment, and industrialization, have been introduced to the agenda of sustainable development in this emerging global development approach. The Sustainable Development Goals (SDGs) have been defined as part of

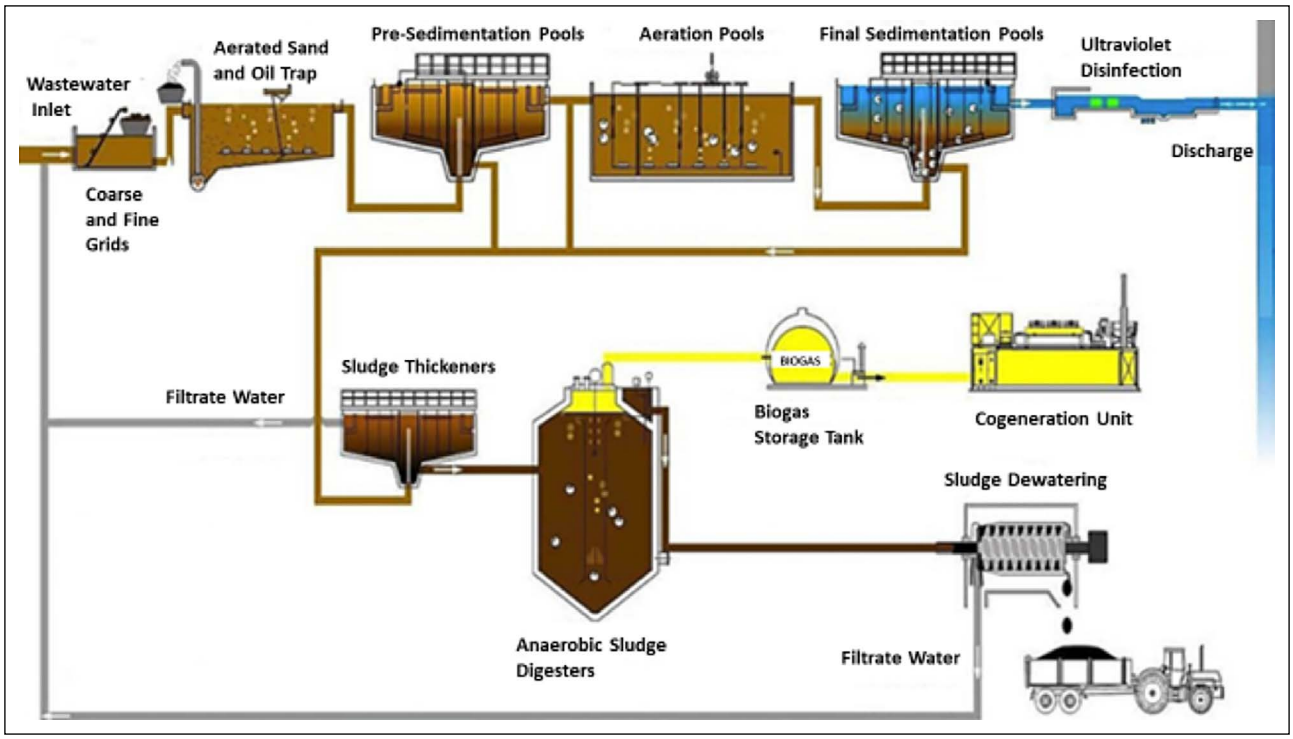

Figure 5. Classic domestic wastewater treatment plant model [15].

the 2030 Agenda, which aims to move the global development trajectory toward a more sustainable path, and a total of 17 Sustainable Development Goals (SDGs) have been identified. The main purpose of SDGs is to work to ensure that no country is left behind in the development process during the period of 2015-2030; it is with the motto of "leaving no one behind." The Sustainable Development Goals (SDGs) include 169 goals and span the economic, social, and environmental components of sustainable development. They have a broader scope than the Millennium Development Goals (MDGs) and go beyond the MDGs by addressing the universal need for development. There is a strong foundation for the SDGs that is based on the achievement and momentum of development achieved by the Millennium Development Goals. "Türkiye's Current Situation Analysis Project within the Scope of Sustainable Creation Objectives" focuses on the development of policy, law, institutional framework, and project concerns for Türkiye in the context of sustainable development goals. Within the scope of the study, the existing status of Türkiye was analyzed for each SDG in light of the results and observations collected; gaps and areas that needed improvement were identified.

