ICOEST 2024
Sarajevo

10TH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY

June 05-09, 2024

BOOK OF PROCEEDINGS

www.icoest.eu

Organized by

Partners

10th INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY (ICOEST)

ISBN 978-605-81426-2-6

ISSN - 2687-2439

BOOK OF PROCEEDINGS OF THE 9th INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY (ICOEST)

SARAJEVO, BOSNIA AND HERZEGOVINA on JUNE 05-09, 2024

Edited by

Prof. Dr. Özer Çınar

Published by:

info@icoest.eu
www.icoest.eu
www.cnrgroup.eu

CNR Group Laboratuvar ve Arge Hizmetleri Sanayi Ticaret Limited Şirketi Çifte Havuzlar Mah., Eski Londra Asfaltı Cad., Kuluçka Mrk., A1 Blok, 151/1C, Iç Kapı No:1 B-20, Esenler / Istanbul, 34220

SCIENTIFIC COMMITTEE

ORGANIZATION COMMITTEE

Chairman(s) of the Conference

Prof. Dr. Özer Çınar – Yıldız Technical University

Members of the Committee

Prof. Dr. M. Asghar Fazel (Co-Chairman) – University of Environment

Dr. Gábor Baranyai (Co-Chairman) – National University of Public Service, Budapest

Prof. Dr. Samir Đug, University of Sarajevo

Assist. Prof. Dr. Sasan Rabieh Shahid Beheshti University

Assist. Prof. Dr. Ševkija Okerić - University of Sarajevo

Assist. Prof. Dr. Nusret Drešković - University of Sarajevo

Assist. Prof. Dr. Ranko Mirić - University of Sarejevo

Musa Kose - Zenith Group Sarajevo

Ismet Uzun - Zenith Group Sarajevo

Alma Ligata - Zenith Group Sarajevo

WELCOME TO ICOEST 2024

On behalf of the organizing committee, we are pleased to announce that the ***10th*** *International Conference on Environmental Science and Technology* ***(ICOEST-2024)*** *is held in* ***Sarajevo, Bosnia and Herzegovina on June 05-09, 2024****. ICOEST provides an ideal academic platform for researchers to present the latest research findings and describe emerging technologies, and directions in Environmental Science and Technology. The conference seeks to contribute to presenting novel research results in all aspects of Environmental Science and Technology. The conference aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results about all aspects of Environmental Science and Technology. It also provides the premier interdisciplinary forum for scientists, engineers, and practitioners to present their latest research results, ideas, developments, and applications in al lareas of Environmental Science and Technology. The conference will bring together leading academic scientists, researchers and scholars in the domain of interest from around the world. ICOEST is the oncoming event of the successful conference series focusing on Environmental Science and Technology. The scientific program focuses on current advances in th eresearch, production and use of Environmental Engineering and Sciences with particular focus on their role in maintaining academic level in Science and Technology and elevating the science level such as: Water and waste water treatment, sludge handling and management, Solid waste and management, Surface water quality monitoring, Noise pollution and control, Air pollution and control, Ecology and ecosystem management, Environmental data analysis and modeling, Environmental education, Environmental planning, management and policies for cities and regions, Green energy and sustainability, Water resources and river basin management. The conference's goals are to provide a scientific forum for all international prestige scholars around the world and enable the interactive exchange of state-of-the-art knowledge. The conference will focus on evidence-based benefits proven in environmental science and engineering experiments.*

Best regards,
Prof. Dr.Özer ÇINAR

ICOEST SARAJEVO

10TH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY

June 05-09 2024 (Hybrid Event)

CONTENT	Country	Page
How Could Affect the Aegean Sea After Chemical Tanker Collusions in the Strait of Canakkale (Dardanelles)	Türkiye	1
Analysis of Solar Radiation and Remote Sensing Indices for Coastal Management in Oman	Oman	6
Exploring the Impact of Solar Radiation on Environmental Dynamics in Oman Normalized Difference Vegetation Index (NDVI)	Oman	13
Analyzing the Impact of Greenhouse Gas Emissions Resulting from Agricultural Activities	Türkiye	19
The Effect of Different Environmental Conditions on Some Morphological Characteristics of Forage Kochia Populations	Türkiye	24
Preparation, Traditional Uses and Benefits of St John's Wort Oil in Turkiye	Türkiye	32
Eco Trends in Civil Engineering	Croatia	36
Feasibility of Using Black Liquor Waste as Cementious Material Admixture: An Example of Algerian Research	Algeria	45

ICOEST SARAJEVO
10TH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY
June 05-09 2024 (Hybrid Event)

How Could Affect the Aegean Sea After Chemical Tanker Collusions in the Strait of Canakkale (Dardanelles)

***Hasan Bora Usluer*[1]**

Abstract

Today's technology and requirements directly affect human needs. According to the International Maritime Organization - IMO, more than 90% of all needs in the world are transported by Maritime Transportation, and ships have a very important role in this regard. It is known that most of the maritime and producing countries are interested in energy transportation and that these kinds of transportation modes are very important for the development of countres. In this context, the navigation in important passages and canals around the world affects both human life and the marine environment. The Straits of Istanbul and Canakkale, which are major parts of the Turkish Straits Sea Area-TSSA, are undoubtedly important natural waterways. If precautions are not taken, especially after an accident that may occur in the Canakkale Strait, pollution will reach the Aegean Sea due to currents. The study describes insights into pollution impacts and prevention activities.

Keywords: Turkish Straits Sea Area(TSSA), Strait of Canakkale (Dardanelle), Marine Pollution Simulation, Strategy of Maritime Management.

1. INTRODUCTION

The Turkish Straits Sea Area-TSSA, an uninterrupted waterway connecting the Caspian and the Mediterranean, is a vital passage for maritime transportation. It's also a crucial habitat for marine creatures. The daily ship passages underscore the urgency of addressing carbon gas emissions, a concern that the IMO deems crucial for maritime transportation. Given the need to protect both local and global maritime areas, it's imperative to focus on the essential waterways that form the regular routes of ships to many ports providing international transportation services, particularly the Turkish Straits. The Republic of Turkey has had an essential geopolitical and strategic position since history. Due to its Straits, Turkey connects the Asian and European continents. Turkish Straits Sea Area-TSSA consists of three main essential elements: The Strait of Istanbul, Canakkale, and the Sea of Marmara. The Strait's well-known names, Boshporus and Dardanelles, come from ancient times and are a great example of the world's natural seaways, such as a valley [1,2,3].

Turkish authorities no longer use the terms of Boshporus and Dardanelle on maps containing geographical names. The entire Turkish Strait maritime area belongs to Turkey's sovereign maritime territory and is subject

[1] *Corresponding author: Galatasaray University, Assoc.Prof.Dr., The Director of Maritime Vocational School, Ciragan Cad.,No.36, 34349, Ortakoy-Besiktas/Istanbul, Turkey.* hbusluer@gsu.edu.tr

to the internal water's regime according to the provisions of UNCLOS. The Turkish Straits Sea Area, a crucial waterway for energy transportation, is the most convenient and safe between the Mediterranean and the Black Sea. Since 1936, the Turkish Straits began to be managed by the Montreux Convention. The Montreux Convention has treaty obligations.

In recent years, the Turkish Straits Sea Area has become a natural trade route that has become even more important due to the importance all developed countries give to energy transportation and oil and petroleum products, that is, chemicals. Turkiye is in a geography where four seasons are experienced, and the climatic effects can be easily felt. It has very special conditions in terms of marine and terrestrial environments, including atmospheric and oceanographic conditions and plant and animal diversity.

Figure 1. Turkish Strait Sea Area Overview (5)

The Turkish Straits, where many different submarine life species exist, have been exposed to the heavy traffic of both sea creatures and marine vessels for centuries. There has been a significant increase in the types and quantities of dangerous cargo carried by the Black Sea coastal states and Central Asian Turkic Republics, which are environmentally adjacent to the sea, and in the size and tonnage of ships passing through the Straits.

As a result of developing and changing technology, the number of ships sailing in the Straits and the presence of hazardous materials on the transportation route pose severe environmental and security hazards for the Turkish Straits Marine Area and surrounding residential areas.

The potential high density of maritime traffic in the Turkish Straits makes navigation a daunting task. Accidents, negligence, and other factors often lead to oil leaks during ship navigation, resulting in serious environmental problems. The study simulated the possible pollution caused by a ship the size of the Independenta tanker, which was responsible for a major marine accident in the Bosphorus in 1979, and attempted to predict the spread of pollution to the Aegean Sea.

2. THE STRAIT OF CANAKKALE MARINE SCIENCE STATUS

The Strait of Canakkale, a distinctive feature of the Turkish Strait Maritime Area (TSSA), stretches almost 20 nautical miles longer than the Strait of Istanbul. Its natural structure, morphology, and geographical situation, which are significantly different from the Strait of Istanbul, make it a fascinating subject of study [9].The Strait of Canakkale, which accounts for 22.56% of TSSA, has a determined NE-SW current and wind direction. The spatial significance of the strait is evident in the areas between Biga and the Gallipoli peninsula, which are relatively narrow, and in the north and south regions where the strait reaches an average depth of 55 to 90 meters. [6,7,8,9]

Figure 2. The Strait of Canakkale and 1915 Canakkale Bridge.[10]

The narrowest point, Kilitbahir and Canakkale, is a mere 1300 meters wide, while the widest point, the shores of Intepe and Domuz Dere, spans a significant 8135 meters [4]. TSSA plays a crucial role in the sea currents. The primary current is the surface current that flows through the Black Sea to the Aegean Sea via the Marmara Sea. The second side or water arm is the undercurrent that originates from the first layer of the Mediterranean Sea and passes through the Aegean Sea towards the Marmara Sea.[11,12,13]

3. COLLISION EFFECTS AFTER TANKER ACCIDENT ON THE STRAITS OF CANAKKALE AND HOW IT' SIMULATE?

It is known as the most critical accident that took place in the Turkish Straits; its effects lasted for days, it was known that there were difficulties in the rescue operation, and it was the subject of lectures. It occurred between M/T INDEPENDENTA and M/V EVRIALI. The collision took place in front of Haydarpasa Port on 15 November 1979. The impact of the Independenta tanker, which leaked more than 30,000 tons of crude oil from M/T Independenta, on the Marmara Sea is around 100,000 tons. This staggering amount of pollution has severely affected the Strait of Istanbul and the Sea of Marmara, raising serious concerns about the long-term environmental impact. SAR, fire extinguishing, and environmental cleaning works lasted approximately two months. The accident, in which 42 sailors lost their lives and many were injured, caused material damage. The impact of the high-level explosion that occurred with the accident damaged the Anatolian side coastline and the settlement around 6 km away.[12,13]

Figure 3. M/T Independenta Disaster photos after collision (URL 1)

While designing the study, it was desired to gain foresight by simulating how much damage and how it would damage the Aegean Sea if an accident such as the Independenta tanker accident occurred in the Strait of Canakkale. Therefore, Independenta tanker dimensions were entered into the simulation as ship information. Chemical cargoes transported from Black Sea Ports were also considered to make the simulation more suitable for today's conditions.

Due to a leakage accident at 40° 24.133 N-026° 41.882 E in front of Gallipoli, the leak reached the Aegean Sea at time t+27.[11]

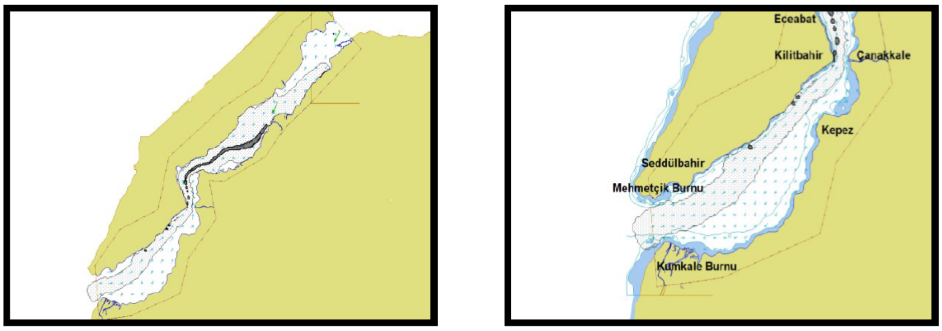


Figure 4. The oil spilled in front of Gallipoli.

Oil leakage started due to grounding at 40° 11.832 N-026° 23.466 E in front of Cape Nara and reached the Aegean Sea at time t+24.[12,13]

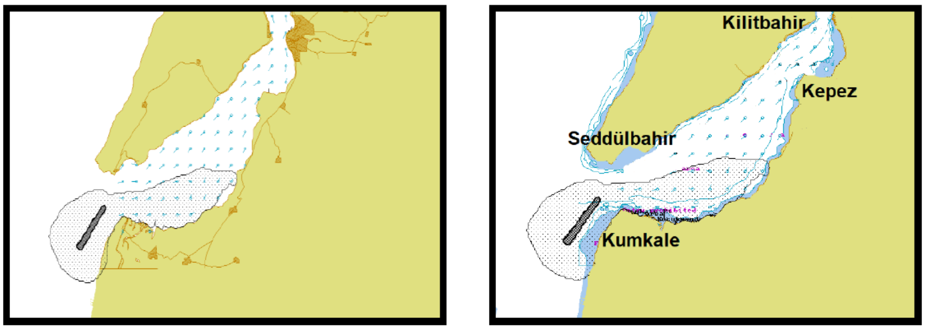


Figure 5 The oil spilled at the point of Nara.

The oil leak started due to the grounding accident at 40° 08.815 N-026° 23.570 E in front of Canakkale and reached the Aegean Sea at time t+24.[12,13]

RESULTS

When, the Strait of Canakkale is examined in detail, the probability of an accident occurring in the light of accident statistics in previous years. It was determined that between Gelibolu and Cardak, in front of Cape Nara, Kilitbahir and Canakkale, and Kumkale and Intepe. Considering these places, between Gallipoli and Cardak and in front of Cape Nara, it was observed that the pollution pouring into the sea reached the Aegean Sea and created pollution.

The study also shows that when a possible tanker accident cannot be intervened in, depending on the location and region, the pollution effect increases over time. It has been understood that it is difficult to intervene in oil, especially in the Nara-Eceabat and Kilitbahir-Canakkale lines, which are among the narrowest areas of the strait and where the current intensity increases, but early intervention is necessary within the first hour. While the 1915 bridge construction is a boon for highways, the threat of accidents and ship-related explosions is a stark reality. To address this, we must develop joint work plans and responsibility protocols. Equally important is the need to coordinate with our coastal neighbor countries, underscoring the significance of international cooperation in maintaining the cleanliness of our territorial waters, particularly in the Aegean Sea.

ACKNOWLEDGMENT

Acknowledge: The Corresponding Author gratefully acknowledge the support of Galatasaray University, Scientific Research Support Programme under grant number of SOA-2023-1162.

REFERENCES

[1]. H.B.USLUER,The Effects of Marine Sciences on Maritime Transportation and Marine Environment at Turkish Straits,Pg.9-16, 5th INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY, Bosna Herzegovina,2019

[2]. H.,B.,Usluer, G.B.Alkan,''Importance of the Marine Science and Charting about Environmental Planning, Management and Policies at the Turkish Straits'', EJSDR European Journal of Sustainable Development Research,Pg.16-25,2016

[3]. Usluer, H. B., Bora, A. G., & Gazioglu, C., (2022). What if the Independenta or Nassia tanker accidents had happened in the Strait of Canakkale (Dardanelle)?. *OCEAN ENGINEERING* , vol.260, 1-12.

[4]. Usluer, H.B., Gazioglu, C., Bora,A.G.,''Simulation of Marine Pollution from a Tanker Accident at the Canakkale Strait (Dardanelle)'' 6th INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY, Belgrade,2020

[5]. (2018) USLUER, H.B., OGUZULGEN, S., Chapter I, REMARKABLE ACCIDENTS AT THE ISTANBUL STRAIT, Oil Spill along the Turkish Straits Sea Area; Accidents, Environmental Pollution, Socio-Economic Impacts and Protection,TUDAV

[6]. (2018) ALPAR, B., USLUER, H.B., AYDIN,S. , Chapter II, GEOGRAPHIC AND BATHYMETRIC RESTRICTIONS ALONG THE TURKISH STRAITS SEA AREA, Oil Spill along the Turkish Straits Sea Area; Accidents, Environmental Pollution, Socio-Economic Impacts and Protection,TUDAV

[7]. (1996) Alpar, B., H. Yuce, and E. Dogan, 1996. Gas-charged late Quaternary sediments in Strait of Canakkale (Dardanelles). Turkish Journal of Marine Sciences, 2(3), 155–169.

[8]. http://www.vda.org.tr/upload/duyuru/T%C3%9CRK%20BO%C4%9EAZLARI%20DEN%C4%B0Z%20TRAF%C4%B0K%20D%C3%9CZEN%C4%B0%20Y%C3%96NETMEL%C4%B0%C4%9E%C4%B0%20%C4%B0NG%C4%B0L%C4%B0ZCE%202019.pdf

[9]. Besiktepe, S., Sur, H. I., Ozsoy, E., Latif, M. A., Oguz, T., Unluata, U. (1994). The circulation and hydrography of the Marmara Sea. Progress in Oceanography, 34 (4), 285-334.

[10]. https://www.aa.com.tr/tr/yasam/1915-canakkale-koprusunde-son-hazirliklar-yapiliyor/2535611

[11]. Besiktepe, S. T., Ozsoy, E., Latif, M. A., Oguz, T. (2000). Marmara Denizi'nin hidrografisi ve dolasimi. B.Ozturk, M.Kadioglu, H.Ozturk, (Eds.), Marmara Denizi 2000 Sempozyumu Bildiriler Kitabi (s. 314-326). Istanbul: Turk Deniz Arastirmalari Vakfi (TUDAV).

[12]. A.G.BORA, Master Thesis, SIMULATED ACCIDENT RISK ASSESSMENT OF TANKERS CARRYING CRUDE OIL IN CANAKKALE STRAIT**,** 2019

[13]. Usluer, H.B., Gazioglu, C., Bora,A.G.,''Simulation of Marine Pollution from a Tanker Accident at the Canakkale Strait (Dardanelle)'' 6th INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY, Belgrade,2020

BIOGRAPHY

Corresponding Author; Assoc. Prof. Dr. Hasan Bora USLUER is the Director of the Maritime Vocational School of T.R. Galatasaray University. He served more than 14 years as a cartographer, a hydrographer, and an oceanographer and survey unit commander at the Turkish Navy, Office of Navigation, Hydrography, and Oceanography. He graduated from Kocaeli University Deck Science 2001, Army Mapping School Command 2002, Italy International Maritime Academy Electronic Chart Production 2004, Anadolu University, Public Administration 2004, Msc Istanbul University Maritime Politics 2011, International Hydrographic Organization, IHO ICA Applied Hydrography B Category Programme 2012, Ph.D. Istanbul University Maritime Transportation and Management Engineering 2016.

ICOEST SARAJEVO
10TH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY
June 05-09 2024 (Hybrid Event)

Analysis of Solar Radiation and Remote Sensing Indices for Coastal Management in Oman

Mohammadu Bello Danbatta[1], Nasser Al-Azri[2]

Abstract

This study examines the seasonal variations in temperature, chlorophyll indices, and solar radiation to enhance coastal management strategies along the coast of Muscat, Oman. Temperature data, measured in Kelvin, revealed a clear warming trend from winter to summer, with mean values increasing from 299.37 K in January to 311.05 K in October. The Chlorophyll-a Index (CAI) and the Normalized Difference Chlorophyll Index (NDCI) were analyzed to assess marine productivity and vegetation health. Results showed negative CAI values in the winter months, indicating lower chlorophyll concentrations, which gradually improved by October. The NDCI remained positive across all months, with the highest mean observed in January, suggesting active photosynthetic vegetation during this period.

Solar radiation, measured as All Sky Surface Shortwave Downward Irradiance (kW-hr/m^2), peaked in April and July, aligning with increased temperatures and indicating maximum solar energy input during these months. This increase in solar radiation was found to significantly influence the chlorophyll indices, reflecting seasonal shifts in marine and coastal ecosystem productivity.

The interrelationship between temperature, chlorophyll indices, and solar radiation highlights the complex environmental dynamics governing coastal processes in Muscat. These findings underscore the importance of integrating solar radiation data and remote sensing techniques into coastal management frameworks. Such an interdisciplinary approach can inform evidence-based strategies for mitigating environmental impacts and fostering sustainable development along Oman's coastlines.

Keywords: Coastal management, Solar Radiation, Climate Change, Sultanate Oman

1. INTRODUCTION

Oman boasts a vast coastline spanning approximately 3,165 kilometers along the Arabian Sea and the Gulf of Oman, making coastal management a critical aspect of environmental stewardship in the country [1]. The coastal zones of Oman are not only vital for biodiversity and marine ecosystems but also play a significant role in supporting economic activities such as fisheries, tourism, and shipping [2]. However, these coastal ecosystems face numerous threats, including habitat degradation, pollution, overfishing, and the impacts of climate change. Effective coastal management is essential to mitigate these threats and ensure the sustainability of Oman's coastal resources for future generations.