FARMING AND AGRICULTURAL APPLICATIONS OF DOMESTIC TREATMENT SLUDGE

An Overview Of Domestic Sewage Sludge

The tremendous growth in population, as well as technological developments and industrialization, has resulted in the contamination of freshwater supplies worldwide. For this reason, wastewater treatment plants using various treatment techniques were designed [14].

Given the presence of potentially hazardous constituents in domestic wastewater, disposal into lakes or rivers is only permitted after it has been cleansed and only under the conditions stated in the legislation.

Solids that are converted into a settleable sedimentable or floatable form from drinking water and wastewater as a result of physical, chemical, and biological treatment processes can be defined as sludge. Sewage sludge is a mixture of particles and liquids that happens during the treatment of water and wastewater. Because of their nature, sewage sludge must be purified before disposal and, if left untreated, can cause environmental damage. They require treatment due to high concentrations of organic matter, nutrients, pathogenic microorganisms, and a high concentration of water in their composition [15].

As can be seen in the flowchart; there are two different types of sludge: chemical waste sludge, which is released as a result of physical treatment in the preliminary settling unit in the facility, and biological waste sludge, which is released as a result of biological treatment from the final settling unit (Fig. 5).

It is appropriate to use biological waste sludge released from the final settling unit in agriculture and agricultural areas. The reason why this sludge is preferred is that it is stabilized sludge free from pathogens. Since biological waste sludge is a fertilizer additive, it can be used in all kinds of agricultural products grown.

Before being disposed of, the sludge from the treatment facilities must be treated. The best method for treating and storing sludge discharged from wastewater treatment facilities is determined by the quality of the waste-

Figure 6. Erzurum domestic wastewater treatment plant sludge images.

water, the chemicals utilized, and existing legislation. Because the disposal of treatment sludge will be regarded as a cost for the facility, the expenditure associated with this should be addressed while establishing the facility, and the design of the facility should be carried out in accordance with this consideration. Costs will vary according to the size of the facility and local conditions.

As can be seen in Table 1; sewage sludge will contain organic compounds, dyes, metal salts, alkalis, phenols, oxidizers, sulfates, oils, hydrocarbons, acids, Cd, Pb, As Fe, Al, Hg, Co, Cu, Cr, organic phosphorus, and nitrogen, depending on the type of industrial structure it was generated [16].

Treatment sludge is rich in heavy metals, pathogenic bacteria, viruses, and toxic chemicals. There are a variety of treatment procedures that are used to clean the treatment sludge, which is generated in large quantities every year, and the aim is to do it in a manner that is safe for human and environmental health (Fig. 6). Developing innovative disposal strategies for the effective and useful use of treatment sludge has become more important in the field of sustainable environmental management [18].

Considering that sewage sludge has a polluting effect, it should be applied carefully to the areas where ornamental plants are grown. Inspections on the subject must be carried out sensitively by complying with the regulations on this subject. Considering the biodegradability of waste sludge and the health hazards arising from its use, there are certain restrictions on the use of treatment sludge in soil in the "Regulation on the Use of Domestic and Urban Treatment Sludges in Soil" of the Ministry of Environment and Forestry dated 03.08.2010 and numbered 27661. Waste sludge may contain toxic organic compounds, heavy metals, pathogenic microorganisms and eggs of parasitic organisms that are harmful to the environment in certain amounts. Biological, chemical (heat) treatments and long-term storage etc. of treatment sludge. The effects are significantly reduced by undergoing appropriate procedures. In addition, sewage sludge can be used as a soil conditioner in soils with low productivity potential [19].

Table 1. Some physical and chemical properties of an average stabilized sludge [17]

Parameters	Unit	Analysis result
Total aluminum	mg/kg	2575
Total nitrogen	mg/kg	3,75
Total copper	mg/kg	15,81
Total iron	mg/kg	5252
Total phosphorus	mg/kg	3715
Total cadmium	mg/kg	0,77
Total lead	mg/kg	9,33
Total nickel	mg/kg	41,04
Total organic matter	%	74,99
Total pH	mg/kg	7,34
Total potassium	mg/kg	1081
C/N	–	11,6
Salt	(µS/cm)	1194

Application of Domestic Sewage Sludge to Soil Environment

The sludge management system should be addressed simultaneously with the design of wastewater treatment plants. As a result, it is vital to building a sustainable sludge management system that incorporates the potential for land usage as well as energy conversion in accordance with the features of the wastewater treatment plant being constructed (Fig. 7) [20].

Different amounts of sludge with distinct characters are released from each unit of the domestic wastewater treatment plant. In addition to being unstable, the sludge produced from the pre-settlement ponds has a high concentration of pathogenic microorganisms. Therefore, it is not suitable for land use. The wastewater is treated biologically in the final settlement ponds, and the sludge generated here is stable and free of pathogenic microorganisms at a high pace, resulting in a stable and pathogen-free sludge. Sewage sludge suitable for field applications is 'Biological Treatment Sludge' released from the final settlement pond.

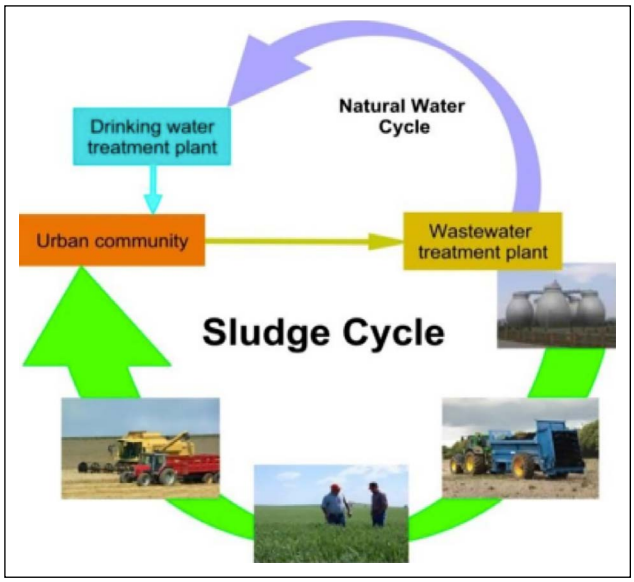

Figure 7. Sludge cycle [20].

Before the biological treatment sludge is released to the soil for any purpose, it is necessary to remove the moisture from it. This sludge should be spread out on a clean outdoor surface and allowed to dry for 2-5 days in the sun for this use. Consequently, the sun's UV rays will both dry and purify the sludge, removing any potentially harmful microbes that may be present in the resulting sludge.

Sewage sludge generated during the treatment of urban wastewater is classified as non-hazardous waste under the "Waste Management Regulation" Annex-IV list issued in the Official Gazette dated 02.05.2015 and numbered 29314 and named with 19 08 05 waste code.

Sludge produced from Wastewater Treatment Plants has a wide range of reuse possibilities. When content analyzes are identified and conform with the permissible limits stipulated in the rules, they can be used in the cultivation of forage crops (clover, sainfoin vetch, oat, clover) and cereal crops (wheat, barley, rye, corn) in agricultural regions. It can also be used in parks, green areas and refuges, and ornamental plant cultivation, as well as in the creation of artificial forest areas, the upgrade of pasture areas, and the conversion of barren lands to the most suitable areas (agricultural land, pasture area, forest).

Although the amount of sewage sludge varies by area and treatment method, most studies estimate that it is high in organic matter, phosphorus, and nitrogen, and it may be released into the soil in a controllable way [21].

Environmentally friendly sludge disposal methods are very costly and time-consuming. It also requires expertise and knowledge. Using sludge for land compared to other disposal methods has been very common recently. Because sewage sludge contains a high amount of organic matter and nutrients (N, P, K) for plant growth, this content stimulates plant yield in the land [22].

Treatment sludge, the amount of which is rising by the day, should be disposed of properly to avoid causing environmental issues. Various methods have been tried for years for sludge disposal, and a great deal of research has been put forward. One of the approaches that are stressed in terms of its contribution to the economy is the disposal of treatment sludge by applying it to the soil. Both sludge disposal and economic advantage in agricultural production may be reached through the use of sewage sludge with acceptable features as an organic fertilizer and soil regulator. It is now common practice to offer treatment sludge with adequate qualities to agricultural areas. When sewage sludge is applied to agricultural land, it delivers the final disposal step and allows the plant nutrients in the sludge to enter their natural cycles in the soil [23].

Wastewater is cleaned to the highest level possible from pathogens and hazardous compounds in its content after going through physical, chemical, and biological treatment procedures. And the obtained sludge may be disposed of in an environmentally friendly manner by using it as a habitat in agriculture, biological repair processes, landscaping, and plant cultivation [17].

Agricultural regions, rehabilitation of unusable degraded areas, artificial forest areas, and sludge storage places can all benefit from treatment sludge. All land use aims at providing more treatment of sewage sludge. Using sunshine, soil bacteria, and the drying impact, many harmful microorganisms and poisonous organic compounds in the sludge are eliminated [24].