[1] *Corresponding author: Department of Mechanical and Industrial Engineering, College of Engineering, Sultan Qaboos University, P.O. Box 50, Muscat, Sultanate of Oman, s143273@student.squ.edu.om.*

[2] *Department of Mechanical and Industrial Engineering, College of Engineering, Sultan Qaboos University, P.O. Box 50, Muscat, Sultanate of Oman, nalazri@squ.edu.om.*

2. STUDY AREA

The research area encompasses the coastal zone of Muscat in Oman, located at approximately 23.6345° N latitude and 58.0962° E longitude. This distinct environmental setting is characterized by a desert climate, with arid conditions prevailing year-round. Summers are characterized by high temperatures, often exceeding 40 degrees Celsius, while winters are relatively mild, with temperatures ranging between 15 and 25 degrees Celsius. Rainfall is typically low, averaging around 100 mm annually and occurring sporadically. The elevation of the Muscat coastal region varies, contributing to its diverse topography. Coastal bathymetry further complicates environmental dynamics, shaping marine ecosystems and influencing coastal processes. The study area encompasses a significant geographical area, including both coastline and adjacent land, providing ample scope for ecological investigations. As the capital city of Oman, Muscat holds considerable population and economic significance. The population of the municipality is dynamic, reflecting urbanization and economic activities. Moreover, the coastal region of Muscat plays a vital role in the country's Gross Domestic Product (GDP) through sectors such as fisheries, tourism, and maritime trade. The investigation covers a region of interest spanning 6,360.03 km².

3. METHODOLOGY

3.1. Satellite Imagery

The data collection for this study in the Muscat coastal region of the sultanate of Oman relies on satellite imagery from the Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIR), obtained through the U.S. Geological Survey (USGS) Earth Explorer. Landsat 8 OLI/TIR provides a valuable dataset with distinctive spatial, spectral, and temporal characteristics, contributing to a comprehensive understanding of the study area. Spatially, Landsat 8 OLI/TIR offers a spatial resolution of 30 meters for multispectral bands, allowing for detailed mapping and analysis of land features [3]. The sensor captures data in multiple spectral bands, providing information on various surface properties. The multispectral bands range from visible to shortwave infrared, enabling the extraction of essential environmental parameters, including vegetation health, land cover, and thermal dynamics [4]. Spectrally, Landsat 8 OLI/TIR's spectral bands cover a wide range of electromagnetic wavelengths, offering a multispectral and thermal perspective of the Earth's surface. This spectral diversity enhances the capacity to discriminate between different land cover types and assess environmental conditions [5]. Temporally, Landsat 8 OLI/TIR provides a revisit time of 16 days, facilitating the acquisition of frequent and temporally dynamic data for monitoring seasonal variations and changes over time [6]. The obtained satellite imagery contributes significantly to the research's objectives by capturing the intricate ecological dynamics of the Muscat coastal region. The scenes used in this study are listed in table 1.

Table 1. *Landsat 8 OLI/TIR satellite scene used*

On Board Sensor	Acquisition Date	Scene Time	WRS (PATH, ROW)
OLI/TIRS	2023-01-05	06:35:01.2220310Z	(158,44)
OLI/TIRS	2023-04-03	06:34:33.9627430Z	(158,44)
OLI/TIRS	2023-07-08	06:34:10.2046779Z	(158,44)
OLI/TIRS	2023-10-04	06:34:43.5675189Z	(158,44)

3.2. Data Preprocessing

In the analysis conducted, radiometric calibration and atmospheric correction was done on all images. Radiometric calibration is done for converting the raw digital numbers obtained from satellite sensors into physically meaningful units, ensuring consistency and comparability across different acquisitions [7]. The atmospheric correction was carried out using the Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubus (FLAASH) method using ENVI 5.3. This enhance the accuracy and reliability of the data derived from Landsat 8 Operational Land Imager and Thermal Infrared Sensor (OLI/TIR) imagery. This correction accounts for factors such as water vapor, aerosols, and gases, mitigating their impact on the emitted thermal radiation from the Earth's surface. The FLAASH algorithm employs radiative transfer equations to model the interactions between the atmosphere and the incoming solar and emitted thermal radiation, enabling the derivation of atmospherically corrected values [8].The radiometric calibration and FLAASH atmospheric correction processes are pivotal steps to ensure the accuracy of the reflectance values, particularly in regions with diverse atmospheric conditions such as coastal environments. Implementing these corrections enhances the reliability of the derived information, allowing for more accurate analyses of surface and contributing to a comprehensive understanding of the environmental dynamics.

Normalized Difference Chlorophyll Index (NDCI)

The Normalized Difference Chlorophyll Index (NDCI) is primarily designed for chlorophyll assessment, its adaptability has been extended to impervious surface mapping due to its sensitivity to built-up structures.

Chlorophyll a Index (CAI)

The Chlorophyll-a Index (CAI) is an important vegetation index designed for the estimation of chlorophyll-a concentrations in water bodies. Unlike traditional vegetation indices, CAI focuses on the spectral characteristics related to water quality. The CAI values are indicative of chlorophyll-a concentrations, with higher values suggesting higher concentrations. This ratio-based index plays a crucial role in assessing water quality and monitoring changes in chlorophyll-a levels within aquatic ecosystems.

Land surface Temperature (LST)

Land Surface Temperature (LST) is a crucial parameter for understanding Earth's surface energy balance and is widely used in various environmental applications. LST represents the temperature of the Earth's surface, excluding the effects of the atmosphere. Accurate estimation of LST is essential for monitoring climate, agriculture, and urban heat islands. It's important to mention that LST is influenced by various factors, including emissivity and atmospheric conditions, which may require additional corrections depending on the specific application/

4. RESULTS AND DISCUSSIONS

The RGB composite image shown in figure 2 after processing demonstrates a notable enhancement in the precision and dependability of the radiometric data linked to the image bands. Through calibration, atmospheric distortions, sensor anomalies, and lighting differences were effectively addressed, leading to improved consistency in radiometric properties across the RGB channels. This enhancement is vital for accurate quantitative assessments, ensuring that the pixel values in the composite image better correspond to the actual surface reflectance values. The calibrated RGB composite establishes a dependable basis for further image analysis, classification, and extraction of valuable data, ultimately enhancing the accuracy and precision.

Figure 2. *Radiometric calibrated and FLAASH Corrected RGB Composite*

4.1. Temperature Variations

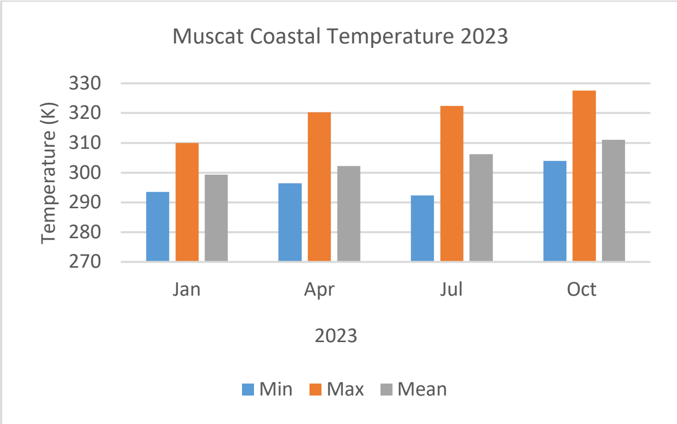
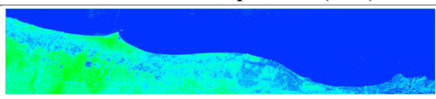
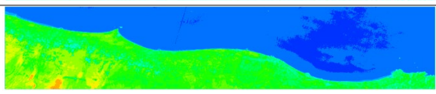
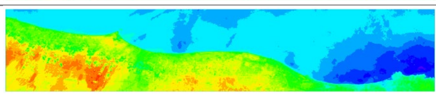
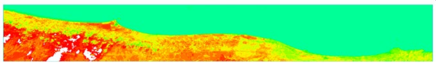


Figure 2. *Temperature Variations*

The temperature data across the four selected months (January, April, July, and October) reveal significant seasonal fluctuations as can be seen in figure 2 and LST in table 2. The mean temperatures in Kelvin (K) for January, April, July, and October are 299.37 K, 302.27 K, 306.23 K, and 311.05 K, respectively. This progression indicates a clear warming trend from winter to summer. January and October exhibit the lowest and highest mean temperatures, respectively.

Month	Land Surface Temperature (LST)
Jan	
Apr	
Jul	
Oct	

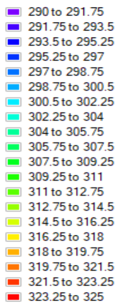


Table 2. *Land Surface Temperature (LST)*

The standard deviations for temperature are relatively high, particularly in April (6.47 K), July (7.515 K), and October (7.2668 K), indicating substantial temperature variability within these months. This variability is less pronounced in January (3.565 K), suggesting more stable temperatures during winter.

4.2. Chlorophyll-a Index (CAI)

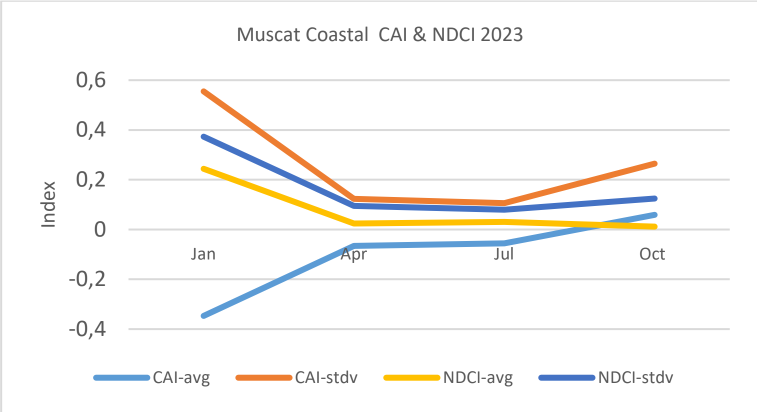
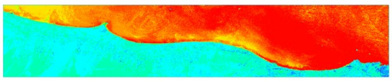
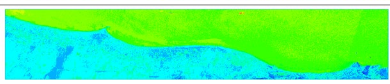
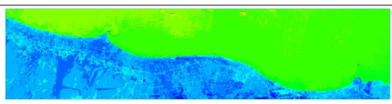
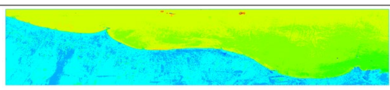


Figure 3. *Standard Deviation and Mean of CAI & NDCI*

The CAI shows negative mean values in January, April, and July, with -0.347, -0.0656, and -0.055, respectively, while October exhibits a positive mean value of 0.059.Table 3 and figure 3 shows the CAI and Standard deviation and mean of the CAI respectively. The substantial negative CAI in January and the relatively low standard deviation (0.555) indicate lower chlorophyll-a concentrations and less variability in winter. In contrast, October's positive mean value and moderate standard deviation (0.265) suggest higher chlorophyll-a concentrations with increased variability during the autumn months.

Month	Chlorophyll Absorption Index (CAI)
Jan	
Apr	
Jul	
Oct	

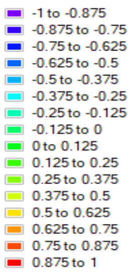
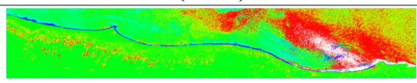
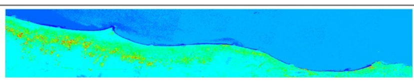


Table 3. *Chlorophyll Absorption Index (CAI)*

4.3. Normalized Difference Chlorophyll Index (NDCI)

The NDCI values show positive means across all months, indicating the presence of chlorophyll and hence photosynthetically active vegetation. The highest mean NDCI is observed in January (0.244), with a standard deviation of 0.373, suggesting high chlorophyll levels but with considerable variability. April, July, and October exhibit lower mean NDCI values of 0.024, 0.03, and 0.0117, respectively, with corresponding standard deviations of 0.095, 0.0796, and 0.12464, indicating relatively stable chlorophyll concentrations during these months.

Month	Normalized Difference Chlorophyll Index (NDCI)
Jan	
Apr	

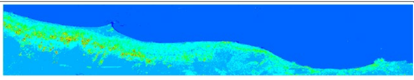
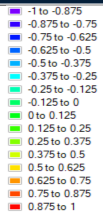
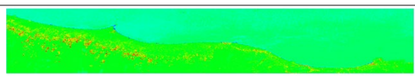
Jul		
Oct		

Table 2. *Normalized Difference Chlorophyll Index (NDCI)*

4.4. Solar Radiation

The analysis of All Sky Surface Shortwave Downward Irradiance, measured in kW-hr/m^2, shows the highest mean values in April (6.3577 kW-hr/m^2) and July (6.1835 kW-hr/m^2), suggesting maximum solar radiation during these months. January has the lowest mean irradiance (4.2190 kW-hr/m^2), consistent with the winter season when solar angles are lower. The standard deviation values indicate that April (1.0150 kW-hr/m^2) and July (0.92797 kW-hr/m^2) have higher variability in solar radiation compared to January (0.5522 kW-hr/m^2) and October (0.6886 kW-hr/m^2). Figure 4 depicts the variation of the solar radiation, the max, min and Mean.

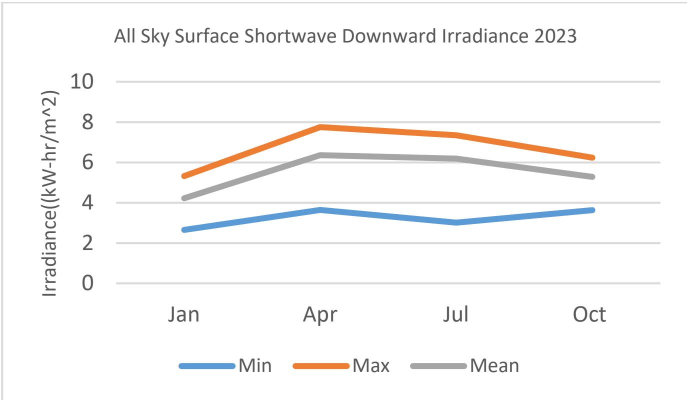


Figure 4. *Solar Radiation*

4.5. Interrelationships

The observed seasonal trends in temperature, CAI, NDCI, and solar radiation illustrate the complex interplay of environmental factors influencing coastal processes in Muscat. The increase in temperature from January to October corresponds with increased solar radiation, particularly in April and July. This rise in solar radiation likely drives the higher temperatures and affects the chlorophyll indices.

The CAI and NDCI variations further highlight seasonal shifts in marine productivity and vegetation health. The negative CAI in the early months suggests lower chlorophyll-a concentrations, potentially due to cooler temperatures and lower sunlight. As temperatures rise and solar radiation increases, the CAI improves, indicating enhanced chlorophyll-a presence. The NDCI values follow a similar trend, supporting the seasonal growth and activity of photosynthetic organisms.

CONCLUSION

This comprehensive seasonal analysis underscores the critical influence of solar radiation on coastal environmental parameters in Muscat. Understanding these dynamics is essential for effective coastal management and ecological conservation efforts. By leveraging remote sensing data and meteorological observations, stakeholders can develop informed strategies to mitigate environmental impacts and promote sustainable development in Oman's coastal regions.

REFERENCES

[1] Al-Farsi, Y. M., Al-Yahyai, M., Al-Zadjali, M. S., & Waly, M. I. (2018). Meteorological variables and distribution of monthly and annual rainfall in different regions of Oman. Atmosphere, 9(1), 31.

[2] Al-Shaqsi, S., Kumar, L., & Duan, Z. (2015). Bathymetric prediction using Landsat 8 OLI and SRTM data in coastal waters: A case study in Muscat, Oman. Geocarto International, 30(3), 298-311.

[3] Wulder, M. A., White, J. C., Loveland, T. R., Woodcock, C. E., Belward, A. S., Cohen, W. B., ... & Herold, M. (2015). The global Landsat archive: Status, consolidation, and direction. Remote Sensing of Environment, 185, 271-283.

[4] Roy, D. P., Wulder, M. A., Loveland, T. R., Woodcock, C. E., Allen, R. G., Anderson, M. C., ... & Scambos, T. A. (2014). Landsat-8: Science and product vision for terrestrial global change research. Remote Sensing of Environment, 145, 154-172.

[5] Markham, B. L., Barsi, J. A., Kaita, E., Malla, R., & Thome, K. (2014). Spectral band adjustment of landsat-8 operational land imager (OLI) to landsat-7 enhanced thematic mapper plus (ETM+). Remote Sensing, 6(10), 10306-10330.

[6] Kovalskyy, V., Roy, D. P., Zhang, H. K., Ju, J., & Vermote, E. F. (2019). Assessment of time series MODIS, MERIS, Landsat, and SPOT NDVI retrievals against year-matched GPP flux tower observations in South Florida, USA. Remote Sensing in Ecology and Conservation, 5(1), 16-31.

[7] Chander, G., Markham, B. L., & Helder, D. L. (2009). Summary of current radiometric calibration coefficients for andsat MSS, TM, ETM+, and EO-1 ALI sensors. Remote Sensing of Environment, 113(5), 893-903.

[8] Hulley, G. C., Hook, S. J., & Abbott, E. A. (2014). An approach for the atmospheric correction of Landsat-8 thermal infrared (TIR) data and the generation of a consistent TIR land surface temperature (LST) record. Remote Sensing, 6(11), 11193-11212.

ICOEST SARAJEVO
10TH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY
June 05-09 2024 (Hybrid Event)

Exploring the Impact of Solar Radiation on Environmental Dynamics in Oman Normalized Difference Vegetation Index (NDVI)

Mohammadu Bello Danbatta [1], Nasser Al-Azri [2]

Abstract

This study delves into the intricate relationship between solar radiation and vegetation health in Oman, focusing on the Normalized Difference Vegetation Index (NDVI) as a key indicator of ecosystem resilience. Utilizing advanced remote sensing techniques and comprehensive climate data, we analyze seasonal variations in solar radiation and NDVI across different ecological landscapes. Our findings reveal distinct seasonal patterns, with solar radiation peaking in April and July, while NDVI values fluctuate, reflecting the vegetation's response to varying environmental conditions. The analysis highlights that high solar irradiance alone does not guarantee robust vegetation health, emphasizing the role of other factors such as temperature and water availability. In particular, summer months exhibit signs of vegetation stress despite high irradiance levels, suggesting the influence of heat and potential drought conditions. This research provides actionable insights for effective environmental management and agricultural practices in Oman, advocating for strategies that consider both solar radiation dynamics and additional climatic factors. By integrating these findings, policymakers and stakeholders can develop informed interventions to enhance vegetation resilience and mitigate the adverse impacts of climate change on Oman's ecosystems. This study contributes to the broader discourse on climate change adaptation, underscoring the necessity of incorporating solar radiation metrics into holistic environmental assessments and sustainability strategies.

Keywords: Oman, Normalized Difference Vegetation Index (NDVI), Solar Radiation

1. INTRODUCTION

Solar radiation, comprising direct and diffuse sunlight, is a primary driver of ecological processes, influencing vegetation growth, photosynthesis, and energy balance in terrestrial ecosystems [1]. The Normalized Difference Vegetation Index (NDVI), derived from satellite imagery, quantifies the density and health of vegetation cover based on the differential reflectance of near-infrared and red wavelengths [2]. NDVI serves as a proxy for vegetation biomass, productivity, and ecosystem functioning, making it a valuable tool for monitoring environmental changes and assessing ecosystem health [3].

Understanding the dynamics of solar radiation and NDVI is crucial for elucidating ecosystem responses to climate variability and anthropogenic disturbances in Oman. Changes in solar radiation patterns, driven by atmospheric processes and land surface characteristics, can influence temperature regimes, precipitation patterns, and ecological productivity [4]. Variations in NDVI reflect changes in vegetation cover, phenology, and species composition, providing insights into ecosystem resilience and vulnerability to environmental stressors [5].

[1] *Department of Mechanical and Industrial Engineering, College of Engineering, Sultan Qaboos University, P.O. Box 50, Muscat, Sultanate of Oman, s143273@student.squ.edu.om*

[2] *Department of Mechanical and Industrial Engineering, College of Engineering, Sultan Qaboos University, P.O. Box 50, Muscat, Sultanate of Oman, nalazri@squ.edu.om*

By exploring the intricate relationship between solar radiation and NDVI dynamics in Oman, this study aims to unravel the underlying mechanisms driving environmental changes and ecosystem responses. Through advanced remote sensing techniques and climate modeling, we seek to analyze the spatiotemporal variations in solar radiation and NDVI across diverse ecological landscapes, shedding light on the complex interactions shaping Oman's ecosystems.

The introduction section of this paper sets the stage by providing background information, contextualizing the research objectives, and delineating the scope of the study. It aims to establish the significance of investigating the impact of solar radiation on environmental dynamics in Oman using the Normalized Difference Vegetation Index (NDVI).