The disposal of sludge by land use has become an attractive option used worldwide. As a result, determining the compatibility of sludge in terms of harmful and carcinogenic compounds is critical in order to make informed decisions about its application in agricultural settings [25].

The disposal of treatment sludge via soil is one of the most notable procedures in terms of its contribution to the economy among the several disposal options available. The fact that the disposal option being considered is both cost-effective and easy to apply is a significant advantage. Both wastewater management and treatment sludge, which is its output, is very important [26].

Sewage sludge, which may be disposed of by planting it in agricultural regions, forest areas, degraded park gardens, and grass areas, has been employed in a variety of fields recently, including land recreation, urban landscape, and sapling production [27–29].

Numerous research has demonstrated that applying sewage sludge and compost at certain rates promotes plant growth, soil physical qualities, and useable nutrient levels. Nitrogen, phosphorus, and potassium are the primary nutrients that enable sludge to be utilized as a fertilizer [30].

The fact that certain sewage sludges have beneficial agricultural qualities while others have detrimental impacts on the environment and human health precludes their uncontrolled application in agricultural regions. As negative effects, heavy metals such as manganese, copper, zinc, cobalt, chromium, lead, nickel and cadmium, salts, toxic organic chemicals, and pathogenic microorgan-

isms can be listed. On the other hand, because treatment sludge cannot be obtained constantly or homogeneously at certain times, it is prohibited from being used directly or converted into a commercial product. In short, the qualities of the sludge coming out of different facilities are different, and this can also change the effect of the sludge on yield and usage areas. As a result, before the treatment sludge is applied to the soil, its composition must be identified by the analysis, and for this aim, various treatment sludges should be tested on soil samples to find the most appropriate dosages [31].

Sewage sludge is biological sewage sludge that is created during biological treatment, which is the last output element of a domestic wastewater treatment plant. A large number of nutrients may be found in biological sewage sludge, and these elements are extremely beneficial to plant growth as well as having fertilizer value. However, besides this, there are pathogenic microorganisms, harmful chemicals, and heavy metals in the sewage sludge. This condition raises concerns regarding the amount of sewage sludge that should be applied to the soil environment. As a result, in order to identify the optimal dose of sewage sludge in sewage sludge uses, experiments in micro fields were conducted first, followed by macro-level studies using the optimum sewage sludge dose.

In recent research, the effects of increasing treatment sludge (0, 2.5, 5, 7.5, and 10%) usage on the yield of the corn plant, various soil qualities, the root and above-root sections of the corn plant, as well as changes in length and diameter have been examined. The applications statistically increased root wet and dry yields, above-root fresh and dry yields, plant height, and diameter of the corn plant in all treatments. Although the sludge improves several plants and soil features when treatment sludge (supplied from Hatay province-Iskenderun district's biological treatment facility) is applied in various ratios to the soil, it is not suitable for use in agricultural areas due to the extremely high salt concentration of it [32].

It was discovered in a recent study that by mixing sewage sludge with different soil types and applying them in varied proportions to the carrot plant's growth medium in a pot, it was possible to examine how the plant developed and how much heavy metal is absorbed. Results showed that sludge application significantly affected soil pH, organic matter (OM), electrical conductivity (EC), potassium (K), and phosphorus (P). After the sludge application, the content of heavy metals such as lead (Pb), cadmium (Cd), nickel (Ni), and chromium (Cr) increased in the soil and plant. The sludge application positively affected carrot growth. The maximum fresh weight (66.3 g plant-1) in 30% sewage sludge application and maximum dry unit weight (5.61 g plant-1) in 50% sewage sludge application were recorded [22].

Again, in a recent study, it was aimed to determine the effect of the stabilized sewage sludge on the yield and nutrient intake of the tomato plant by drying and applying it at different doses (0% (control), 1%, 2%, 3%, 4%, 5%, and chemical fertilization). The maximum yield was observed in the application of the most treated sludge (5%). As 5% sludge was applied, an increase in the dry weight of the root, stem, and green portions of the plant of about 187%, 254%, and 132% was seen, respectively, when compared to the control. On average, the yield of plants developed as a result of basic chemical fertilization was comparable to 1% treatment sludge application [26].

In research in which sewage sludge was applied at various rates to the pot of tomato plants, fruit mass was found to be greatest in pots treated with 20% sludge compared to all other treatments. The yield of tomato fruit was determined as control <10%<30%<20%. The absence of appropriate nutrients in the control and 10% sludge treated pots slowed tomato development, but the toxicity of the 30% sludge applied pot suppressed tomato growth. The development of the pot was optimal when 20% sludge was added [33].

Domestic waste sludge provides benefits to plants, agricultural fields, and agricultural practices because of its content. Literature has also proven that sewage sludge creates a fertilizer effect for the plant. Due to the chemicals, heavy metals, and pathogenic microorganisms present in sewage sludge, the dosage administered is critical. As demonstrated by studies, it will not help the plant if applied in excess of what is necessary and will have a detrimental effect on the soil and the plant if applied in excess of what is necessary. The aforementioned studies were carried out to determine the optimum dosage of micro-level waste sludge. The optimal dose of waste sludge found via the tests may be safely administered at the macro level to agricultural and farming areas.

3. AN EXAMINATION OF THE SUITABILITY OF SEWAGE SLUDGE FOR AGRICULTURAL AREAS İN CONFORMANCE WITH SUSTAINABLE DEVELOPMENT GOALS

The Sustainable Development Goals (SDGs) that our government has set for 2030 cover a wide range of themes, from individual education to the social obligations we should undertake. These goals outline how we should prioritize individuals, society, nature, and each living creature. Sustainable development goals, which are meticulously crafted to ensure the long-term viability of nature and its transfer to future generations, include a list of adaptable, dynamic, and current issues that may be included in any subject.

Using sewage sludge in agriculture and farming indirectly contributes to the environmental SDGs? (Goal 6-7-9-11-12-13-14-15) while especially directly contributing to 12th and 15th goals. With this ecologically friendly process, sewage sludge may be disposed of without causing harm to the ecosystem, and waste can be minimized within the framework of Responsible Consumption and Production. Additionally, utilizing treatment waste as an input in natural areas allows the sustainable and effective management of natural resources within the context of the Life on Land goal (Fig. 8).

Figure 8. SDGs that stand out in environmental issues.

Sustainable Development Goals; Goal 11 (Sustainable Cities And Communities)

It is known that more than half of the world's population lives in cities. The concept of sustainable city, which has recently become one of the most important concepts around the world; deals with the increase of urbanization, the development of the economy, the ability to cope with the increasing environmental problems with rapid population growth and the protection of the ecosystem. Creating a city that is beneficial to the environment, nature and people and meets the needs of future generations is the main task of Sustainable Cities and Communities [34].

Sustainable Development Goals; Goal 11 (Sustainable Cities and Communities) is to make cities and human settlements inclusive, safe, resilient and sustainable. In line with this purpose, the sustainable use of waste from the treatment system in the city as a raw material for another system is directly related to Goal Target 11.6. This goal target is defined as "by 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality, municipal and other waste management" [35].

Goal target 11.a "support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning" is emphasized to support economic and environmental relations. Recycling of domestic waste sludge to agricultural and agricultural fields is directly related to this goal target.

Target goal 11.b "By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels" is another important goal in this regard. The reuse of domestic waste sludge in a circular economy is directly compatible with the resource efficiency included in this goal target. In addition, this process indirectly affects adaptation to climate change, reducing climate change.

Sustainable Development Goals; Goal 12 (Responsible Consumption And Production)

According to research released by the United Nations Population Fund, if the world population hits 11 billion in 2050, we would require the equivalent of three planets to support present lifestyles and provide the necessary natural resources.

One of the most critical stages toward attaining sustainable development is decreasing the use of natural resources, the consumption of harmful substances, and the waste and pollution generated by these activities across the whole production and consumption process.

Türkiye has a multitude of policies, legislation, institutional structures, and practices aimed at achieving responsible production and consumption, and when the objectives are analyzed individually, a large national capacity emerges. However, the need for a more comprehensive approach to sustainable management and effective use of natural resources, chemical management, cleaner manufacturing/eco-efficiency practices, and research and development activities persists.

Through a number of measures, including particular legislation and international agreements on the management of environmentally damaging products, Sustainable Development Goal 12 supports more sustainable consumption and production practices [35].

Goal target 12.2 "By 2030 achieve sustainable management and efficient use of natural resources" which is included in Goal 12, can be related to this issue. Again, the treatment process can be associated with goal target 12.4 "By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cy-

cle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment".