The primary purpose of this study is to explore the intricate relationship between solar radiation and environmental dynamics in Oman, with a specific focus on utilizing the Normalized Difference Vegetation Index (NDVI) as a key indicator of vegetation health and ecosystem resilience. By leveraging advanced remote sensing techniques and sophisticated climate models, the research seeks to conduct a comprehensive analysis of the spatiotemporal variations in solar radiation and NDVI across diverse ecological landscapes in Oman.

2. STUDY AREA

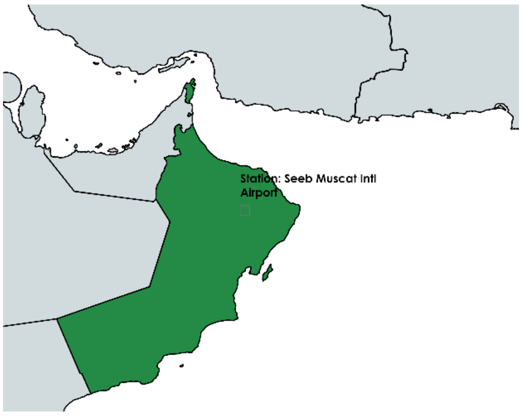


Figure 1 Sultanate of Oman

The study area was meticulously selected based on several criteria to ensure a representative sampling of Oman's diverse ecological landscapes. Key considerations included:

1. Geographical Diversity: To capture variations in environmental conditions and vegetation cover, the study included different regions of Oman, encompassing coastal areas, mountainous regions, and desert landscapes. This geographical diversity ensures that the study accounts for the wide range of ecological and climatic conditions present across the country.

2. Ecological Significance: Areas with high biodiversity and unique ecosystems were prioritized to gain insights into the impact of solar radiation on environmental dynamics in key ecological hotspots. This focus on ecologically significant regions allows for a deeper understanding of how solar radiation influences vegetation health and ecosystem resilience.

3. Accessibility and Data Availability: Regions with readily available satellite imagery, meteorological data, and ground truth information were selected to facilitate comprehensive and accurate assessments. This criterion ensures that the study is based on robust data, enhancing the reliability of the findings regarding solar radiation patterns and NDVI variations.

Description of Ecological Landscapes in Oman

Oman boasts a rich diversity of ecological landscapes, which are categorized as follows:

Coastal Areas: Along Oman's coastlines, diverse marine ecosystems such as coral reefs, seagrass beds, and mangrove forests thrive. These ecosystems are crucial for supporting marine biodiversity and enhancing coastal resilience. The coastal regions are significant not only for their ecological value but also for their role in sustaining local fisheries and protecting shorelines from erosion [6].

Desert Regions: Inland, the landscape transitions into arid and semi-arid desert regions characterized by sparse vegetation and extreme temperatures. Despite the harsh conditions, oases and wadis (valleys) within these deserts provide vital habitats for unique flora and fauna. These areas illustrate the resilience and adaptability of desert ecosystems[7].

Mountainous Regions: The mountainous areas of Oman, including the Al Hajar Mountains, exhibit a range of microclimates due to elevation gradients. These regions support diverse vegetation types, from Mediterranean-like forests and juniper woodlands to alpine meadows. The varied climatic conditions across different elevations create unique habitats for a wide array of plant and animal species[8].

Relevance to Study Objectives

The selection of these diverse ecological landscapes reflects Oman's environmental heterogeneity and ensures comprehensive coverage of the factors influencing solar radiation dynamics and NDVI variations. By including regions with distinct environmental characteristics, this study aims to provide a holistic understanding of how solar radiation interacts with various ecological settings, informing strategies for environmental management and sustainable development in Oman.

The selection of ecological landscapes in Oman reflects the country's environmental heterogeneity and ensures comprehensive coverage of the factors influencing solar radiation dynamics and NDVI variations.

3. METHODOLOGY

3.1 Data Collection

3.1.1. NDVI Data Source

For this study, remote sensing data was acquired from multiple sources to capture the spatiotemporal variations in solar radiation and NDVI across Oman's diverse ecological landscapes. Satellite imagery, obtained from platforms such as Landsat and Sentinel, provided high-resolution data suitable for monitoring vegetation dynamics and solar radiation patterns over large geographic extents [9][10].

3.1.2. Solar Radiation Data Source

In conjunction with remote sensing data, climate data from NASA POWER were utilized to supplement the analysis and provide contextual information on meteorological parameters such as temperature, precipitation, and humidity.

4. RESULTS AND DISCUSSIONS

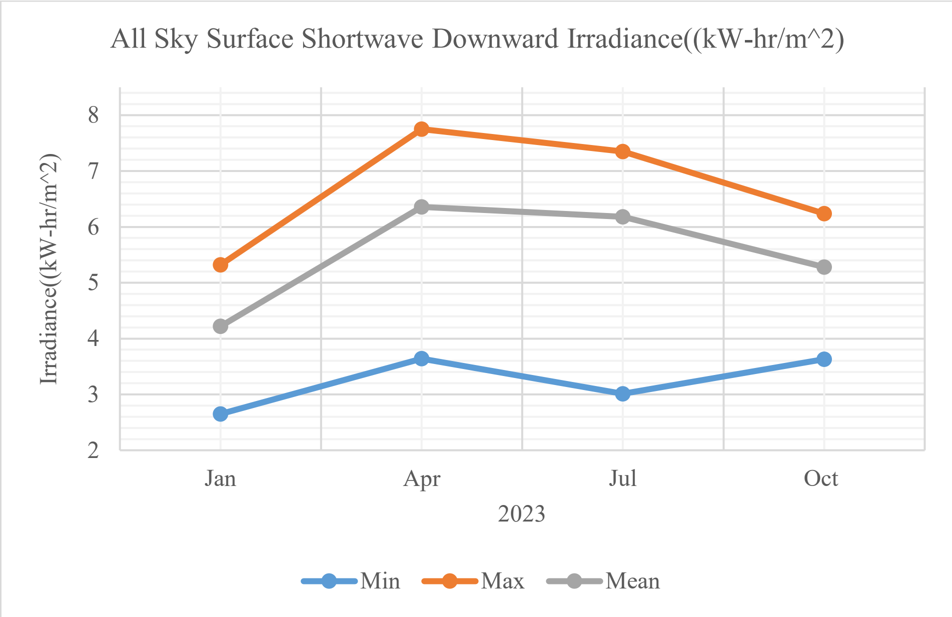


Figure 2 All Sky Surface Shortwave Downward Irradiance

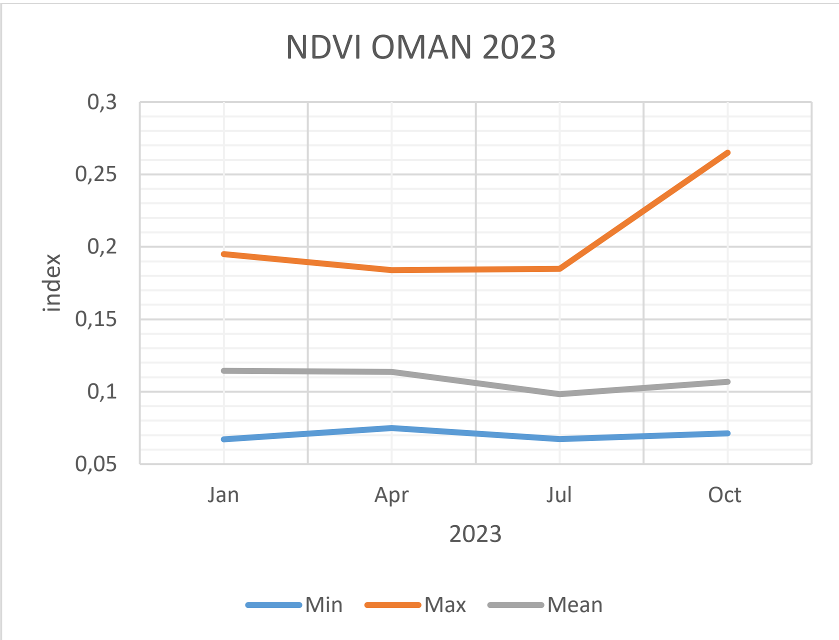


Figure 3 Sultanate of Oman

This section discusses the seasonal variations in Sky Surface Shortwave Downward Irradiance (SSSDI) and the Normalized Difference Vegetation Index (NDVI) data for the months of January, April, July, and October.

Analysis of Solar Radiation

January: Minimum: 2.65 kW-hr/m², Maximum: 5.32 kW-hr/m², Mean: 4.22 kW-hr/m², Standard Deviation: 0.55 kW-hr/m². In January, the mean irradiance is the lowest among the months observed, which correlates with winter conditions where solar insolation is typically reduced. The relatively low standard deviation suggests consistent irradiance values throughout the month.

April: Minimum: 3.64 kW-hr/m², Maximum: 7.75 kW-hr/m², Mean: 6.36 kW-hr/m², Standard Deviation: 1.02 kW-hr/m². April has the highest mean irradiance, indicating a transition to summer with increased solar exposure. The high standard deviation reflects greater variability in solar irradiance, likely due to changes in weather patterns and atmospheric conditions during spring.

July: Minimum: 3.01 kW-hr/m², Maximum: 7.35 kW-hr/m², Mean: 6.18 kW-hr/m², Standard Deviation: 0.93 kW-hr/m². July maintains high irradiance levels, similar to April, but slightly lower on average. The substantial standard deviation indicates notable variability, potentially influenced by summer weather fluctuations such as cloud cover and humidity.

October: Minimum: 3.63 kW-hr/m², Maximum: 6.24 kW-hr/m², Mean: 5.28 kW-hr/m², Standard Deviation: 0.69 kW-hr/m². In October, irradiance levels decrease as the season transitions to autumn. The mean irradiance is higher than in January but lower than in April and July. The standard deviation indicates moderate variability, suggesting relatively stable but slightly variable solar conditions.

Analysis of NDVI

*January:*Minimum: 0.0671, Maximum: 0.195, Mean: 0.1144, Standard Deviation: 0.0249

The mean NDVI in January indicates moderate vegetation health. The low standard deviation suggests consistent vegetation conditions across the region, which aligns with the relatively stable irradiance during this period.

April: Minimum: 0.0749, Maximum: 0.1839, Mean: 0.1136, Standard Deviation: 0.0247

In April, the NDVI mean is similar to January, indicating stable vegetation conditions. Despite the high irradiance variability, the vegetation health appears to be steady, which could be due to favorable spring growth conditions compensating for irradiance fluctuations.

July: Minimum: 0.0673, Maximum: 0.1848, Mean: 0.0983, Standard Deviation: 0.0239

July shows the lowest mean NDVI, suggesting stressed vegetation. This could be due to high temperatures and potential drought conditions, despite the high mean irradiance. The lower standard deviation reflects a uniform response of vegetation to the harsh summer conditions.

October: Minimum: 0.0712, Maximum: 0.265, Mean: 0.1067, Standard Deviation: 0.0342. October exhibits a higher NDVI variability, with the highest standard deviation among the months. This indicates diverse vegetation responses possibly due to the mix of residual summer heat and the onset of cooler autumn conditions, which can create varied microclimates and vegetation responses.

Correlation and Seasonal Dynamics

The correlation between SSSDI and NDVI highlights the complex interplay between solar radiation and vegetation health across seasons:

High Irradiance Months (April and July): These months experience high solar irradiance, yet the NDVI response differs. While April maintains stable NDVI, July shows signs of vegetation stress. This suggests that high solar irradiance alone does not guarantee healthy vegetation; other factors like temperature and water availability play critical roles.

Moderate Irradiance Months (October and January): These months have lower irradiance levels with moderate to high NDVI values. This indicates that lower solar radiation can still support healthy vegetation if other conditions are favorable.

Implications for Vegetation Health and Management

Understanding the seasonal dynamics of solar irradiance and vegetation health is crucial for effective environmental management and agricultural practices. The data suggests:

April: Optimal for vegetation growth due to high irradiance and stable NDVI, indicating robust vegetation health. This period is ideal for planting and intensive agricultural activities.

July: High irradiance coupled with low NDVI suggests potential heat and water stress on vegetation. Measures such as irrigation and shading may be necessary to support vegetation health during this period.

October: The variability in NDVI suggests a need for targeted interventions based on specific local conditions. This period can be used to prepare for the upcoming winter by ensuring vegetation is healthy and resilient.

January: Stable conditions with moderate NDVI indicate a period of maintenance. Agricultural activities should focus on protecting vegetation from potential cold stress and preparing for the spring growth period.

CONCLUSION

This analysis of Sky Surface Shortwave Downward Irradiance and NDVI across four months reveals significant seasonal variations in both irradiance and vegetation health. The highest irradiance occurs in April, with July also showing high levels, yet the NDVI in July indicates stressed vegetation, possibly due to extreme temperatures or drought conditions. October presents the highest variability in NDVI, suggesting diverse vegetation responses to environmental factors during this month. Understanding these dynamics is crucial for optimizing agricultural practices and managing natural resources. The insights into how different months affect vegetation health can guide planting schedules, irrigation practices, and conservation efforts to enhance sustainability and productivity in regions with similar climatic conditions.

REFERENCES

[1] Chen, M., et al. (2016). Quantifying the effects of solar radiation on ecosystem processes. International Journal of Biometeorology, 60(9), 1443-1452.
[2] Wang, X., Liu, Y., Zhang, Z. (2019). "Quantifying the Impact of Solar Radiation on Vegetation Dynamics Using Remote Sensing Data." Remote Sensing of Environment, 210, 89-104.
[3] Pettorelli, N., et al. (2005). Using the satellite-derived NDVI to assess ecological responses to environmental change. Trends in Ecology & Evolution, 20(9), 503-510.
[4]Ahlstrom, A., et al. (2015). The dominant role of semi-arid ecosystems in the trend and variability of the land CO2 sink. Science, 348(6237), 895-899.
[5] Huete, A. R., Didan, K., Miura, T., Rodriguez, E. P., Gao, X., & Ferreira, L. G. (2002). Overview of the radiometric and biophysical performance of the MODIS vegetation indices. Remote Sensing of Environment, 83(1-2), 195-213.
[6] Jones, D. A., Donato-Woodger, S., & Krishnaswamy, J. (2018). Mangroves of Oman: Status, threats, conservation and management. Ocean & Coastal Management, 162, 49-60.
[7] Al-Harthi, S., Hamad, M., Al-Amri, I., Al-Siyabi, M., & Al-Zadjali, M. (2017). Land use/cover mapping and change detection in arid environment: The case of Oman. Environmental Monitoring and Assessment, 189(6), 285.
[8] Al-Kalbani, M., Said, A. R., & Al-Kalbani, H. M. (2020). Ecosystem services and biodiversity of the Arabian Peninsula. In The Arabian Peninsula (pp. 375-392). Springer, Cham.
Al-Hashmi, K., et al. (2017). Coastal marine ecosystems of Oman: Patterns, status, and threats. Marine Pollution Bulletin, 114(2), 679-691.
[9] Smith, J., et al. (2018). Spatiotemporal Variations in Solar Radiation and NDVI Dynamics in Arid Regions: Insights from Remote Sensing and Climate Models. Remote Sensing, 35(4), 387-401. [Insert in-text citation for Smith et al. (2018)
[10] Smith, A.B., Jones, C.D. (2020). "Remote Sensing Techniques for Analyzing Solar Radiation Dynamics in Environmental Studies." Journal of Environmental Science, 25(3), 123-145.

ICOEST SARAJEVO
10TH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY
June 05-09 2024 (Hybrid Event)

Analyzing the Impact of Greenhouse Gas Emissions Resulting from Agricultural Activities

Fatma Kunt*[1], Busenur Kopuklu[1]

Abstract

Due to the rapid increase in the world population, the need for food is considered one of the most important problems of today. The hunger problem will cause malnutrition in many parts of the world and with it, the health system will collapse. New technologies and inputs have begun to be used in agricultural production to obtain quality and efficient products to avoid famine in the future. Agricultural pesticides, which are used as new inputs and called pesticides, have been widely used in recent years to protect agricultural products from invasive insects, disease agents, and weeds, due to their ease of use and short duration of action. Greenhouse gases resulting from agricultural production are carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These gases, which are effective in food production, have contributed to the acceleration of global climate change. In this review article, the harmful effects of greenhouse gases resulting from agricultural activities and their prediction models are mentioned. In addition, information is given about wrong practices used in agriculture. The article aims to provide a two-way perspective on the effects of greenhouse gas emissions on global warming and the effects of global warming on agriculture. As a result, air pollutants released from human activities such as animal husbandry, paddy fields, and applied techniques in agricultural production accumulate in the atmosphere and increase rapidly, creating greenhouse gases. Increasing greenhouse gases disrupt the radiation balance on the earth and increase surface temperatures by strengthening the effect of gases. In this case, it again reduces the quality and efficiency of agricultural production.

Keywords: agriculture, agricultural pesticides, climate change, global warming, greenhouse gases, famine, food security

1. INTRODUCTION

Global warming began with the rise of industry in the late 19th century. Its effects became more pronounced in the 1980s, and today it has led to a decline in biodiversity as the oceans warm. The burning of fossil fuels due to urbanization and development is one of the most apparent causes of global warming, especially in the 21st century. Another significant factor is agricultural activities [1, 2, 3].

Processes such as soil cultivation during agricultural activities, motor vehicles, irrigation methods, fertilizers and chemicals, and livestock activities are factors that may contribute to global warming [4]. To prevent famine caused by the world's growing population, agriculture is implementing new techniques and inputs to increase production. Urbanization has led to a reduction in agricultural areas and subsequently, a decrease in production. Pesticides are now commonly used as inputs in agriculture. The reason for this is that it increases the amount of product produced per unit area. It is thought that industries, technology, and the economy will suffer significant losses if the products produced cannot meet the needs of the population [5]. Because agricultural products not only meet food needs but also serve as raw materials in various industries [6].

[1]*Authors: Necmettin Erbakan University, Department of Environmental Engineering, Engineering Faculty Konya/Turkiye*
Corresponding author: drfatmakunt@gmail.com , bnur.kpkl@gmail.com

These applications are utilized to acquire more efficient, high-quality products within a short time frame and in confined spaces [7]. The most damaging practices include the use of chemical fertilizers, excessive irrigation, and improper soil cultivation [4]. Chemical products used in agriculture, known as pesticides (synthetic organic compounds), protect crops from invaders such as insects, weeds, and diseases. They are easy to use and show effects quickly. Today, a majority of agricultural products are obtained through the use of pesticides for their ease of use and long-lasting effects. With the reality of climate change, the prediction of agricultural conditions is evolving daily. This contributes to an increased reliance on pesticides, making them indispensable [8].

The greenhouse gases most commonly associated with agricultural activities are carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O). In agricultural areas, the soil contributes to the CO2 levels by converting the carbon retained in biomass products and organic matter [9]. Moreover, organic carbon becomes a source of CO2 emissions when soil is mismanaged. Improper irrigation and tillage practices lead to soil loosening, which in turn exposes organic carbon to heat and oxygen, causing it to convert into CO2 and be released. Wrong agricultural practices can enhance the biological and physical activities of the soil, leading to the emission of approximately 10% of the atmospheric CO2 from the soil [10].

From a different perspective, the agricultural sector is one of the sectors most impacted by global warming. However, global warming is largely caused by greenhouse gases produced from chemicals used in agriculture. Global warming leads to changes in rainfall patterns, higher temperatures, and harm to plant growth, resulting in water and food shortages as well as reduced agricultural productivity [4]. According to some researchers today, the main cause of climate change is the increase in greenhouse gases due to human activities such as industry, transportation, energy production, and agriculture. The atmosphere contains greenhouse gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), chlorofluorocarbons (CFCs), ozone (O_3), and water vapor (H_2O). These gases allow sunlight to pass through but trap heat, making them less permeable to the Earth's surface. This situation causes the soil to warm up more than it should, leading to the "greenhouse gas effect". Greenhouse gases are expected to be at reasonable levels in the atmosphere. If these gases did not exist, the Earth's average temperature would be very low, and the probability of survival for living things would decrease. The issue is not the existence of greenhouse gases, but rather their increase due to human activities, which disrupts the natural balance [11, 12, 13].

2. MATERIALS

The decline in water resources in a region suggests that salinity issues in agricultural areas will worsen. Consequently, excessive fertilizer will be utilized to boost agricultural productivity. This can lead to water and soil pollution, as well as increased greenhouse gas emissions. Moreover, there is a risk of heavy metal accumulation in the soil [11, 10].

The effects of pesticides on human and environmental health have been widely studied, but there is limited research on their impact on greenhouse gas emissions. A recent study evaluated the use of herbicides and fungicides among agricultural pesticides in terms of their environmental and economic implications. The study utilized FMOLS and DOLS analyses to determine whether these pesticides had a significant effect on greenhouse gas emissions. According to [8], a study found that a 1% increase in the amount of herbicide use (kg/ha) could lead to a 0.36% increase in agricultural greenhouse gas emissions, while a 1% increase in fungicide use (kg/ha) could lead to a 0.16% increase in agricultural greenhouse gas emissions. The results indicate that while pesticide use increases productivity, it also contributes to more environmental pollution over time. While the use of pesticides improves product quality, it also causes significant harm to humans and the ecosystem in the long run. These chemicals, when introduced into agriculture, disrupt the natural balance and lead to environmental problems. Pesticides can transform when they mix with soil, water, and air [7]. Especially as a result of spraying applications, chemicals can mix with the atmosphere. They can also be moved from one region to another by meteorological factors such as wind and rain [5].