Goal 12 highlights the sustainable management of resources and waste, sustainability reporting, sustainable public procurement and promoting tourism. Sustainable consumption and production ensures the effective use of resources and reducing waste production, increasing the quality of life together with economic activities. In short, it aims to "do more and better with less".

Within the framework of Goal 12 Goals; The biological waste sludge of the domestic wastewater treatment plant is recycled to the nature. It will be prevented that the waste harms the ecological life. waste sludge; It will make a financial contribution to the fertilizer industry by providing fertilizer support to agriculture and agricultural fields. Sustainable economy will be supported by bringing the fertilizer value of the waste sludge into the circular economy.

Sustainable Development Goals; Goal 15 (Life On Land)
In the last 50 years, 60% of the world's ecosystems have been disrupted, their food chains and material flows have been interrupted, and many living species have faced extinction. Today, this situation continues to reduce our natural resources at an alarming rate.

According to the 2019 Global Assessment Report on Biodiversity and Ecosystem Services, approximately 1 million animal and plant species are in danger of extinction within 10 years.

The primary needs identified within the scope of this purpose are to monitor indicators in a variety of critical areas, such as local/sectoral adaptation and climate risk plans, in addition to standard indicators, to promote efficient water use in agriculture, to protect agricultural lands, to rehabilitate meadow/pasture areas, to counteract erosion, and to detect risks early and to develop novel techniques for difficulties such as drought-resistant species selection in agriculture and livestock production.

Its objectives within the scope of terrestrial life are: to protect, restore and support the sustainable use of terrestrial ecosystems; ensuring sustainable forest management; combating desertification; stopping and reversing land degradation; to prevent the loss of biodiversity. In this framework, the use of waste sludge as fertilizer in all kinds of green areas and agricultural areas will be a great step towards the sustainability of the ecosystem, green areas and forests targeted in Article 15. Thus, it will contribute to the plant life and ecosystem on land. As explained above; recycling of waste sludge into nature, not only ensures the disposal of a waste without causing environmental pollution, but also contributes to the production by adding fertilizer to the agricultural fields. Thus, in our agricultural country, it is predicted that this effect will be beneficial to the whole eco-life and economy, with the revival of agriculture with a cost-free fertilizer.

CONCLUSIONS

The main theme of the Sustainable Development Goals is constituted by the elimination of inequalities, the reinforcing of economic growth and employment; improving the air quality in cities and populated neighborhoods; improving the quality of urban life; working to ensure the industrialization of the world; safeguarding ocean and ecosystems; generating more renewable energy; combating climate change; promoting sustainable production and consumption; and enhancing human rights.

In line with the Sustainable Development Goals, the use and disposal of sewage sludge from urban wastewater treatment plants as a raw material for another system in the city is directly related to SDGs.

By using the wastes of treatment plants as renewable raw materials in different systems; it can be said that SDG 11 (Sustainable Cities and Communities) directly contributes to the creation of cities that are beneficial to the environment, nature and people, and that also meet the needs of future generations. In addition, by using this method in the city, it is possible to develop safe, sustainable methods that are inclusive of cities and human settlements.

Following the Sustainable Development Goals, it is intended that residential sewage sludge, which is considered trash, would be used in agricultural regions to enhance soils and for other purposes such as agriculture, landscaping, and other landscaping. It also aims to benefit the plant as fertilizer by recycling a significant quantity of waste that has been left to nature in an uncontrolled manner without ensuring suitable conditions, to prevent damage to the environment caused by the waste, and to obtain the greatest possible benefit from it. Furthermore, sewage sludge will be able to participate in the fertilizer industry as a result of this application, and no extra fertilizer will be required. For this purpose, agricultural use of sewage sludge is directly related to the 12th article of SDGs.

Adding domestic sewage sludge to the soil can improve the soil's quality and deliver fertilizer effects, which will be critical in enhancing agricultural lands. Thus, by implementing responsible production and consumption, agricultural regions will be expanded, and the production sector will thrive. In addition, by creating larger green areas, we will be enabling the sustainability of the environment. In this direction, the agricultural use of sewage sludge is directly related 15th article of SDGs.