According to research, the rate of damage caused by harmful organisms to plant products varies between 30-100%. It is widely accepted that if harmful organisms are not combated, the loss of quality and efficiency in plant production will be approximately 30-40% [14].

Therefore, the use of pesticides in agricultural production is considered inevitable. Based on 2020 data, 38% of the world's agricultural areas are located in Asia, 24% in America, 18% in Africa, 18% in Europe, and 2% in Australia. Although Asia has a larger agricultural area than America, the productivity of agricultural products is lower due to the higher mechanization and pesticide use in American agriculture, which results in higher productivity of agricultural products. The American continent stands out as the primary producer of agricultural products per unit area worldwide. The global use of pesticides in agriculture has increased from 2 million tons in 2000 to 2.6 million tons in 2020, with an average annual growth rate of 1.3%. Approximately 51% of this amount is used in America, 25% in Asia, 18% in Europe, 4% in Africa, and 3% in Australia [4].

Table 1: Shows the change in total pesticide sales in BRICS (Brazil, Russia, India, China and South Africa) countries over the years [4].

Countries	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2019**
Brasil	49.695	92.967	140.423	232.232	342.580	395.646	377.176
Russia	25.961	25.961	30.194	37.249	44.305	51.360	77.307
India	75.000	61.257	44.958	35.342	40.094	56.720	61.702
China	154.561	215.216	250.607	284.885	339.782	345.983	273.376
South Africa	16.582	18.025	26.857	26.857	26.857	26.857	26.857

According to Table 1, at the beginning of the period considered, the highest pesticide sales in the BRICS countries were in China, totaling 154.561 tons, while the lowest pesticide sales were in South Africa, amounting to 16.582 tons [15].

These countries continue to use chemicals extensively in agricultural production. According to TUIK (2019) data, the distribution amounts of Turkey's main greenhouse gases by years are shown in Figure 1 [16, 10].

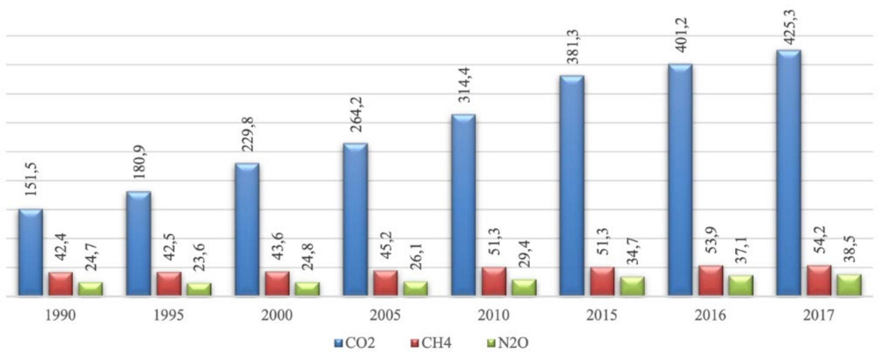


Figure 1: Amount of basic greenhouse gases emissions in Turkey as annually (CO_2 equivalent million tonnes [10]

Figure 1 illustrates a significant increase in CO_2 emissions over the years, surpassing other basic greenhouse gases. The emissions of all greenhouse gases, especially CO_2, need to be reduced. To address this issue, we need to implement practices that reduce carbon emissions and enhance carbon sequestration. These practices may involve reduced tillage, limited or controlled irrigation, decreased fertilizer use, reusing agricultural residues, and increasing soil organic matter [10].

When it comes to agriculture, nitrous oxide (N_2O) is one of the main greenhouse gases. It is also known as nitrogen peroxide or laughing gas. Nitrous oxide can remain in the atmosphere for more than 100 years after its release. It occurs naturally in the atmosphere as part of the world's nitrogen cycle. 40% of nitrous oxide emissions, which make up 6% of greenhouse gases in the atmosphere, are caused by human activities [17]. The most important resources are agricultural activities and animal husbandry within agriculture also includes this [18].

Methane (CH_4), a potent greenhouse gas, is generated by agricultural activities, energy production, waste management, and biomass burning. It has a shorter residence time in the atmosphere compared to other gases [17]. A significant amount of methane emissions comes from animal husbandry in agricultural production. 80% of total agricultural methane emissions and 35% of total anthropogenic methane emissions come from livestock [18].

According to the data from the Turkish Statistical Institute [19] and the Intergovernmental Panel on Climate Change guide, 7% of the total greenhouse gas emissions in 2010 were attributed to agricultural activities. The breakdown of greenhouse gases is as follows: 4% comes from CO_2, 30% from CH_4, and 74% from agricultural activities. Although CO_2 is generally the most important issue, CH_4 and N_2O are the primary greenhouse gases associated with agricultural activities. The emission of N_2O resulting from nitrogen inputs in plant and soil applications accounts for 74% of the overall emissions in Turkey. Specifically, soil cultivation and fertilizer use are responsible for the release of greenhouse gases [9].

The impact of agriculture on greenhouse gases cannot be ignored. However, from another perspective, agricultural activities are one of the sectors most affected by global warming. In recent years, higher-than-normal temperatures on Earth and seasonal changes have reduced productivity in agriculture [4]. Crop production, which primarily takes place in open areas around the world and relies on natural conditions, is directly or indirectly impacted by global warming and affected by climate-related factors such as temperature, precipitation, sunlight exposure, frost, wind, and humidity [18].

Climate change is projected to be the main cause of biodiversity loss in the next 100 years, leading to shifts in species distributions, timing of natural events, and ecological relationships. Another concern is the invasion of agricultural systems by weeds [20].

3. RESULT AND DISCUSSIONS

Pesticides are hazardous, harmful, and toxic substances. Their long-term, extensive, frequent, and unconscious use harms the environment and human health and increases greenhouse gas emissions [7]. Practices such as the use of pesticides, chemical fertilizers, excessive irrigation, and improper soil cultivation result in the emission of greenhouse gases. These gases contribute to global warming, leading to adverse effects on agricultural products, such as developmental disorders and reduced quality [21].

In recent years, the detrimental impacts of greenhouse gases from agriculture have been observed, leading to bans or limitations on chemical inputs in developed countries. However, inadequate inspections have hindered progress. Scientific research on greenhouse gases is ongoing [7]. There is limited research in Turkey and around the world on reducing emissions of CO_2, N_2O, and CH_4 gases from agricultural areas. Furthermore, the studies that have been conducted have many deficiencies. More research is needed in agriculture to understand the inefficiency of plants growing in arid and low-quality soils, the use of chemical fertilizers, and the impact of global climate change. Additionally, new models and methods should be developed to estimate the balance of CO_2, N_2O, and CH_4 gases originating from the agricultural sector [9]. Modern agricultural techniques need to be developed to prevent future problems. Excessive use of chemical fertilizers and over-cultivation of soil should be avoided. It's important to raise awareness of proper and organic agricultural practices, especially among communities involved in agriculture.

ACKNOWLEDGMENT

I would like to thank Ass. Prof. Dr. Fatma Kunt for guiding and supporting me while writing this article.

REFERENCES

[1] M. MacCracken , «Global Warming: A Science Overview,» *In Global Warming and Energy Policy,* pp. 151-159, 2001.

[2] J. Houghton, «Global Warming,» *Reports on Progress in Physics,* cilt 68, no. 6, p. 1345, 2005.

[3] H. Pathak ve R. Wassmann, «Introducing Greenhaouse Gas Mitigation as a Development Objective in Rice-Based Agriculture: 1. Genetation of Technical Coefficients,» *Agricultural Systems,* cilt 94, pp. 807-825, 2007.

[4] S. Tirasci ve U. Erdogan , «Kuresel Isinmanin Tarima Etkisi,» *Tarim, Gida, Cevre ve Hayvancilik Bilimleri Dergisi,* cilt 2, no. 1, pp. 16-33, 2021.

[5] A. Altikat, T. Turan, F. Ekmekyapar Torun ve Z. Bingul, «Pesticide Use in Turkey and Its Effects on the Environment,» *Ataturk University Faculty of Agriculture Journal,* cilt 40, no. 2, pp. 87-92, 2009.

[6] F. Onder, «The Impact of Agricultural Loans on Growth in Turkey: A Panel Data Estimation,» *Turkish Journal of Agriculture and Natural Sciences,* cilt 10, no. 2, pp. 1039-1050, 2023.

[7] H. H. Tiras, «Tarim Ilaclarinin Sera Gazi Emisyonlarina Etkisi: BRICS Ulkeleri Ornegi,» *Turkish Journal of Agriculture and Natural Sciences,* cilt 11, no. 1, pp. 130-139, 2024.

[8] M. Ayyildiz, «Evaluation of Chemical Pesticide Use in Turkey in Terms of Economy and Environment,» *COMU Faculty of Agriculture Journal,* cilt 10, no. 2, pp. 267-274, 2022.

[9] H. H. Kayikcioglu ve N. Okur, «Sera Gazi Salinimlarinda Tarimin Rolu,» *Journal of Adnan Menderes University Agricultural Faculty,* cilt 9, no. 2, pp. 25-28, 2012.

[10] C. Yerli, U. Sahin, T. Cakmakci ve S. Tufenkci, «Effects of Agricultural Applications on CO2 Emission and Ways to Reduce,» *Turkish Journal of Agriculture - Food Science and Technology,* cilt 7, no. 9, pp. 1446-1456, 2019.

[11] G. Akin, «Global Warming, Causes and Consequences,» *Journal of Ankara University Faculty of Languages, History and Geography,* cilt 46, no. 2, pp. 29-43, 2006.

[12] Y. Arikan ve G. Ozsoy, «Climate Change Bedside Guide From A to Z,» *REC Turkiye, Ankara: Regional Environmental Center,* pp. 1-128, 2008.

[13] M. Ozturk ve A. Ozturk, «From the UNFCCC to the Paris Agreement: The United Nations Efforts to Combat Climate Change,» *Omer Halisdemir University, Journal of the Faculty of Economics and Administrative Sciences,* cilt 12, no. 4, pp. 527-541, 2019.

[14] N. Tezer, «Effects of Pesticides on Human and Environmental Health,» *Union of Chambers of Agriculture of Turkiye, Ankara,* 2021.

[15] OECD, «Environmental Performance of Agriculture - Indicators,» 13 10 2023. [Cevrimici]. Available: https://stats.oecd.org/viewhtml.aspx?datasetcode=AEI_OTHER&lang=en .

[16] TUIK, «Turkish Statistical Institute, Environment and Energy Statistics,» 14 11 2019. [Cevrimici]. Available: http://www.tuik.gov.tr/UstMenu.do?metod=temelist.

[17] EPA, «Greenhouse Gas Emissions,» 12 12 2023. [Cevrimici]. Available: https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data.

[18] G. Kara, I. Yaliniz ve M. Sayar, «Greenhouse Gas Emissions from Animal Manure in Konya Province,» 2019.

[19] TUIK, «Greenhouse gas Emission Inventory 1990 -2010. T.R. Statistical Institute News Bulletin,» 2012. Available: https://www.tuik.gov.tr.

[20] P. Cotty ve R. Jaime-Garcia, «Influences of Climate on Aflatoxin Producing Fungi and Aflatoxin Contamination,» *International Journal of Food Microbiology,* cilt 119, no. 1-2, pp. 109-115, 2007.

[21] A. Gurel ve Z. Senel , «Examining the Measures to Be Taken in the Relationship Between Agriculture and Climate Change in Terms of Agricultural Extension,» %1 icinde *Turkiye 9th Agricultural Economics Congress*, Sanliurfa, 2010.

ICOEST
SARAJEVO
10TH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY
June 05-09 2024 (Hybrid Event)

The Effect of Different Environmental Conditions on Some Morphological Characteristics of Forage Kochia Populations

Nur Koc Koyun [1]

Abstract

Forage kochia (Bassia prostrata (L.) Beck) is a perennial, semi-shrub form C4 plant adaptable to drought and cold climates, soil salinity, and high calcareous conditions. In addition, this species can be used not only as a fodder crop but also for fire prevention and erosion, thus supporting biodiversity, protecting natural resources, and enabling sustainable land use. For this reason, five plants belonging to three different forage kochia populations were studied in our preliminary study to determine the morphological differences between the plants in three ecological environments. In the study, plants were grown in arid, salt-affected soil (SASs) conditions throughout 2018 and 2019. In the spring of 2020, the plants under SASs environmental conditions were transplanted, irrigated conditions (IC), and cultivated throughout 2020 and 2021. At the end of 2021, the same plants were uprooted and grown with organic barnyard manure (FWM) conditions for 2022 and 2023 in an area without soil salinity. The same observations and measurements were made during the six-year flowering period of the plants. The canopy diameter, related to the area covered by the plant above the soil, was 172.7 cm in the second year of the KKK population grown under IC. It has the lightest stigma color under IC. Considering these data, Broad-sense heritability (H^2) was calculated to determine how much of the traits of the genotypes were caused by the environment and genetics. As a result of these calculations, it was determined that canopy diameter and stigma color were affected by environmental conditions, respectively. The trait most affected 85% and 81% by environmental conditions ($1-H^2$) was leaf length, with 95%. As a result, it can be interpreted that some morphological characteristics of forage kochia are highly affected by environmental conditions, contributing to its adaptation to different ecological conditions.

Keywords: *Bassia prostrata*, Ecosystem Management, Rangeland Improvement, Salt- Affected Soils

1. INTRODUCTION

Forage kochia (*Bassia prostrata* (L.) Beck), a perennial, semi-shrub C4 plant, demonstrates high adaptability to drought and cold climates, thriving in saline and highly calcareous soil conditions [1], [2]. In arid regions dominated by continental climates, this plant remains green during summer, providing high-quality forage for livestock [1], [3]. Moreover, due to its ability to stay green in summer, it serves as a forage plant and plays a role in fire prevention. Its deep root system and extensive ground coverage help prevent erosion, support biodiversity, conserve natural resources, and enable sustainable land use [4].

Forage kochia or prostrate summer- cypress has ecotypes with morphological differences [5]-[7]. In Russia, from 2008 to 2016, six samples of prostrate summer- cypress were studied in the Northwestern Caspian Sea region across stony, sandy, and clayey soils, revealing yield differences among ecotypes [8]. A similar study in Kazakhstan's Atyrau region examined 40-44 samples of forage kochia planted in meadow-brown soils in 2016 and 2017, with fruit-based forage quality analyzed in 2020 under alluvial-meadow soil conditions. The study highlighted that 2016 growing conditions significantly influenced the chemical composition, including metabolic energy, digestible protein, and phosphorus [9]. These studies compared morphological traits to assess the environmental impact on plant responses across different conditions [8]-[10].

[1] *Corresponding author: Selcuk University, Faculty of Agriculture, Department of Field Crops, 42079, Selcuklu/Konya, Turkiye. nurkocr@selcuk.edu.tr*

Generally, phenotypic variance is the sum of genotypic and environmental variances, so the variation among inbred individuals grown under different conditions is known to be due to environmental factors. Broad-sense heritability (H^2) is defined as the proportion of phenotypic variance attributable to the overall variance for the genotype. Broad-sense heritability ranges from 0 to 1, with values closer to 0 indicating a higher influence of environmental factors on the trait being studied. It is essential to estimate H^2 on a genotype-mean basis because, in plant breeding, genotypes are often tested across a wide range of environments in designed, replicated experiments [11], [12]. Therefore, in our preliminary study, the same plants were replanted in other trial sites instead of using inbred lines. Five plants from three different forage kochia populations were grown under various conditions, or in other words, different ecological environments, for two years. The aim was to determine the extent of environmental influence on the morphological differences and traits observed in the plants.

2. MATERIAL AND METHODS

Koc Koyun [13] cultivated forage kochia in a problematic area in Konya Aslim Farm in October 2017 with a row spacing of 1.4 m and a row top of 1 m. As a result of the study, the plants with the best growth and high adaptability were selected and used as material in this preliminary study (Table 1).

Table 1. Plants and populations selected for the study

KKK Pop.	BIARI Pop.	SUFA Pop.
125	215	319
134	216	3313
1311	226	3418
1312	2216	529
1313	2217	5211
1314	2311	531
1315	2313	532
1316	2314	5313
		5419

KKK: Karapinar, Kartal Kayalari; BIARI: Bahri Dagdas International Agriculture Research Institute; SUFA: Selcuk University Faculty of Agriculture

In the study, these plants were grown under salt-affected soil conditions (SASs) during 2018 and 2019 (Figure 1A). According to soil analysis results, the experimental field's soil is slightly alkaline (pH 7.8) and has high organic matter (5.41%). The field has problematic soil, with very high lime content (68.4%), high salinity (9.03 dS m^{-1} ECe), and boron toxicity (57.36 mg kg^{-1}). The soil texture is clay loam, and the potassium, calcium, and magnesium levels are excessive. Examining the climatic characteristics of the SASs area, the average monthly temperature and total precipitation were recorded as 11.86°C and 375 mm in the planting year (2017), 13.78°C and 443 mm in 2018 (first year), and 12.85°C and 367.20 mm in 2019 (second year). Among the plants grown in the SASs area, plants coded 125, 226, 2314, 3313, and 529 did not flower during the growing period but continued to grow.

To examine the responses of the genotypes under different environmental conditions, they were removed from the SASs field in 2020 and transferred to the experimental area at Selcuk University, Faculty of Agriculture (SUFA) with 1 m above and 1 m between rows (Figure 1B). The area has a clay loam soil structure, low organic matter content (1.43%), pH 7.54, high lime content (43%), and no salinity (ECe 2.61 dS m^{-1}) in the soil. This soil also has no boron toxicity (0.90 mg kg^{-1}). Plants were grown with approximately 300 mm of water during the summer period in 2020 and 2021. Examining the climatic characteristics of the irrigated condition (IC) area, the average monthly temperature and total precipitation were recorded as 13.1°C and 292 mm in 2020 (first year) and 12.5°C and 360 mm in 2021 (second year), respectively. Among the genotypes transferred to this area, some of the plants coded 1311, 1312, 1314, 215, 216, 2314, 3418, 5211, and 531 did not survive due to their inability to adapt to the environment or their lack of resistance to pathogens developed from irrigation.

The study's third environment, examining manure's effect, is located within the SUFA experimental field. This area had not previously undergone cultural practices such as irrigation and fertilization. At the end of 2021, the transplanted plants were planted in furrows in this area (Figure 1C). The planting was done with 1.5 meters between rows and 1 meter between plants. After planting, a mixture of sheep and cattle manure with a moisture content of 5.27% was applied at 10 tons per hectare. The barn manure had an organic matter content of 6.41% and a pH of 7.09. Examining the climatic characteristics of the fertilized with manure (FWM) area, the average monthly temperature and total precipitation were recorded as 12.1°C and 289 mm in 2022 (first year) and 13.0°C and 348 mm in 2023 (second year), respectively. Among the genotypes transferred to this area, the plant coded 532 could not adapt to the new environment and did not survive.

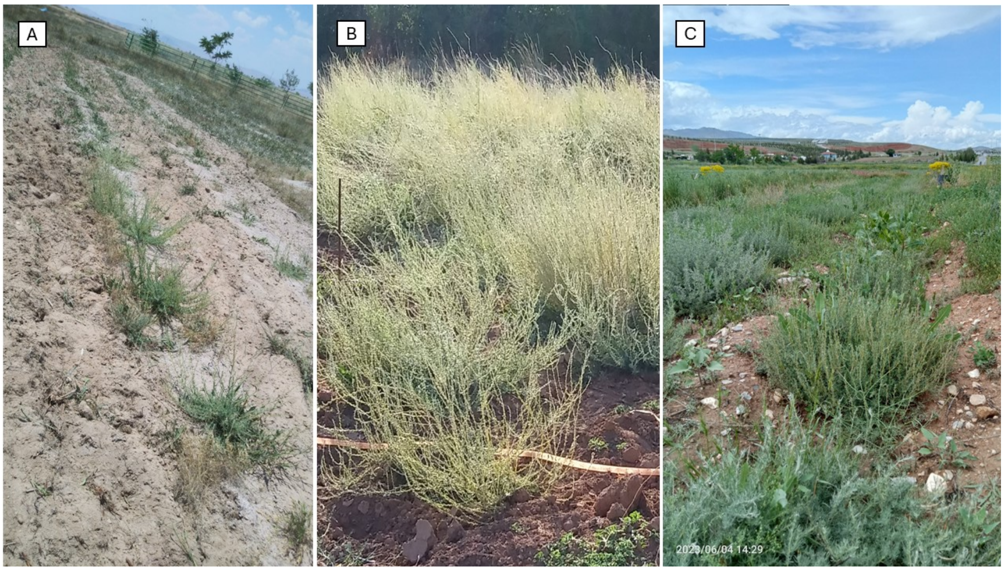


Figure 1. Forage kochia's changes in different growing environments; (A) SASs, (B) IC, (C) FWM

Table 2. Genotypes used in statistical analysis

Replication	KKK	BIARI	SUFA
1	125	226	319
2	134	2216	3313
3	1313	2217	529
4	1315	2311	5313
5	1316	2313	5419

At the end of the six-year study, the plants that remained viable and flowered at any time during this period were used in statistical analyses. These types are listed in Table 2. As shown in Table 2, five replications were used in this preliminary study. Each replication consisted of a single plant [14].

During the six years (2018-2023), observations and measurements of plant height (PH), canopy diameter (CD), stem diameter (SD), leaf length (LL), leaf width (LW), leaf hairiness (LH), and stigma color (SC) and anther color (AC) in flowering plants were taken between August and October, the flowering period [15]. Plant height was measured from the soil surface, canopy diameter was averaged from the maximum and minimum diameters, and both were recorded in centimeters. The stem diameter of the branch from five new shoots was measured with calipers and recorded in millimeters [16]. Leaf length and width were gauged on five leaves, showing the best development using a digital caliper. The color of anthers and stigmas was scored on a scale of 1-9 (1: Yellow, 3: Orange/Pomegranate, 5: Pink, 7: Dark Red, 9: no blooming or anther/stigma absent in flower) [13]. Plants were cut at an 8 cm height at the end of each growing season to minimize age-related variation in the same plants transferred to different environments [7]. Descriptive statistics (Mean, CV, SD, Min, Max) for the data obtained in the study were performed using JMP 7 software [17].

In this study, considering these data, broad-sense heritability (H2) was calculated to determine how much of the traits of the genotypes were caused by environmental and genetic factors. Broad-sense heritability is typically computed using pure lines developed through selfing to assess the influence of genetics and environment across different locations [11]. For this purpose, due to the perennial nature of the species used in our study, homogeneity, and environmental variation were ensured by planting the same plants in different environments.

Expected mean square values were calculated using the JMP 7 software package, and three factors were used to calculate them in the study. The first factor, location, had three levels (SASs, IC, and FWM). The second factor, year, was evaluated at two levels (first and second year) in Table 3. The third factor, genotype, included three different populations (KKK, BIARI, and SUFA). Broad-sense heritability (H2) was calculated using the below formulas [18].

Tablo 3. Year factor and its levels

Years	SASs	IC	FWM
First Year	2018	2020	2022
Second Year	2019	2021	2023

$\sigma 2p = \sigma 2e/rly + \sigma 2gly + \sigma 2gy/y + \sigma 2gl/l + \sigma 2g$

Broad-sense Heritability ($H^2_{Standard}$) = $\sigma 2g/\sigma 2p$

$\frac{\sigma 2p}{\sigma 2p} = \frac{\sigma 2g}{\sigma 2p} + \frac{\sigma 2e}{\sigma 2p}$(Environmental factors)

Environmental factors= 1- $H^2_{Standard}$

Since phenotypic variance (σ2p) is the sum of genotypic variance (σ2g) and environmental variance (σ2e), environmental factors were calculated for the traits using the above formula to account for the environmental variance in the study [11].

3. RESULTS AND DISCUSSION

In our study, descriptive statistics for the examined traits are provided in Table 4, and the mean values for the location * year * genotype interaction are presented in Figure 2.

Table 4. Descriptive statistics results of the analyzed traits

	PH (cm)	CD (cm)	SD (mm)	LL (mm)	LW (mm)	LH (Scoring[1])	SC (Scoring[2])	AC (Scoring[2])
Mean	49,94	80,24	2,89	13,21	1,97	6,56	4,98	4,76
Min	0,00	1,00	0,50	3,00	0,50	3,00	0,50	0,50
Max	102,00	185,00	12,67	26,00	8,70	9,00	9,00	9,00
CV	42,65	60,64	87,10	44,59	84,62	18,49	53,85	60,89
SD	21,30	48,65	2,52	5,89	1,66	1,21	2,68	2,90

Scoring[1] = 1: Very rare or absent, 3: Rare, 5: Moderate, 7: Frequent, 9: Very frequent
Scoring[2] = 1: Yellow, 3: Orange/Pomegranate, 5: Pink, 7: Dark Red, 9: no blooming or Anther /Stigma absent in flower

Regarding plant height, plants grown under SASs environmental conditions showed an average growth of 40.73 cm, while they averaged 54 cm in the other two environments. In the second year, the highest plant height was recorded at 65.8 cm for the BIARI genotype under IC environmental conditions. The canopy diameter, an essential trait for preventing erosion due to the area covered by the plant above ground, was narrowest at 47.93 cm in the SASs environment and widest at 100.63 cm in the IC conditions. The widest canopy diameter was also found in the IC environment, with the KKK genotype reaching 172.7 cm in the second year.

The thickest stem diameter for new shoots was 4.48 mm, observed in plants grown in irrigated areas. The thickest stem diameter was 7.6 mm, recorded in the second year for the BIARI and SUFA genotypes in the same irrigated area. The longest leaf length was 18.02 mm, found in the IC environment, with the SUFA genotype achieving the longest leaf length of 21.1 mm in the second year. However, the highest leaf width value of 3.02 mm was recorded in the FWM environment, where the BIARI genotype produced the widest leaf (5.9 mm) in the first year. Regarding leaf hairiness, the growing environments responded similarly, scoring approximately 6. The densest leaf hairiness was observed in the FWM environment, with the SUFA genotype scoring 7.8 in the second year.

Among the growing environments, the highest average stigma color score was 5.02, observed in both SASs and IC environments. In the SASs environment, plants under stress showed increased anthocyanin production, limiting growth under stress factors [13], [19]. Additionally, the high value of stigma and anther color in the IC environment was due to the presence of flowers that did not produce anthers or stigmas (score 9). Consequently, the highest stigma color (score 7.3) and anther color (score 8) were recorded in the first year for the SUFA genotype in the IC environment. Furthermore, flower color changes can result from soil conditions and adaptation to abiotic stress conditions such as temperature, drought, and UV radiation exposure [20].

Nidyulin et al. [8] indicated that stigma emergence in forage kochia occurs 7-20 days before anther emergence. Between 2014 and 2016, they identified and cultivated six forage kochia samples as three ecotypes. Their research found that the stone ecotype had a greater plant height (70 cm) and longer flowering period than other ecotypes, which led to higher forage and seed yields, making it more prominent. Shamsutdinov [10] examined the impact of ecology on forage kochia growth, planting different soil-adapted ecotypes in the Caspian semi-desert conditions in 2018 and 2019. The study reported that the average plant height over four years ranged from 40.2 cm to 77.0 cm for the 2018 plantings, while the 2019 plantings had a three-year average plant height ranging from 47.7 cm to 76.6 cm.

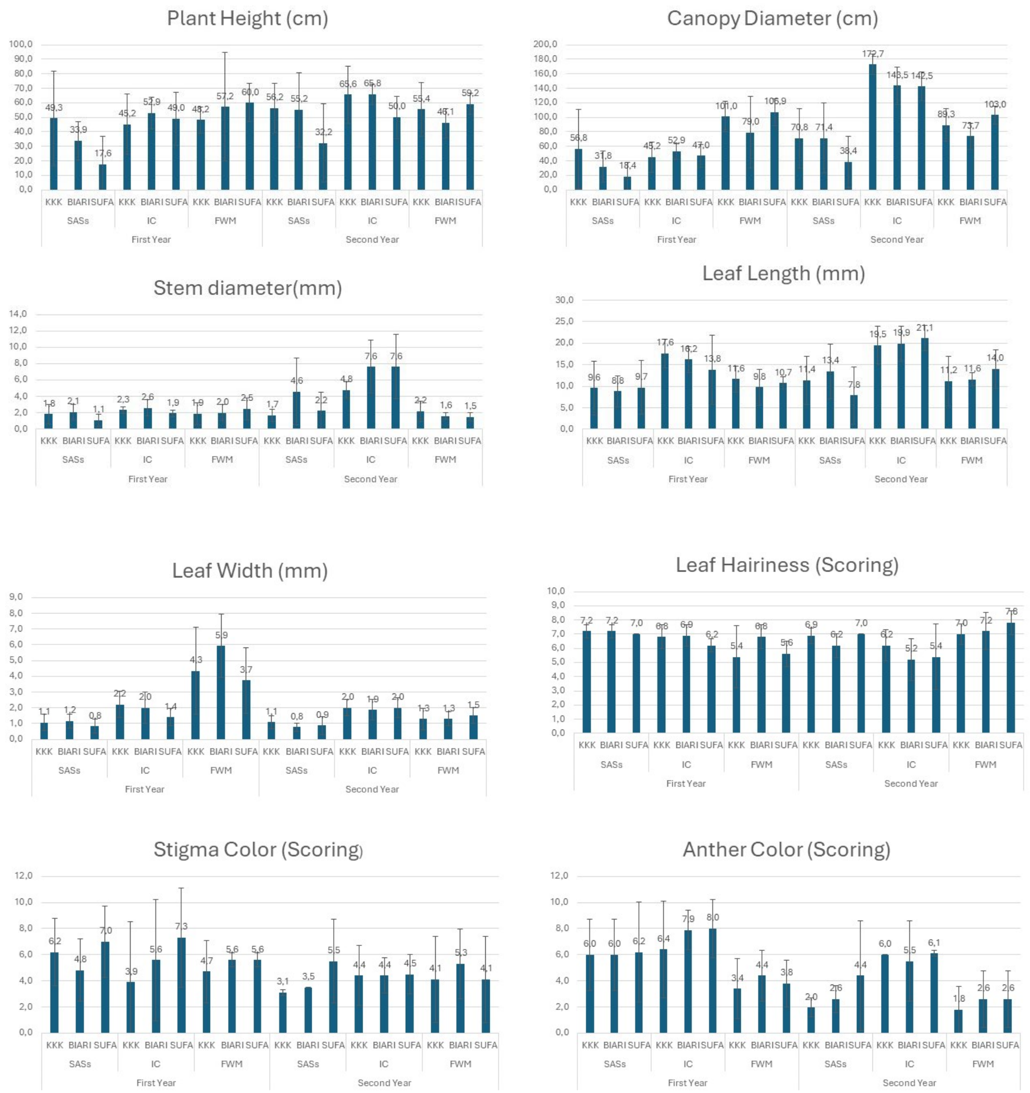


Figure 2. Interaction means of the analyzed traits (Scoring for leaf hairiness = 1: Very rare or absent, 3: Rare, 5: Moderate, 7: Frequent, 9: Very frequent, scoring for stigma and anther color = 1: Yellow, 3: Orange/Pomegranate, 5: Pink, 7: Dark Red, 9: no blooming or Anther /Stigma absent in flower)

In this study, Table 5 presents the expected mean square values for determining the degree of genotypic and environmental differences in forage kochia genotypes grown in different environments. Table 5 shows the broad-sense heritability and environmental factor values.

Our meticulous examination of the values in Table 6 reveals that leaf hairiness, with a heritability of 27%, is the trait most influenced by genetic factors in forage kochia. Conversely, plant height and leaf length, with heritability of 6% and 5% respectively, are the traits least influenced by genetics. The environmental factor value (1-H^2) further underscores the precision of our research, indicating that leaf length, at 95%, is the trait most affected by environmental differences, followed by plant height at 94% and canopy diameter at 85%.

Table 5. Expected means squares values of the analyzed traits

	DF	PH	CD	SD	LL	LW	LH	SC	AC
L	2	1912,05	24021,85	57,65	535,00	31,77	4,94	12,41	0,14
Y	1	1457,65	37271,03	67,20	136,41	27,58	0,01	0,01	38,68
L*Y	2	535,28	24780,63	43,61	19,22	27,28	12,05	4,04	2,67
R [L, Y]	24	392,39	1119,47	2,93	29,41	1,06	0,84	5,23	5,09
G	2	642,20	1850,50	7,06	2,98	1,53	0,07	8,98	12,31
G x L	4	928,11	2022,07	4,20	11,10	0,89	1,59	1,41	5,08
G x Y	2	81,87	73,91	4,46	10,80	2,65	3,22	5,62	2,21
G x L x Y	4	248,44	710,73	4,09	21,47	0,86	0,20	3,87	4,00
PE	48	384,324	711,75	3,49	20,40	1,24	1,31	6,02	8,49

DF: Degree of Freedom, L: Location, Y: Year, G: Genotype, PE: Pooled Error

Table 6. Broad-sense heritability and environmental factor of the traits examined

	σ2g	σ2gl	σ2gy	σ2gyl	σ2e	σ2p	H^2	1-H^2
Plant Height	3,98	67,97	11,10	27,18	384,32	72,17	0,06	0,94
Canopy Diameter	15,51	131,13	42,45	0,20	711,75	104,37	0,15	0,85
Stem diameter	0,08	0,01	0,02	0,12	3,49	0,33	0,25	0,75
Leaf Length	0,08	1,04	0,71	0,21	20,40	1,68	0,05	0,95
Leaf Width	0,04	0,00	0,12	0,08	1,24	0,22	0,18	0,82
Leaf Hairiness	0,15	0,14	0,20	0,22	1,31	0,56	0,27	0,73
Stigma Color	0,30	0,11	0,12	0,90	8,49	1,58	0,19	0,81
Anther Color	0,21	0,13	0,06	0,74	6,09	1,23	0,17	0,83

Klug et al. [11] stated that traits with a low heritability close to $H^2 = 0.0$ indicate that the phenotypic variation observed in the population is due to environmental differences. This study's results also suggest that all examined traits have low heritability. It implies that plants with low heritability traits, especially in plant breeding and selection studies, may exhibit different characteristics in each region, leading to difficulty in evaluating the relationships between traits [21].

Furthermore, according to Grime's plant adaptation strategies, forage kochia has been classified as a C (competitive) type. This means it is highly competitive and capable of capturing and holding territory for a long time due to its rapid growth, suppressing rivals through its vigorous growth, and full use of environmental resources [10]. As mentioned in our study, the high influence of environmental factors over genetic factors in determining the morphological characteristics of forage kochia could be impact on its competitive ability.

CONCLUSION

For forage kochia populations grown under three different environmental conditions, it can be inferred that there may be changes in morphological characteristics under different ecological conditions. This situation presents a challenge for selection based on morphological observations in forage kochia breeding studies. To overcome this issue, selection using molecular markers would achieve success more quickly and easily. As a result, it can be interpreted that some morphological characteristics of forage kochia are highly affected by environmental conditions, contributing to its adaptation to different ecological conditions.

REFERENCES

[1]. Acar, R. (2013). The importance of forage kochia (*Kochia prostrata* (L.) Schrad.) in KOP Natural Areas and advantages of its use in rangeland breeding. I. KOP Bolgesel Kalkinma Sempozyumu Bildiri Kitabi,14-16 Novemer 2013 Konya, Turkey (In Turskish).
[2]. Anonymous, 2019. National Plant Germplasm System, Germplasm Resources Information Network (GRIN-Taxonomy), National Germplasm Resources Laboratory
[3]. Acar, R., Inal, F., Koc Koyun, N., Kahraman, O., & Ozbilgin, A. (2021). The feed values of three forage Kochia phenotypes at different growth periods. *Bahri Dagdas Bitkisel Arastirma Dergisi*, *10*(1), 57-63.
[4]. Heston, S. (2023). *Exploring the plant communities of historical greenstrip seedings containing forage kochia (Bassia prostrata) across northern Nevada* (Master Degree Thesis), University of Nevada, Reno, USA
[5]. Acar, R., & Dursun, S. (2010). Vegetative methods to prevent wind erosion in central Anatolia region. *International Journal of Sustainable Water and Environmental Systems*, *1*(1), 25-28.
[6]. Guo H-c, Yan C, Wei Y, 2014. Study on the flowering dynamic, pollen viability and stigma receptivity of *Kochia prostrata*. *Acta Prataculturae Sinica*, 23, 4, 87-93.
[7]. Acar, R., Koc, N. (2019). The determination of yield and some yield components of different forage kochia (*Kochia prostrata* (L.) Schrad.) phenotypes collected and grown from natural areas. Fresenius Environmental Bulletin, 28, 2 A, 1429-33.
[8]. Nidyulin, V. N., Sangadzhieva, S. A., Staselko, E. A., Germasheva, Y. S., & Mushaeva, K. B. (2020). Ecological aspects and analysis of ecotypes of kochia prostrate (Kochia prostrata (L.) Schrad). In *IOP Conference Series: Earth and Environmental Science* (Vol. 579, No. 1, p. 012064). IOP Publishing.
[9]. Mukhambetov, B., Nasiyev, B., Abdinov, R., Kadasheva, Z., & Mamyrova, L. (2023). Influence of soil and climatic conditions on the chemical composition and nutritional value of Kochia prostrata feed in the arid zone of Western Kazakhstan. *Caspian Journal of Environmental Sciences*, *21*(4), 853-863.
[10]. Shamsutdinov, N. (2022). Ecological and biological characteristics and productivity of Kochia prostrata in the conditions of the Caspian semi-desert. In *BIO Web of Conferences* (Vol. 43, p. 02025). EDP Sciences
[11]. Klug, W.S., Cummings, M.R., Spencer, C.A. (2011). Genetik kavramlar (Cev. Oner, C., Sumer, S., Oner, R., Ogus, A., Acik, L.) Palme Yayincilik, Ankara, Turkiye
[12]. Schmidt P, Hartung J, Rath J, Piepho H-P (2019) Estimating broad-sense heritability with unbalanced data from agricultural cultivar trials. Crop Sci 59:525–536. https://doi.org/10.2135/cropsci2018.06.0376
[13]. Koc Koyun, N. 2021. The Determination of Genetic Relationships and Some Botanical Properties of Forage Kochia (*Kochia prostrata* (L) Scrad) Population Grown in Konya Conditions. The Graduate School of Natural and Applied Science of Selcuk University. PhD Thesis, Konya, 235 p (In Turkish).
[14]. Karimi, M., Banakar, M. H., Yazdani Bouki, R. 2021. Effect of nitrogen and phosphorous fertilizers on forage production of saltbush (Atriplex canescens) under saline conditions. Crop Science Research in Arid Regions, 2(2), 141-154.
[15]. Koc Koyun, N., & Acar, R. (2021). The determination of botanical properties of forage kochia population grown in Konya conditions. *International Journal of Innovative Approaches in Agricultural Research (Online)*, *5*(3), 311-321.
[16]. Aygun, C., Olgun, M. (2015). The observation criteria belonging to shrub and bushy plants. (Cali ve Calimsi Bitkilere ait Gozlem Kriterleri). Gida, Tarim ve Hayvancilik Bakanligi ISBN: 978-605-68346-0-8, Eskisehir (In Turkish)
[17]. Sall J, Stephens ML, Lehman A, Loring S, 2017. JMP start statistics: a guide to statistics and data analysis using JMP, Sas Institute.
[18]. Ntawuruhunga, P., & Dixon, A. G. (2010). Quantitative variation and interrelationship between factors influencing cassava yield. *Journal of Applied Biosciences*, *26*(4), 1594-1602.
[19]. Heldt H-W, Piechulla B, 2015. Bitki Biyokimyasi (Pflanzenbiochemie), (Cev. Ayaz, F.A., Sokmen, A.), Nobel yayincilik, Ankara, Turkiye.
[20]. Vaidya, P., McDurmon, A., Mattoon, E., Keefe, M., Carley, L., Lee, C.R., Bingham, R., Anderson, J.T. (2018). Ecological causes and consequences of flower color polymorphism in a self-pollinating plant (Boechera stricta). New Phytologist, 218, 1, 380-92.
[21]. Jamoza, J. E., Owuoche, J., Kiplagat, O., & Opile, W. (2014). Broad-sense heritability estimation and correlation among sugarcane (Saccharum spp. hybrids) yield and some agronomic traits in western Kenya. nternational Journal of Agricultural Policy and Research Vol.2 (1): 016-025.

Biography: Nur Koc Koyun is an Assist. Prof. Dr. in the Department of Field Crops at Selcuk University in Konya, Turkiye. For more than 10 years, she has been working as a staff at Selcuk University. In 2011, she graduated from Selcuk University, Faculty of Agriculture, Department of Agricultural Engineering. She completed two master's degrees in Field Crops, one on oil crop false flax (*Camelina sativa)* in 2014, and the other on the effects of salt dose on *Agropyron* sp. species in 2017. In 2021, she was granted a PhD degree in Field Crops, focusing on Forage kochia (*Bassia prostrata)* populations. Her research interests include the Rangeland and Pasture Improvement, Shrub Forage Crops, Forage Crops Breeding, and Population Genetics. She has lived, worked, and studied in Konya, Turkiye.