Efforts geared towards the goal are needed to ensure and promote the sustainable use and preservation of ecosystems. Sustainable development goals will contribute to leaving a cleaner and greener planet for future generations by assuring that ecosystems, which are at a particularly vulnerable stage, are influenced by production and consumption activities in the most favorable way. Exorbitant volumes of sludge are created, particularly in wastewater treatment facilities, while assuring that the whole city's wastewater (domestic and industrial) is treated and returned to the water environment. The eco-friendly disposal of this sludge conforms with all of the Sustainable Development Goals in its entirety. As a result, we should make global efforts to encourage the recycling of sewage sludge from urban wastewater treatment facilities to agricultural and farming areas.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

REFERENCES

[1] S. Sauvé, S. Bernard, and P. Sloan, "Environmental sciences, sustainable development and circular economy: Alternative concepts for trans-disciplinary research," Environmental Development, Vol 17, pp. 48–56, 2016. [CrossRef]

[2] M. Mukheed, and A. Khan, "Plastic pollution in Pakistan: Environmental and health implications," Journal of Pollution Effects & Control, Vol. 8(4) Article 251, 2020.

[3] H. Özbek, Z. Kaya, M. Gök, and H. Kaptan, "Toprak Bilimi", 12. Baskı P. Schachtschabel H.-P. Blume, G. Brümmer, K.-H. Hartge, U. Schwerthmann (Çev.). Çukurova Üniversitesi Ziraat Fakültesi Genel Yayın No: 73, Ders Kitapları Yayın No: 16, 1995.

[4] S. A. Wimalawansa, and S. Wimalawansa, "Agrochemical-related environmental pollution: Effects on human health," Global Journal of Biology, Agriculture & Health Sciences, Vol. 3(3), pp. 72–83, 2014.

[5] C. T. Onions, "The shorter oxfort english dictonary," Clarendan Press, 1964.

[6] H. Tıraş, "Sustainable development and environment: an examine in theory," KSÜ İİBF Dergisi, Vol. 2(2), pp. 57–73, 2012. [Turkish]

[7] E. Karakurt Tosun, "Sürdürülebilirlik olgusu ve kentsel yapiya etkileri," Paradoks, Ekonomi, Sosyoloji ve Politika Dergisi, Vol. 2, 2009. [Turkish]

[8] J. Jeffery, "Governance for a sustainable future," Public Health, Vol 120, pp. 604–608, 2006. [CrossRef]

[9] A. Şahinöz, "Unsustainable "sustainable growth," Ufuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, Vol. 8(15), pp. 77–101, 2019. [Turkish]

[10] World Health Organization, "Ecosystems and human well-being,"World Health Organization, 2005.

[11] K. Hiruy, and R. Eversole, "The contribution of research for development to the sustainable development goals: lessons from fisheries research in Southeast Asia and the Pacific Island countries," International Journal of Sustainable Development & World Ecology, Vol. 27(2), pp. 153–166, 2020. [CrossRef]

[12] The Evrimagacı, "Sürdürülebilir kalkınma hedefleri nelerdir? Dünya, kimseyi geride bırakmadan kalkınabilir mi?" 2022. https://evrimagaci.org/surdurulebilir-kalkinma-hedefleri-nelerdir-dunya-kimseyi-geride-birakmadan-kalkinabilir-mi-8935 [Turkish]

[13] The United Nations, "17 Goals to Transform Our World," 2022. https://www.un.org/sustainabledevelopment/

[14] E. Güllüce, "Approach disintegration of sewage sludge with rotor type hydrodynamic cavitation reactors. In Y. Asci, (Ed.). Engineering Sciences Innovative Approaches Publisher pp. (88-101). Livre de Lyon, 2021.

[15] Ş. Yıldız, E. Yılmaz, and E. Ölmez, "Evsel nitelikli arıtma çamurlarının stabilizasyonla bertaraf alternatifleri: İstanbul örneği," TÜRKAY Solid Waste Management Symposium in Turkiye, Jun 15-17 İstanbul Turkiye. 2009. [Turkish]

[16] B. Taşatar. "Endüstriyel nitelikli arıtma çamurlarının bazı toprak özelliklerine etkileri," [Master Thesis], Ankara University, 1997. [Turkish]

[17] H. Akat, G. Çetinkale Demirkan, Ö. Akat, and İ. Yokaş. (2015). "Utilization of sewage sludge which were used as ornamentel plant growing mixed material on the cultivation of limonium sinuatum grown under different growing media," Tekirdağ Ziraat Fakültesi Dergisi, Vol. 12(1), pp. 81–90, 2015. [Turkish]

[18] T. Ekici, "Evsel atik su arıtma çamurunun kurutma parametrelerinin araştırılması," [Master's Thesis], Namik Kemal University, Tekirdağ, 2020. [Turkish]

[19] G. Ç. Demirkan, H. Akat, and İ. Yokaş, "Effects of sewage sludge on the growth and flower development of Clarkia amoena," Journal of Agricultural Faculty of Uludag University, Vol. 28, pp. 49–58, 2014. [Turkish]

[20] J. Hall, "Sludge management and marketing plan," MWH-Yüksel Proje Consortium, Final Report, 2013.