ICOEST
SARAJEVO
10TH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY
June 05-09 2024 (Hybrid Event)

Preparation, Traditional Uses and Benefits of St John's Wort Oil in Turkiye

***Irem Ayran Colak*[1]**

Abstract

Turkiye is one of the richest countries in the world in terms of plant biodiversity due to its geographical location and different ecological characteristics. There are approximately 12.476 plant taxa in the flora of Turkiye and approximately 500 of these plant species are used for medicinal purposes. St. John's Wort (Hypericum perforatum L.) is a significant medicinal plants with a global reputation, which has been used as a raw material with traditional medicine for more than 2000 years. St. John's Wort extract is used in the treatment of depression, sleep disorders, anxiety, myalgia, de-worming, rectal inflammation, mild pain; the medicinal oil is an important that is frequently used in wound and burn treatments among the people and has also been the subject of many scientific researches. The pharmacologically important components of St John's Wort and its medicinal oil are hypericin and hyperforin. Thanks to these bioactive components, its usage area in food, pharmaceutical and cosmetic industry is increasing day by day. For this reason, it is one of the important medicinal plants whose sustainable production should be increased in our country. In this study will examine the morphological characteristics of Hypericum perforatum L., commonly known as St. John's Wort, which is naturally distributed and cultivated in Turkiye. Additionally, the preparation, traditionally uses, chemical composition and benefits of the St. John's Wort oil will be presented.

Keywords: *Hypericum perforatum* L., medicinal oil, St. John's Wort, traditional use

1. INTRODUCTION

People have used medicinal plants and the products obtained from these plants in order to live a better life since their existence. Turkiye is one of the richest countries in the world in terms of plant biodiversity due to its geographical location and different ecological characteristics. There are approximately 12.476 plant taxa in the flora of Turkiye [1] and approximately 500 of these plant species are used for medicinal purposes [2]. However, medicinal plants are used in many sectors such as food, paint, cosmetics, animal husbandry, beekeeping, agriculture, ornamental plants and textiles.

It is important to learn how to make St. John's Wort oil, because firstly, it is easy to make at home and in addition to this making the oil at home can be more cost-effective. The medicinal oil is also an advantage that it is easy to do. St. John's Wort oil offers a natural alternative for treating various health issues such as wound healing, skin problems, burns, and muscle pain. These reasons highlight the importance of learning to make St. John's Wort oil for personal health, natural treatment options, economic, environmental and sustainable benefits. In this study, the preparation, traditionally uses, chemical composition and benefits of the St. John's Wort oil will be presented.

1.1. General Information and Morphological Characteristics of St. John's Wort

St. John's Wort has been used as a valuable medicinal plant for over 2000 years [3]. St John's Wort (*Hypericum perforatum* L.) is an important perennial species belonging to the Hypericaceae family. The genus *Hypericum* has approximately 482 species in the world [4] and 46 of 94 species are endemic in Turkiye [5;6]. The most widely used of these species in the world is *Hypericum perforatum* L.

Hypericum perforatum L. is a perennial herbaceous plant with yellow flowers, highly branching, upright stems 30-90 cm tall [7]. The glandular pockets in the plant are found in the flowers, but also in the leaves, and when

[1] *Corresponding author: Selcuk University, Faculty of Agriculture, Department of Field Crops, 42130, Konya, Turkey.* irem.ayran@selcuk.edu.tr

crushed, a reddish colour appears as shown in Figure 1. It is known that the red colour is caused by hypericin [8]. St. John's Wort has a fringe root structure. Leaves are opposite and sessile. The flowers are 5-parted at the end of the branches [9].

Figure 1. The flowers of St. John's Wort exhibit a reddish due to the presence of hypericin [10]

1.2. Production of St. John's Wort

The seeds of St. John's Wort are small and are found in capsules and the average weight of a thousand grains is 0,125 grams. Production is done by seeds and seedlings. Although it varies according to the region where it is grown, the plant is sewing in the field in April, May and the 2nd growing period of *Hypericum perforatum* L. blooms in July and August [10].

1.3. Geographical distribution

The plant is naturally distributed in Asia, Europe, North Africa, Anatolia, Western Asia and America [11]. As shown in Figure 2, it is found in the natural flora of Marmara, Black Sea, Aegean, Central and Eastern Anatolia, Mediterranean and Southeastern Anatolia regions in Turkiye [5;12].

Figure 2. Geographical distribution of St John's Wort (Hypericum perforatum L.) in Turkiye

1.4. Chemical composition of the flowering herb;

The parts of St. John's Wort used for medicinal purposes are the flowering herb and have flavonoids (hyperoside, rutin, quercitrin, isocercitrin, quercetin, kemferol, apigenin), phenolic acids (caffeic acid, chlorogenic acid, ferulic acid), sterols, xanthones, phenylpropanoids, vitamins (A, C, E), oligomeric procyanidins and tannic substances [9;13;14].

2. PREPARATION OF ST. JOHN'S WORT OIL

The stages of the production of St. John's Wort oil are presented in Figure 3, according to the studies of [14].

1. In order to harvest St. John's Wort, it is necessary for the plant to reach full flowering. 	 **2.**The top 2/3 of the herba of St. John's Wort is harvested.
 **3.**The fresh plant material is cut into small pieces.	 **4.**Plant materials are placed in glass jars and 1/5 or 1/10 ratio olive oil is added on it.
5.It is subjected to maceration for an average of 30-45 days in a sterile environment exposed to the sun. 	**6.**The plant material in the oil is pressed down with a sterile spatula every two to three days to prevent mould. Because the plants coming out of the oil cause mould. 
 **7.**At the end of the masere period, the filtering process is performed.	**The filtered St. John's Wort oils are stored in amber colored glass bottles in a place out of direct sunlight.

Figure 3. Steps in the production of St. John's Wort Oil

2.1. Benefits of St John's Wort Oil

This oil has long been known to give very good results in the treatment of wounds, burns and sunburn, and in spot treatments. In addition, when used orally, it is good for stomach and intestinal disorders / wounds. Oleum Hyperici is also used externally as antiseptic and antimicrobial. After applying this oil, do not expose your skin to the sun, as it may cause skin damage or staining. In addition, it is applied topically for hair and skin care, muscle pain, rheumatism, and arthritis, reducing pain, menstural cramps and inflammation through massage [9;10].

CONCLUSIONS

In this study, in the production process of St. John's Wort oil, which is widely used among the people in Turkiye; the correct harvest time of the plant, the plant part used, whether the plant is dry or wet, correct selection of the maceration environment (sun), quality/selection of the oil to be used in maceration, plant/oil ratio, holding time, tool equipment specification and hygiene, storage conditions information about many parameters is given.

Thanks to the important bioactive components found in St John's Wort oil, its usage area is increasing day by day. In conclusion, St John's Wort oil is a versatile and valuable herbal remedy with a long history of use in traditional medicine. It is simple to prepare and its benefits for skin health, pain relief and inflammation are well supported by both traditional practices and modern research. Therefore, it is essential to increase the sustainable production of this important medicinal plant in our country.

Biography: Asst. Prof. Dr. Irem Ayran Colak is employed at Selcuk University, Faculty of Agriculture, Department of Field Crops in Turkiye. Her area of expertise is Medicinal and Aromatic Plants.

REFERENCES

[1]. A. Karagoz, N. Zencirci, A. Tan, T. Taskin, H. Koksel, M. Surek, C. Toker, and K. Ozbek, "Bitki genetik kaynaklarinin korunmasi ve kullanimi," Turkiye Ziraat Muhendisligi VII. Teknik Kongresi, 1, 155-177, 2010.
[2]. Anonymous, (2019). Tibbi ve aromatik bitki cesitliliginin korunmasinda, bunlarin uretiminde ve pazarlanmasinda karsilasilan sorunlar ile alinmasi gereken tedbirlerin belirlenmesi amaciyla kurulan meclis arastirmasi komisyonu raporu, TBMM Basimevi, 1-159. Available: https://www.tbmm.gov.tr/sirasayi/donem27/yil01/ss159.pdf.
[3]. Anonymous, (2016) Sari Kantaron, Tabcag El Kitaplari, Afyon Kocatepe Universitesi, Afyon.
[4]. S. L. Crockett, and N. K. Robson, N. K, "Taxonomy and chemotaxonomy of the genus Hypericum," *Medicinal and aromatic plant science and biotechnology*, 5 (Special Issue 1), 1, 2011.
[5]. (2024) Turkiye Bitkileri Veri Servisi (TUBIVES) website. [Online]. Available: http://www.tubives.com/index.php?sayfa=1&tax_id=2102
[6]. Y. Kan, Dogu karadeniz bolgesi tibbi ve aromatik bitkilerin envanterinin cikarilmasi, ticari kullaniminin arastirilmasi ve ureticilerin egitimi projesi egitim kitabi, 1-178, 2017.
[7]. T. Baytop, Turkce bitki adlari sozlugu, Turk Dil Kurumu, Ankara, 1994.
[8]. C. Cirak, and D. Kurt, "Onemli tibbi bitkiler olarak hypericum turleri ve kullanim alanlari," Anadolu, J. of Aari. 24(1), 42-58, 2014.
[9]. J. Gruenwald, T. Brendler, and C. Jaenicke, PDR for herbal medicines. 3rd Ed, Montvale, N.J., Thomson Healthcare, London, 2004.
[10]. Ayran, "Geleneksel tip uygulamalarinda kullanilan sari kantaron (*Hypericum perforatum* L.) yaginin standardizasyonunun belirlenmesi (PhD thesis). Selcuk University Institute of Science and Technology, Konya, December, 2021.
[11]. N. K. B. Robson, "Studies in the genus Hypericum L. (Guttiferae) 4 (2). Section 9. Hypericum sensu lato (part 2): subsection 1. Hypericum series 1. Hypericum," *Bulletins of the Natural History Museum: Botany Series*, 32 (2), 61-123, 2002.
[12]. O. Kacar, and N. Azkan, "Turkiye'de bulunan bazi Hypericum L. (Hyperiaceae) turleri uzerinde sayisal taksonomik bir calisma," *Firat Universitesi Fen ve Muhendislik Bilimleri Dergisi*, 17 (2), 424-434, 2005.
[13]. O, Aksu, and B. Altinterim, "Kantaron otu (*Hypericum perforatum*) ve hiperisin," Bilim ve Teknik Dergisi. ISSN: 2148-0273, 3(1), 2015.
[14]. I. Ayran, and Y. Kan, "Geleneksel tip uygulamalarinda kullanilan sari kantaron (Hypericum perforatum l.) yaginin standardizasyonunun belirlenmesine yonelik yurutulen bazi kalite analizlerinin incelenmesi," *Biological Diversity and Conservation*, *15*(2), 249-257, 2022.

ICOEST SARAJEVO
10TH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY
June 05-09 2024 (Hybrid Event)

Eco Trends in Civil Engineering

Ena Grčić[1], Marija Šperac[2], Dino Obradović[3]

Abstract

Civil engineering is a human activity, a scientific and technical discipline that includes the design, organization and execution of all civil engineering and construction works. Some of the common construction products are roads, bridges, railways, tunnels, ports, drainage and water supply systems, dams, residential and public buildings, sports halls, etc. The construction of new buildings reduces the amount of green or arable land needed by the population. Also, the demolition of existing buildings creates waste that needs to be properly disposed. The problem of waste disposal is very pronounced nowadays, so it is necessary to look for new ways of using existing as well as newly created waste. One of the available ways of using waste is its incorporation into materials used in the construction of buildings. The above can be observed through the concept of circular economy, which is the opposite of linear economy. Circular economy says that products should be kept as long as possible in their life cycle, i.e. that no waste is created. Such resources should be reused in other products. The paper will present some of the materials that can be reused in construction, as well as application of certain products that improve certain properties of construction products. Some examples are reuse of glass fiber reinforced plastic in concrete, utilizing biosilica to enhance the compressive strength of cement mortar, boosting concrete strength with sewage sludge fly ash, adding rubber into the concrete mix and polyethylene terephthalate (PET) waste in concrete mixture. Eco trends must be applied in all phases: from design to construction and to removal of various objects. Eco trends in civil engineering are aimed at protecting the environment by reducing the amount of unusable waste material and saving on construction material prices.

Keywords: circular economy, civil engineering, eco trends, recycling, waste materials

1. INTRODUCTION

Construction sector is one of the largest and most dynamic sectors in Europe, currently accounting for 25% [1] of the total industrial production in Europe. Since the construction industry requires a large amount of raw materials, this makes it unsustainable. The fact behind the benefits of using recycled materials in construction is that if people mismanage and overuse natural resources — as they do now — these will eventually run out, so replacing natural resources with waste recycled products is the first step towards a circular economy and sustainable construction. Recycling materials contribute to reduction of waste, resource conservation, greenhouse gas emission reduction, and increased energy efficiency. Increased profitability and cost savings are two further benefits of employing recycled materials in the construction sector [2]. Utilizing recycled materials may prove to be more cost-effective compared to virgin materials, particularly when obtained from nearby sources and incurring reduced transportation expenses. Additionally, they have the potential to decrease the necessity for costly charges associated with waste management, such as disposal fees and taxes. Recycled materials have the potential to foster new markets and open up new opportunities for companies and workers in the recycling industry. This, in turn, can contribute to the growth of local economy and generate additional income. On the other hand, recycled materials may have different properties and characteristics than the original materials, such as strength, durability, quality and compatibility, so it is important to conduct extensive

[1] *Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering and Architecture Osijek, 31000 Osijek, Croatia, egrcic@gfos.hr*

[2] *Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering and Architecture Osijek, 31000 Osijek, Croatia, msperac@gfos.hr*

[3] *Corresponding author: Josip Juraj Strossmayer University of Osijek, Faculty of Civil Engineering and Architecture Osijek, 31000 Osijek, Croatia, dobradovic@gfos.hr*

laboratory research. In this context, this paper reviews the use of biosilica, glass fiber reinforced plastic, sludge fly ash, rubber and PET waste in concrete mix. A review of these five studies shows that the use of recycled materials has positive effects on the mechanical properties of concrete, indicating that their application is the basis for future innovation development.

2. CIRCULAR ECONOMY IN THE CONSTRUCTION INDUSTRY

Construction sector has been a sustainable sector since ancient times. The materials and building techniques used in the past were effective, creating ecologically designed structures while utilizing environmentally friendly materials that had a high potential for reuse and recyclability [3].

Sustainable circular economy represents a new economic model where the focus shifts from the narrow growth of gross domestic product to a multidimensional progress – broadly strengthening the quality of the environment, human well-being, and economic prosperity for current and future generations. The circular economy is a business model with the potential to generate competitiveness of an economic entity in combination with innovation and sustainability. In order to implement this model, the traditional approach to the market, customers, and natural resources must change [4].

The construction industry has always had a significant impact on every national economy, evident from its contribution to the GDP structure and employment of a large workforce [5].

The transition from linear to circular economy is inevitable as linear production is associated with mass production and consumption of raw materials, without concern for the potential limitations of the availability of these resources [6]. Circular economy can make positive contribution to sustainability. It must be fully integrated with the sustainable development of an economic entity, expanding its scope from closed-loop recycling and short-term economic gain to a transformed economy that organizes resource access for maintaining or enhancing social welfare and environmental quality [4]. The concept of circular economy is shown on figure 1.

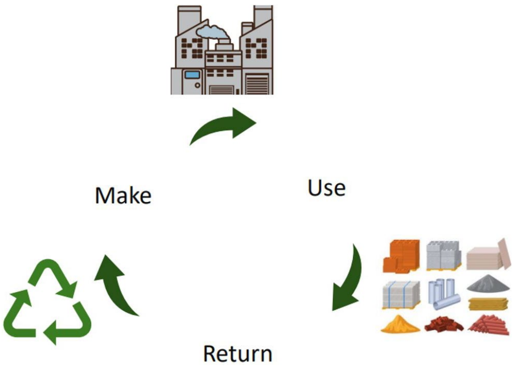


Figure 1. Concept of circular economy [7]

3. USE OF RECYCLED MATERIALS IN CONSTRUCTION

3.1. Utilizing biosilica to enhance the compressive strength of cement mortar

Recent developments in the industrial sector involve the use of microsilica, a byproduct of metallurgical operations used to create metallic silicon, ferrosilicon, silumin, and other silicon alloys. Additionally, biosilica obtained by thermochemical processes from natural sources, like rice husk ash, is of considerable interest [8], [9]. The possibility that biosilica, a kind of silica that is naturally produced by diatoms, might improve the mechanical properties of cement-based materials is being studied. Due to the fact that it comes from a sustainable source and is biodegradable, biosilica has several advantages over traditional silica additions. In the building materials field, the use of biosilica in cement mortar is becoming increasingly important. Because of its special characteristics, which include a wide surface area, small particle dimensions, and pozzolanic activity, it is a desirable addition for cement-based products to improve their mechanical performance.

The efficacy of an addition in cement mortar is determined not only by its intrinsic qualities, but also by the technique of inclusion into the mortar mixture. To produce a homogeneous dispersion of additives, maintain sufficient contact with the cement matrix, and influence the performance of composites, mixing processes are essential. Therefore, it is necessary to comprehend how mixing methods impact this material to maximize its efficacy and realize its full potential when using biosilica in cement mortar [9]. Biosilica synthesis from rice husk is shown on figure 2.

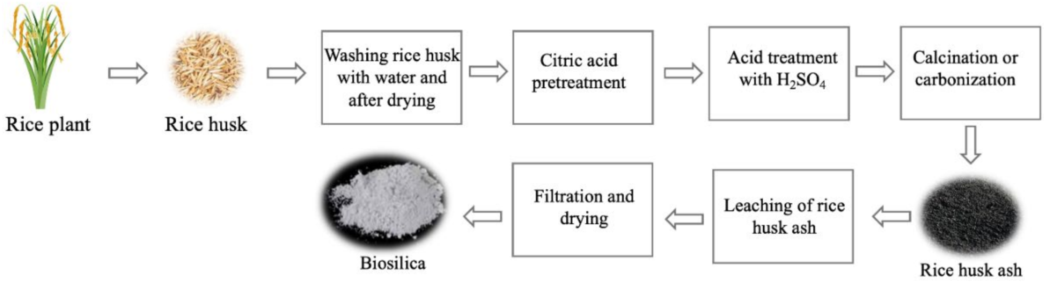


Figure 2. Schematic of biosilica synthesis from rice husk [10]

Research shows that integrating a significant quantity of biosilica can fill cracks, potentially boosting compressive strength and minimizing water absorption. Biosilica particles are capable of bearing compressive loads, contributing to enhanced strength. Owing to their minute dimensions, these particles can occupy empty spaces within the cement, resulting in heightened density. The presence of biosilica renders the pores rigid, aiding in preserving the structural integrity [9], [11].

3.2. Boosting concrete strength with sewage sludge fly ash

According to European regulations, sewage sludge fly ash (SSFA) waste generated by the combustion of municipal waste sludge in a fluidized bed should not end up in landfills, but must be subjected to different treatment methods. Considering the large quantities being produced, it is necessary to explore new approaches to managing this waste. Storage of SSFA has negative environmental consequences, including water pollution, changes in soil pH and adverse effects on flora and fauna [12], [13], [14].

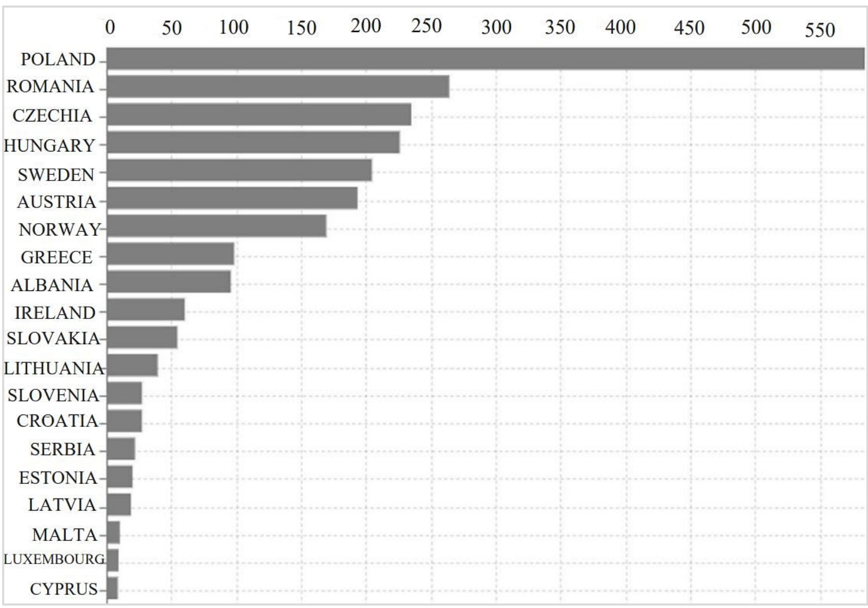


Figure 3. Sewage sludge production and disposal for 2021 [1]

Figure 3 shows sewage sludge production and disposal for countries in Europe for 2021. Quantities are expressed in thousands of tons. There is no data for Bulgaria, Germany, Spain, France, Netherlands, Portugal, Finland, Switzerland and United Kingdom.

Adding SSFA to cement and concrete brings a number of financial and environmental benefits. This reduces the amount of waste sludge in landfills, optimizes the costs and quality of construction materials, and reduces total disposal costs, including those specific to landfills. It also reduces the need for primary raw materials and promotes the sustainable development of the economy through the conversion of waste sludge into useful products. In addition, energy savings and the reduction in emissions of harmful substances such as NOx, CO_2 and other pollutants are achieved [15].

Considering the results of the experiments, it was observed that the compressive strength of concrete increases when SSFA is added, considering this fact, SSFA can be successfully used as an admixture in concrete. Furthermore, there are no legal guidelines related to the requirements of the physical and chemical properties of SSFA, as well as the possibility of its use in concrete production. By tailoring it to the unique requirements of the construction industry, we can successfully decrease SSFA [16]. By adapting it to the unique requirements of the construction industry, we can successfully reduce SSFA which is a starting point for further research.

3.3. Reuse of glass fibre-reinforced plastic in concrete

Glass fibre-reinforced plastic, or GFRP, is becoming increasingly popular in several sectors. It is used, for instance, in the automotive, aerospace, building, marine, and renewable energy sectors [17]. A substantial quantity of glass fibre-reinforced plastic waste is expected to decrease in the coming years due to the growth in production and use of the product on the basis of GFRP [18].

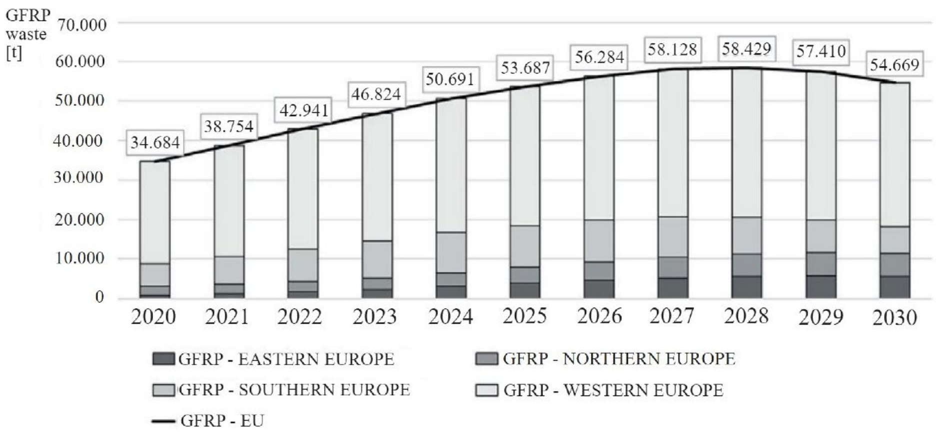


Figure 4. Amount of GFRP waste per region [19]

Figure 4 shows the amount of GFRP waste that appears in Europe. Data for Eastern, Northern, Southern and Western Europe from 2020 to 2030 are displayed. The black line across the graph represents the total waste from GFRP in the EU. The Y-axis represents the "Amount of GFRP waste per region" and ranges from 0 to 70,000. The X-axis represents the years from 2020 to 2030. Western Europe has the most GFRP waste in 2024, and Northern Europe the least. Western Europe has approximately 55,000 tons of waste and Northern Europe has approximately 20,000 tons of waste [19].

Sorting, trimming, pulverizing, and sifting are just some of the steps in the mechanical recycling process that are used to reduce the amount of GFRP waste [2], [20]. In the production of concrete, the use of mechanically recycled glass fibre-reinforced plastic (rGFRP) appears to be a viable choice. This tactic not only lessens the quantity of materials that must be disposed of in landfills, but it also maintains and occasionally even enhances the concrete's quality [21].

Currently, three methods may integrate rGFRP from mechanical recycling in concrete. One method entails transforming GFRP waste into fine granules that can be used as fine aggregate in concrete mix. Another method entails cutting the GFRP waste into larger pieces, which are suitable for replacing the coarse aggregate in the concrete mix. In addition, GFRP waste that is turned into fine fibres by mechanical processing can be used in the production of reinforcing bars. Fibres further improve the mechanical properties of reinforcing bars. These three methods for incorporating rGFRP into concrete have potential advantages as they can greatly improve the mechanical properties of concrete.

Research [22], [23], [24] showed that adding GFRP to concrete has increased the flexural strength, toughness of concrete, durability of concrete, control of cracking due to drying and reduction of moisture in the concrete mixture.

GFRP holds the potential to improve the properties of concrete mixture, but its application in concrete has not received enough research yet. Evaluating the long-term effects of using GFRP waste on the durability of concrete is also crucial. Further research into the possibilities of waste glass fiber reinforced polymer in concrete is becoming more pertinent due to the growing need for sustainable materials in the building industry.

3.4. PET waste in concrete mixture

Significant environmental problems have arisen as a result of the massive amounts of stable waste made by polyethylene terephthalate (PET). Though they trail behind in terms of recycling and reuse, they nonetheless represent a sizable amount of all plastic waste. Recent research has investigated the viability of using recycled PET solid wastes as short fibres in cementitious composites [25].

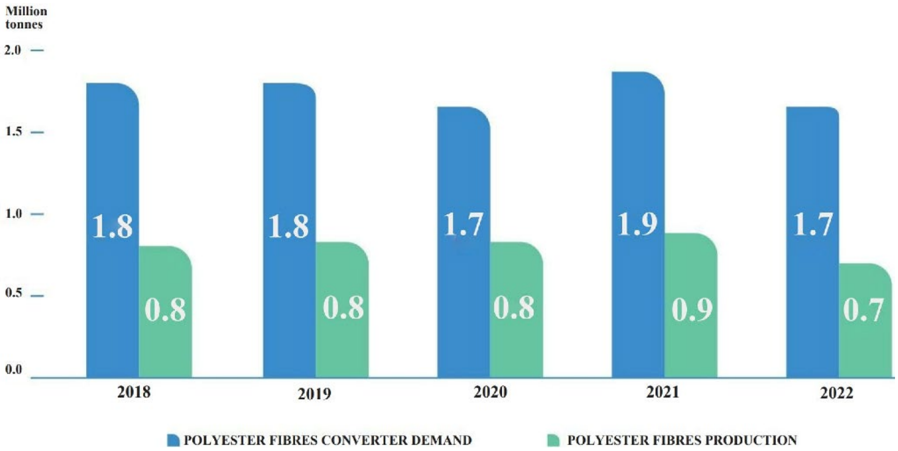


Figure 5. Polyester fibres production and converter demand evolution between 2018 and 2022 for EU [26]

Figure 5 shows the comparison of polyester fibre demand (blue bars) and production (green bars) from 2018 to 2022. The highest demand was recorded in 2021 and amounted to 1.9 million tons, while the lowest production was in 2022 and amounted to 700,000 tons. In 2022, the demand decreased due to unfavorable economic conditions, rising prices, and recessionary issues. Fibre production process is shown on figure 6. Also, table 1 shows the summary of test results on the mechanical properties of concrete modified with PET fibres.

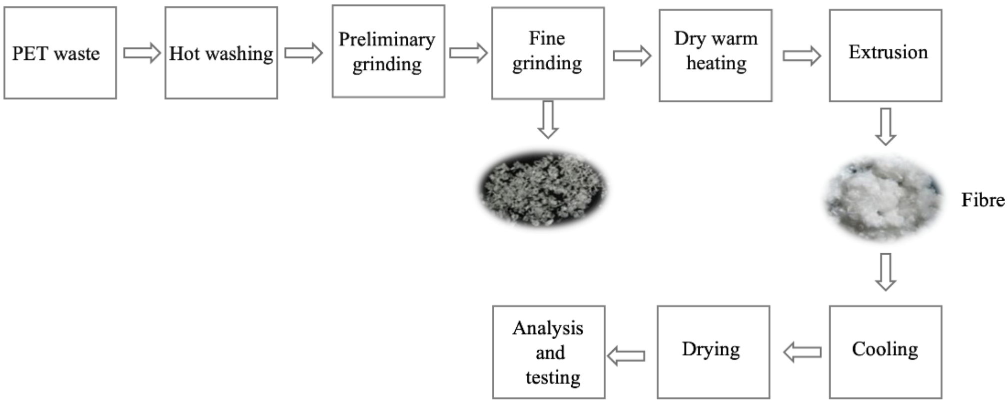


Figure 6. Fibre production process [27]

Table 1. Test results on the mechanical properties of concrete modified with PET fibres

Mechanical properties	Test results	Reference
Compressive strength	**With a higher proportion of fibres, the compressive strength decreases**	**[27]**
Flexural strength	**Increases as the percentage of fibres in concrete increases**	**[28]**
Split tensile strength	**Fiber can enhance the tensile splitting strength of concrete**	**[29]**
Shear strength	**At 1 % volume percent of plastic fibres, the shear strength of concrete increases, and it decreases as the volume fraction of fibres increases thereafter**	**[27]**
Modulus of elasticity	**With a higher proportion of fibres, the modulus of elasticity decreases**	**[30]**
Bulk density	**With a higher proportion of fibres, the modulus of elasticity decreases**	**[31]**
Energy consumption	**Increases as the percentage of fibres in concrete increases**	**[32]**

Apart from the fact that plastic is very useful for any form of industry, it also creates a big problem for the environment due to its slow decomposition. Considering the large quantities of PET waste, its use in concrete in the form of fibres provides an alternative to the disposal of large quantities of PET waste. Adding PET fibres to concrete improves flexural strength, split tensile strength, energy consumption and shear strength (depending on fibre concentration), while it has a negative impact on compressive strength and bulk density. For further research, it is necessary to examine how different concentrations, lengths, thicknesses, shapes, textures and surface treatments of PET fibres affect the mechanical properties of concrete under different loads and environmental conditions.

3.5. Adding rubber into the concrete mix

European countries face the problem of rehabilitation of a large amount of polymer waste that has no practical application. Rubber floor mats for cars belong to the group of polymer waste. Polymeric waste is a big problem because there is currently no effective method for disposing this type of waste. Some European Union countries charge an environmental fee for the disposal of rubber car floor mats, and the first country to introduce an environmental fee for this type of waste is Poland. Due to the mentioned problem, the option of adding polymer waste to concrete as a substitute for aggregate is being considered more and more [33]. Shredding process of rubber floor mats for cars is shown on figure 7.

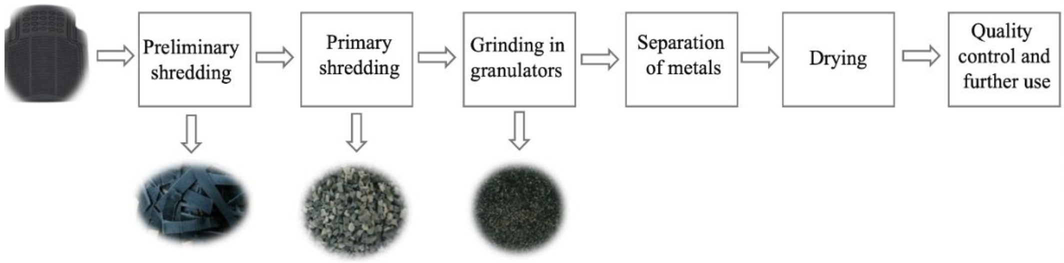


Figure 7. Shredding process of rubber floor mats for cars [34]

Table 2. Advantages and disadvantages of adding rubber as an aggregate to the concrete mixture [35], [36], [37]

Advantages	Disadvantages
increases shrinkage	**increases the penetration of chloride ions**
increases electrical resistance	**reduces workability**
increases the ductility and deformation capacity of concrete	**reduces the fire resistance**
increases thermal insulation	**reduces resistance to carbonation**
improves impact load behaviour and impact load behaviour	**reduces density**
increases the wear resistance of concrete	**reduces mechanical strength**
increases sound absorption	

Rubber has many benefits over natural aggregates in mortars and concrete, including lower matrix density, greater flexibility, durability, better resistance to impact loads, better freeze-thaw resistance, better thermal and acoustic insulation, increased deformation capacity, and better energy absorption capabilities. However, using shredded rubber in place of natural aggregates in mortar or concrete formulations may have some disadvantages. A few examples are reduced workability, increased drying shrinkage, higher water absorption, and improved chloride ion penetration. To sum up, crumb rubber is a great material to use for creating lightweight mortars and concrete. Two interesting applications for it are as a shock absorber in road construction and as a shock-wave dampener in construction.

4. CONCLUSION

Sustainable construction and responsibility towards the environment requires the use of eco-friendly materials, waste reduction and the application of net zero building. The future of construction in the framework of sustainable development is reflected in the application of advanced construction technologies and sustainable designs. This implies the use of various environmentally acceptable materials. All this points to the necessity of adopting the principles of the circular economy in construction. Circular economy implies circular flows of materials, reuse of waste and resources, which ultimately results in an increase in ecological efficiency.

REFERENCES

[1]. Eurostat, EC Data Browser, Sewage sludge production and disposal, 2024, [Online]. Available: https://ec.europa.eu/eurostat/databrowser/view/env_ww_spd/default/bar?lang=en&category=env.env_wat.env_nwat. (Accessed: 04.05.2024.)

[2]. A. E. Krauklis, C. W. Karl, A. I. Gagani, and J. K. Jørgensen, "Composite Material Recycling Technology—State-of-the-Art and Sustainable Development for the 2020s," *Journal of Composites Science*, vol. 5, no. 1, p. 28, 2021, doi: 10.3390/jcs5010028

[3]. P. Núñez-Cacho, J. Górecki, V. Molina, and F. A. Corpas-Iglesias, "New Measures of Circular Economy Thinking In Construction Companies," *Journal of EU Research in Business*, vol. 2018, pp. 1–16, Apr. 2018, doi: 10.5171/2018.909360

[4]. K. Vićentijević, "Održivost i cirkularna ekonomija", in *Zbornik radova MES*, vol. 1, no. 9, Oct. 2023, doi: 10.7251/BLCZR0623287V

[5]. L. Lovrenčić Butković and M. Mihaljević, "Poznavanje koncepta kružne ekonomije u građevinskom sektoru", *Ekonomska misao i praksa*, vol. 30, no. 2, pp. 587–608, Dec. 2021, doi: 10.17818/EMIP/2021/2.14.

[6]. M. Geissdoerfer, P. Savaget, N. M. P. Bocken, and E. J. Hultink, "The Circular Economy – A new sustainability paradigm?," *Journal of Cleaner Production*, vol. 143, pp. 757–768, Feb. 2017, doi: 10.1016/j.jclepro.2016.12.048.

[7]. C. K. Purchase *et al.*, "Circular Economy of Construction and Demolition Waste: A Literature Review on Lessons, Challenges, and Benefits," *Materials*, vol. 15, no. 1, p. 76, Dec. 2021, doi: 10.3390/ma15010076.

[8]. J. Li, W. Zhang, C. Li, and P. J. M. Monteiro, "Green concrete containing diatomaceous earth and limestone: Workability, mechanical properties, and life-cycle assessment," *Journal of Cleaner Production*, vol. 223, pp. 662–679, Jun. 2019, doi: 10.1016/j.jclepro.2019.03.077.

[9]. N. G. Muradyan *et al.*, "The Use of Biosilica to Increase the Compressive Strength of Cement Mortar: The Effect of the Mixing Method," *Materials*, vol. 16, no. 16, p. 5516, Aug. 2023, doi: 10.3390/ma16165516.

[10]. S. Nawaz, F. Jamil, P. Akhter, M. Hussain, H. Jang, and Y.-K. Park, "Valorization of lignocellulosic rice husk producing biosilica and biofuels—a review," *Journal of Physics: Energy*, vol. 5, no. 1, p. 012003, 2023, doi: 10.1088/2515-7655/aca5b4.

[11]. L. P. Singh, S. R. Karade, S. K. Bhattacharyya, M. M. Yousuf, and S. Ahalawat, "Beneficial role of nanosilica in cement based materials – A review," *Construction and Building Materials*, vol. 47, pp. 1069–1077, Oct. 2013, doi: 10.1016/j.conbuildmat.2013.05.052.

[12]. T. Umar, M. Yousaf, M. Akbar, N. Abbas, Z. Hussain, and W. S. Ansari, "An Experimental Study on Non-Destructive Evaluation of the Mechanical Characteristics of a Sustainable Concrete Incorporating Industrial Waste," *Materials*, vol. 15, no. 20, p. 7346, 2022, doi: 10.3390/ma15207346.

[13]. Z. Hussain *et al.*, "Effect of fiber dosage on water permeability using a newly designed apparatus and crack monitoring of steel fiber–reinforced concrete under direct tensile loading," *Structural Health Monitoring*, vol. 21, no. 5, pp. 2083–2096, Sep. 2022, doi: 10.1177/14759217211052855.

[14]. S. Ahmed, A. Hussain, Z. Hussain, Z. Pu, K. A. Ostrowski, and R. Walczak, "Effect of Carbon Black and Hybrid Steel-Polypropylene Fiber on the Mechanical and Self-Sensing Characteristics of Concrete Considering Different Coarse Aggregates' Sizes," *Materials*, vol. 14, no. 23, p. 7455, Dec. 2021, doi: 10.3390/ma14237455.

[15]. O. Ginés, J. M. Chimenos, A. Vizcarro, J. Formosa, and J. R. Rosell, "Combined use of MSWI bottom ash and fly ash as aggregate in concrete formulation: Environmental and mechanical considerations," *Journal of Hazardous Materials*, vol. 169, no. 1–3, pp. 643–650, Sep. 2009, doi: 10.1016/j.jhazmat.2009.03.141.

[16]. T. Kalak, P. Szypura, R. Cierpiszewski, and M. Ulewicz, "Modification of Concrete Composition Doped by Sewage Sludge Fly Ash and Its Effect on Compressive Strength," *Materials*, vol. 16, no. 11, p. 4043, May 2023, doi: 10.3390/ma16114043.

[17]. C. B. Farinha, J. de Brito, and R. Veiga, "Assessment of glass fibre reinforced polymer waste reuse as filler in mortars," *Journal of Cleaner Production*, vol. 210, pp. 1579–1594, 2019, doi: 10.1016/j.jclepro.2018.11.080.

[18]. F. Tittarelli and S. P. Shah, "Effect of low dosages of waste GRP dust on fresh and hardened properties of mortars: Part 1," *Construction and Buildings Materials*, vol. 47, pp. 1532–1538, 2013, doi: 10.1016/j.conbuildmat.2013.06.043.

[19]. V. Sommer, J. Stockschläder, and G. Walther, "Estimation of glass and carbon fiber reinforced plastic waste from end-of-life rotor blades of wind power plants within the European Union," *Waste Management*, vol. 115, pp. 83–94, Sep. 2020, doi: 10.1016/j.wasman.2020.06.043.

[20]. A. C. Meira Castro *et al.*, "Sustainable waste recycling solution for the glass fibre reinforced polymer composite materials industry," *Construction and Building Materials*, vol. 45, pp. 87–94, 2013, doi: 10.1016/j.conbuildmat.2013.03.092.

[21]. N. Sebaibi, M. Benzerzour, N. E. Abriak, and C. Binetruy, "Mechanical properties of concrete-reinforced fibres and powders with crushed thermoset composites: The influence of fibre/matrix interaction," *Constr Build Mater*, vol. 29, pp. 332–338, 2012, doi: 10.1016/j.conbuildmat.2011.10.026.

[22]. B. Fu, K. C. Liu, J. F. Chen, and J. G. Teng, "Concrete reinforced with macro fibres recycled from waste GFRP," *Construction and Building Materials*, vol. 310, p. 125063, Dec. 2021, doi: 10.1016/j.conbuildmat.2021.125063.

[23]. A. Yazdanbakhsh, L. C. Bank, and C. Chen, "Use of recycled FRP reinforcing bar in concrete as coarse aggregate and its impact on the mechanical properties of concrete," *Construction and Building Materials*, vol. 121, pp. 278–284, Sep. 2016, doi: 10.1016/j.conbuildmat.2016.05.165.

[24]. M. Mastali, Z. Abdollahnejad, A. Dalvand, A. Sattarifard, and M. Illikainen, "Comparative effects of using recycled CFRP and GFRP fibers on fresh- and hardened-state properties of self-compacting concretes: a review," in *New Materials in Civil Engineering*, Elsevier, 2020, pp. 643–655. doi: 10.1016/B978-0-12-818961-0.00019-3.

[25]. J. Yu *et al.*, "Tensile performance of sustainable Strain-Hardening Cementitious Composites with hybrid PVA and recycled PET fibers," *Cement and Concrete Research*, vol. 107, pp. 110–123, May 2018, doi: 10.1016/j.cemconres.2018.02.013.

[26]. Pet Market in Europe: State of Play, Independent Commodity Intelligence Services, 2024, [Online]. Available: https://www.unesda.eu/wp-content/uploads/2024/03/PET-Market-in-Europe-State-of-Play.pdf. (Accessed: 25.05.2024.)

[27]. R. N. Nibudey, P. B. Nagarnaik, D. K. Parbat, and A. M. Pande, "A model for compressive strength of PET fiber reinforced concrete," *American Journal of Engineering Research*, vol. 02, no. 12, pp. 367–372, 2013.

[28]. R. Kandasamy and R. Murugesan, "Fiber Reinforced Self Compacting Concrete Using Domestic Waste Plastics as Fibres," *Journal of Engineering and Applied Sciences*, vol. 7, no. 6, pp. 405–410, Jun. 2012, doi: 10.3923/jeasci.2012.405.410.

[29]. D. Foti, "Preliminary analysis of concrete reinforced with waste bottles PET fibers," *Construction and Building Materials*, vol. 25, no. 4, pp. 1906–1915, Apr. 2011, doi: 10.1016/j.conbuildmat.2010.11.066.