[21] K. Çimrin, M. Bozkurt, and İ. Erdal, "The use of municipal sewage sludge as phosphorus source in agriculture," Yüzüncü Yıl Üniversitesi Tarım Bilimleri Dergisi (J. Agric, Sci.), Vol. 10(1), pp. 85–90, 2000. [Turkish]

[22] N. Nahar, and S. Hossen, "Influence of sewage sludge application on soil properties, carrot growth and heavy metal uptake," Communications in Soil Science and Plant Analysis, Vol. 52(1), pp. 1–10, 2021. [CrossRef]

[23] F. O. Kocaer, A. Kemiksiz, and H. S. Başkaya, "A study on mineralization of organic nitrogen in a sludge-amended soil," Ekoloji Çevre Dergisi, Vol. 12(46), pp. 12–16. 2003

[24] İ. Alyanak, "Atıksu çamurlarının değerlendirilmesiyle ilgili türkiye'deki uygulamalar," 4. Turkish-German Water Partnership Day. Sep 23-24; Antalya, Türkiye, 2014. [Turkish]

[25] E. Yakamercan, A. Ari, and A. Aygün, "Land application of municipal sewage sludge: human health risk assessment of heavy metals," Journal of Cleaner Production, Vol. 319, Article 128568, 2021. [CrossRef]

[26] M. Öztürk, Ş. Aslan, and A. Demirbaş, "Effect of domestic wastewater sewage sludge applications on yield and nutrient uptake of tomato plant," Sivas Turkish Journal of Agriculture-Food Science and Technology, Vol. 8(7), pp. 1508–1516, 2020. [Turkish] [CrossRef]

[27] U. Tolay, Y. Yavuzsefik, M. Tolay, and N. Söğüt, "Usage of sewage sludge on the growth of ornamental plants". Turkish Journal of Agriculture and Forestry, Vol. 24(6), pp. 705–712, 2000. [Turkish]

[28] M. Ünal, A. Karaca, Ç. S. Camcı, and A. Çelik, "Effects of sewage sludge originated from urban waste water treatment plant on growth of Freesia Spp. and some properties of soil," Selçuk Tarım ve Gıda Bilimleri Dergisi, Vol. 25(2), pp. 46–56, 2011. [Turkish]

[29] G. Yalçın, R. Yavuz, M. Yılmaz, and K. Taşpınar, "Evaluation of sewage sludge on agricultural lands," Mühendislik ve Fen Bilimleri Dergisi, Vol. 3, pp. 156–164, 2011. [Turkish]

[30] M. Soumare, F. M. G. Tack, and M. G. Verloo, "Characterization of malianand belgian solid waste composts with respect to fertilityand suitability for land application," Waste Management, Vol. 23, pp. 517–522, 2003. [CrossRef]

[31] H. Çakır, and K. Çimrin, "Effect of municipal sewage sludge applications: II. on some mikro nutrient and heavy metal contents plant corn and soil," KSU Journal of Agriculture and Nature, Vol. 21(6), pp. 882–890, 2018. [Turkish] [CrossRef]

[32] H. N. Çakır, and K. M. Çimrin, "The effect of sewage sludge applications on the growth of maize (zea mays l.) and some soil properties," Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi, Vol. 23(2), pp. 321–327, 2020. [Turkish] [CrossRef]

[33] A. Elmi, A. Al-Khaldy, and M. A. Alolayan, "Sewage sludge land application: balancing act between agronomic benefits and environmental concerns," Journal of Cleaner Production, Vol. 250, Article 119512, 2020. [CrossRef]

[34] H. M. K. Delanka-Pedige, S. P. Munasinghe-Arachchige, I. S. A. Abeysiriwardana-Arachchige, and N. Nirmalakhandan, "Wastewater infrastructure for sustainable cities: assessment based on UN sustainable development goals (SDGs)," International Journal of Sustainable Development & World Ecology, Vol. 28(3), pp. 203–209, 2021. [CrossRef]

[35] Republic of Turkey Presidency of Strategy and Budget, "Sürdürülebilir kalkınma amaçları değerlendirme raporu," 2019. [Turkish]