[30]. J. M. Irwan, R. M. Asyraf, N. Othman, K. H. Koh, M. M. K. Annas, and S. K. Faisal, "The Mechanical Properties of PET Fiber Reinforced Concrete from Recycled Bottle Wastes," *Advanced Materials Research*, vol. 795, pp. 347–351, Sep. 2013, doi: 10.4028/www.scientific.net/AMR.795.347.

[31]. Sampada Chavan and Pooja Rao, "Utilization of Waste PET Bottle Fibers in Concrete as an Innovation in Building Materials," *International Journal of Engineering Research*, vol. 5, pp. 304–307, 2016.

[32]. M. da Silva Magalhães and M. Soares Viana Fernandes, "Bending Behaviour of Recycled PET Fiber Reinforced Cement-Based CompositeBending Behaviour of Recycled PET Fiber Reinforced Cement-Based Composite," *International Journal of Engineering and Technology*, vol. 7, no. 4, pp. 282–285, Aug. 2015, doi: 10.7763/IJET.2015.V7.805.

[33]. A. Pietrzak and M. Ulewicz, "Influence of Post-Consumer Waste Thermoplastic Elastomers Obtained from Used Car Floor Mats on Concrete Properties," *Materials*, vol. 16, no. 6, p. 2231, Mar. 2023, doi: 10.3390/ma16062231.

[34]. A. Pietrzak and M. Ulewicz, "Influence of Post-Consumer Waste Thermoplastic Elastomers Obtained from Used Car Floor Mats on Concrete Properties," *Materials*, vol. 16, no. 6, p. 2231, Mar. 2023, doi: 10.3390/ma16062231.

[35]. N. M. Al-Akhras and M. M. Smadi, "Properties of tire rubber ash mortar," *Cement and Concrete Composites*, vol. 26, no. 7, pp. 821–826, Oct. 2004, doi: 10.1016/j.cemconcomp.2004.01.004.

[36]. A. O. Atahan and A. O. Yucel, "Crumb rubber in concrete: Static and dynamic evaluation," *Construction and Building Materials*, vol. 36, pp. 617–622, Nov. 2012, doi: 10.1016/j.conbuildmat.2012.04.068.

[37]. A. Benazzouk, O. Douzane, T. Langlet, K. Mezreb, J. M. Roucoult, and M. Quéneudec, "Physico-mechanical properties and water absorption of cement composite containing shredded rubber wastes," *Cement and Concrete Composites*, vol. 29, no. 10, pp. 732–740, Nov. 2007, doi: 10.1016/j.cemconcomp.2007.07.001.

ICOEST SARAJEVO
10TH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY
June 05-09 2024 (Hybrid Event)

Feasibility of Using Black Liquor Waste as Cementious Material Admixture: An Example of Algerian Research

Miloud Beddar[1], Abdelaziz Meddah[2], Djelloul Laadjal[1], Aziz Chikouche[1]

Abstract

Over the past few decades, extensive research has been conducted on the use of waste from paper plants in many parts of the world by valorizing it into civil engineering materials. This approach aims to minimize the environmental degradation that results from the dumping of these huge quantities of liquid into valleys and rivers. The main aim of this experimental study was to investigate the feasibility of using black liquor obtained from paper plants in Algeria as an admixture in cement materials. Black liquor was added in different percentages: 0.2, 0.25, 0.3, and 0.35% by weight of cement for the cement paste study. For concrete, the percentage of black liquor varied from 2% to 6% by weight of cement, with increments of 0.05%. The results obtained show that black liquor considerably decreases the consistency of cement paste by more than 10% and also reduces the initial setting time of the cement. The fluidity and compressive strength of the concrete were significantly increased by the addition of black liquor. Moreover, the analysis of the experiment results indicated that adding black liquor acts as an effective admixture in both concrete and mortar.

Keywords: Admixture , Black liquor, Consistency , Lignin, Shrinkage , Workability.

1. INTRODUCTION

In Algeria, the paper industry, which has gradually developed since independence, has an important place due to the growing need for paper and the availability of raw materials, especially esparto grass called ALFA. The use of the ALFA in the Algerian industry and its importance were based on Alfa's unique fibre character, making it one of the finest pulps for high-grade printing paper [1].

For a long time, the Alfa plant was used as feedstock for the Algerian paper industry and produced a large amount of black liquor waste. The black liquor of the paper industry, Algeria's only potential source of lignin material, is still discharged into valleys , rivers rivers and sewers, causing serious environmental impacts [2].

Given the nature of this highly polluting waste and its large volume, it is vital to research the possibility of valorising it in the form of a useful product with commercial value, since it can advantageously replace imported products.

Among the numerous possible applications of black liquor is to use it as an admixture in cementitious materials in this study.

Admixtures are substances introduced into mortar or concrete mixes to alter or improve the properties of fresh or hardened concrete or both [3]. In general, these changes are affected by the influence of the admixtures on hydration, heat liberation, pore formation, and gel structure development. Concrete admixtures should only be considered for use when the required modifications cannot be made by varying the composition and proportion of the basic constituent materials, or when the admixture can produce the required effects more economically.

The present experimental work, revealed that black liquor, a waste product from the paper industry taken from the BABA ALI paper plant, has low viscosity and high solubility, and is composed mainly of lignin,

[1] *Laboratory of Materials and Mechanics of Structures, Technology Faculty, Department of Civil Engineering, M'sila University, P.O. Box 166, Ichbilia, 28000 Msila, Algeria (miloud.beddar@univ-msila.dz)*

which is usually used as a binder, surface-active agent dispersant, and emulsifier [4,5]. Lignin refers to lignosulfonate acids, which are commonly used as water-reducing and fluidity-improving agents in concrete

Over the past few decades, many researchers have attempted to invistigate how black liquor waste can be valorized in civil engineering field. Many researchers reported that the amount of lignin is continuously increasing around the world [4,5,6]. The authors also reported that current trends in the solution of world energy problems cannot be regarded as environmentally safe and completely admissible if the problem of the utilization of lignin wastes via their conversion into commercial products remains unsolved.
The main objective of this paper was to investigate the feasibility of using black liquor as an admixture. The experimental approach followed in this paper aims to study the effects of black liquor on the properties of cemnt paste, mortar and concrete.

2. MATERIALS

2.1. Black liquor: The black liquor used in this study was obtained with sodium hydroxide, produced by Paper Alfa plant in the BABA ALI region (Algeria). Black liquor is a by-product (waste) of the manufacturing industry's paper paste. This is a concentrated aqueous phase that contains dissolved organic and inorganic material, mostly polysaccharides derived from the degradation of hemicelluloses and cellulose; lignin, which is more or less transformed and degraded; extractable timber; organic and mineral residues; and chemical residues added for cooking (mainly sodium, potassium, sulfate, sulfide, thiosulfate, sulfite and carbonate). It is a brown liquid with a density of 1.004 (very diluted) and has an acrid odor. To increase the amount of dry matter in the solution, black liquor was subjected to heat treatment. The main properties of the black liquor are shown in Table 1.

Table 1. Analysis of black liquor produced by the National Society of Cellulose and Paper

Density (g/cm^3)	Solid Content (%)	Lignin content (g/l)	PH	Surface tension $dyn.cm^{-1}$
1.1	27	125	10	40

Lignin is the main substance in the composition of black liquor, and has a high surface effectiveness. This property makes concrete or mortar a highly workable material, so the process of finding a water-reducing substance from the heat treatment process of the black liquid from the Algerian paper mills seems very feasible, and the research conducted on this liquid confirms that this substance after heat treatment has the same properties as the substance known as lignosulfonic acid, which is currently used as a water-reducing additive in concrete and mortar, and if it contains a quantity of sugar, it is used as an anti-freeze additive. The purpose of heat treatment of black liquid is to increase its concentration and increase its surface tension, which leads to an increase in the effect of additive activity on the fluidity of fresh concrete and mortar.

2.2. Aggregates: The fine aggregates used were dune sand, which was clean and siliceous, and contained very little fine dust or clay. The coarse aggregate is also a local aggregate obtained from crushing limestone rock from the quarry of COSIDER, which is situated in the El-EUCH region. This aggregate has two fractions, 3/8 and 8/15. The principal characteristics of the two aggregates are shown in Table 2.

Table 2. Some characteristics of the sand and gravel used in the tests

Materials	Density	Porous/dense	compactness	Porosity	Sand equivalent
Sand	2.56	1.64/1.83	36.42/70.76	36.58/29.24	75.4/77.2
Gravel 3/8	2.68	1.28	47.46	52.24	……………….
Gravel 8/15	2.68	1.32	49.25	50.75	…………………

2.3. Cement : The cement used in this study was ordinary Portland cement (OPC). It comes from the cement factory of the AIN-TOUTA Company, and is composed of clinker (95%) and gypsum (5%), for the regularization of the setting. The chemical analysis of the cement showed that it conforms with standard NF.P 15-301[9], with a % [MgO + CaO (free)] < 5%. The chemical and physico-mechanical properties of the used cement are presented in Table 3 and 4.

***Table 3**. Chemical composition of O.P.C. (C.P.A325)*

Content %								
SiO_2	Al_2O3	CaO	MgO	MnO	K_2O	FeO	SO_3	IR
22.64	4.79	63.6	1.63	1.18	0.2	3.44	2.29	< 3

***Table 4**. Physical and mechanical properties of O.P.C. (C.P.A325)*

Specific density (kg/dm^3)	Blaine fineness m^2/kg	Normal consistency (%)	Setting time(mn) Intial	Setting time(mn) Final	Compressive strength (MPA)	Shrinkage µm/ml
3050	3200	25	210	360	40	800

3. Preliminary tests.

To determine the effect of black liquor on the physical, rheological, and mechanical properties of cement paste and concrete, several tests have been carried out. However, before starting these tests, trail tests on the black liquor were carried out to evaluate the dry matter in the liquid. The relationship between black liquor density and dry matter is presented in Figure 1.

The cement paste, mortar and concrete specimens were demolded after 24 hours of preparation and cured under laboratory conditions (25°C and 50–60 RH). The compressive strength and shrinkage strength were evaluated after 7 and 28 days of curing under the conditions cited above, and the arithmetic mean of three values was calculated. Cubic specimens (150×150×150 mm) were used to measure the concrete compressive strength, and prismatic specimens (40×40×160 mm) were used to evaluated compressive, flexural and shrinkage of the mortar.

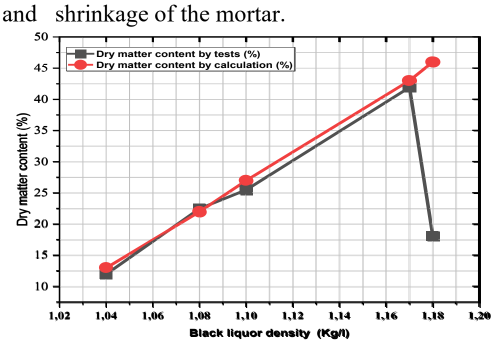


Fig.1 Relationship between black liquor density and dry matter content

4. RESULTS AND DISCUSSION

4.1. Effect of black liquor on the setting time and consistency of cement paste

Initial experiments to determine the effect of adding black liquid to the cement paste were carried out by using Portland cement CPA 325. The results illustrated in Figures 2,3 and 4 , show the effect of black liquor on the consistency, and the setting time of the cement. The obtained results show that the use of black liquor leads to a decrease in the consistency of the cement paste . For example, incorporating 0.35% black liquor reduces the water consistency by 10% in comparison with that of the control mixture (without black liquor). On the other hand, the initial setting time decreased from 195 minutes to 62 minutes, which means that the black liquor accelerated the mixture. Moreover, the final setting time was not a major change.

The addition of the black liquor was carried out at different values. The results show that there are effects on the cement paste that can be explained as follows: The additive is concentrated on the contact surface between the cement particles and water. This concentration leads to a change in the physico-chemical forces applied to this surface, on the one hand, and on the other hand, the additive particules adhere to the cement particles, giving them negative charges, which leads to repulsion of the cement particles between them (Fig

5). This repulsion expands the surface area prepared for the interaction between cement particles and water, and at the same time, the water trapped between the cement particles collected before the addition is released, thus increasing the workability and freedom of the water movement in the cement mixture. The air bubbles are repelled and prevented from sticking to the cement particules by the charged additives, and thus the distance between the cement particules among themselves and between them and the air bubbles increases, allowing the water molecules to move easily, and water in the meantime plays a lubricating role for the solid particles.

The setting time of the cement remains almost constant with different percentages of black liquor admixture, but from a dosage of 030% onwards, the setting time is significantly shortened. It should be noted that in any case, the setting time exceeds the standard time (45 minutes); this shows that concrete and mortar with black liquor admixtures can be used in a wide range of applications

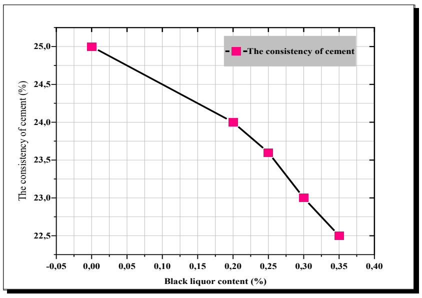


Fig 2. Variation of cement consistency in function of black liquor content

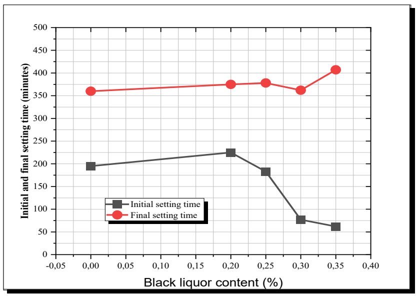


Fig 3. The setting time change in relation to the black liquor content

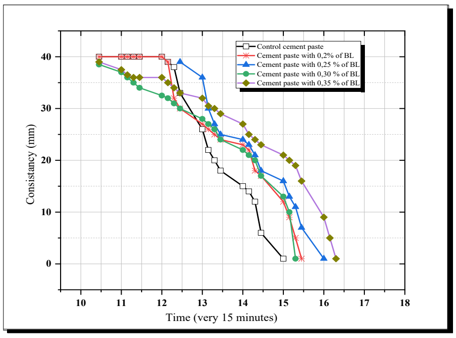


Figure 4. Paste cement consistency in function of time

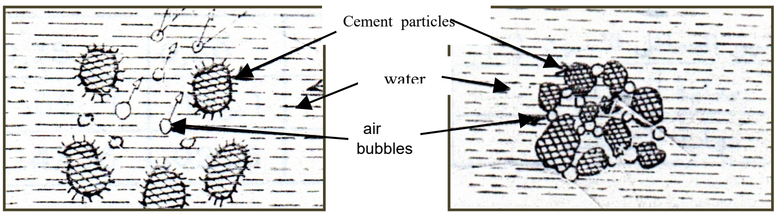


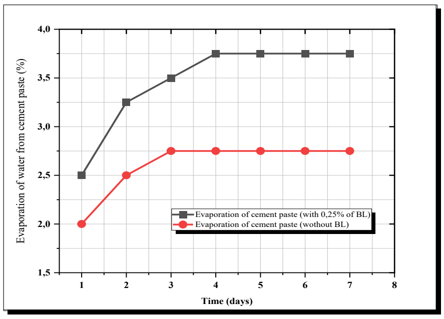
Fig 5. The effect of the black liquid on the structure of the cement paste

4.2. Effect of black liquor on cement paste evaporation.

Water evaporation is much slower for cement paste containing black liquor than for cement paste not containing black liquor. The results were obtained after exposing the cement paste samples to a dry medium, at a temperature of 35 °C, and the amount of evaporation lost by the paste, was calculated daily. The samples were weighed at the beginning and after each day; evaporation is expressed as the difference between the initial weight and the successive weight, which is presented as a percentage relative to the weight of the water released from the paste. The results obtained from this experiment are presented in Figure 6 , which shows the the percentage of water evaporation from the cement paste over time. From the Figure 6, we can conclude that the slowing down process of the cement paste is favourable for the complete completion of the hydration process. Increasing the resistance of the concrete and mortar and providing enough time for heat leakage reduces the phenomenon of cracking

Specimen appellation	Cement/sand	Water/cement	Black liquor	Water reduction ΔE (%)	Mortar maniability Slump test (cm)	Volumic weight (kg/l)
M_0	1/3	0.55	0	0	4.25	2.37
M1	1/3	0.55	0.05	0	5.57	2.37
M2	1/3	0.51	0.05	7	2.73	2.37
M3	1/3	0.57	0.20	0	6.58	2.32
M4	1/3	0.52	0.20	6	4.35	2.37
M5	1/3	0.55	0.25	0	7.18	2.30
M6	1/3	0.51	0.25	7	4.68	2.31
M7	1/3	0.55	0.30	0	7.86	2.30
M8	1/3	0.48	0.30	12	4.12	2.35
M9	1/3	0.55	0.35	0	7.96	2.28
M10	1/3	0.47	0.35	14	4.06	2.305
M11	1/3	0.55	0.40	0	7.98	2.28
M12	1/3	0.46	0.40	16	3.58	2.31
M13	1/3	0.55	0.45	0	8.16	2.30
M14	1/3	0.46	0.45	17	3.41	2.33

of the concrete surface limited by evaporation.



Vater evaporation from cement paste (with and without BL) in function of time

4.3. Effect of black liquor on mortar.

4.3.1. Effect of black liquid on mortar fluidity and volumic weight

We prepared fifteen mortar mixtures containing M0, M1...M14. The compositions of all mixtures are presented in the table 5.

- M_0 mortar is the mortar without additives (control),
- Mortars M_1, M_3, M_5, M_7, M_9, and M_{11} are mortars with different proportions of additives (0.05, 0.20, 0.25, 0.30, 0.35, 0.40, 0.45) and no water reduction.
- The M_2, M_4, M_6, M_8, M_{10}, and M_{12} mortars with additives in the above proportions, but with reduced water content and almost the same fluidity as the control mortar.

The fluidity of a mortar is expressed by the depth of penetration in the mortar of a standardized cone weighing 300 g with an angle at the top of 30°. The results obtained are shown in the table 9 .

The densities of the mortars do not differ considerably, showing that they have almost the same compactness.

However, compared with that of the control mortar, the fluidity of the mortars increased with increasing dosage of the Black liquor admixture.To keep the fluidity almost constant, the water content or the W/C ratio of the mortar can be significantly reduced.

Table 5. *Mixtures composition of mortars and the results of maniability and volumic weight*

4.3.2. Effect of black liquor on the fluidity loss of fresh mortar.

To evaluate the loss of fluidity of a fresh mortar exposed to a hot climate, three mortar mixes, M0, M7 and M8, were prepared. The initial weights of the three mixtures were determined, and then the mixtures were exposed to open air under sunlight at a temperature of 35 °C. Fluidity tests were carried out every

15 minutes. The results obtained are illustrated in figure 7, while figure 8 shows the relatonship between mortar maniability and black liquor content . From these results, it can be seen that there was no clear difference between the loss of fluidity of the mortars without adjuvant and with adjuvant without water reduction. It is obvious that the loss of fluidity of the mortar with admixture and water reduction is much lower than that of the mortar without admixture. This also reveals the remarkable advantageous effect of the admixture on concrete and mortar made under the hot and humid conditions of Algeria. Resurgence does not occur in mortar with admixture and water reduction, whereas it is serious in mortar without admixture and mortar with admixture without water reduction. This can be explained by the water reduction and high water retention capacity of the admixed mortar.

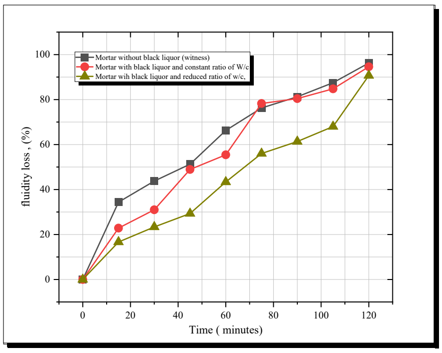


Figure 7. The fluidity loss of fresh mortar in function of time

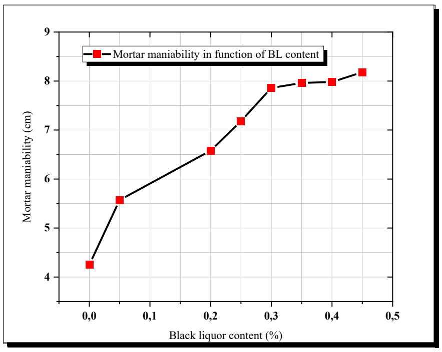


Figure 8. Mortar maniability in function of black liquor content

4.3.3. Effect of black liquid on mortar shrinkage phenomena

Test specimens (4x4x16 cm), were used to determine the shrinkage of the mortar. Four types of mortar were prepared according to the compositions shown in the table..Both mortars were used to mould two similar test pieces. A small screw with a spherical head was placed at the end of each test piece. After 24 hours, the specimens were stripped, and the distance between two screws in each specimen was measured almost every day on a device equipped with a 1 µm precision dial gauge to determine the shrinkage of the mortar and its increase over time. The results are shown in the Figure 9, while figure 10 represents the water reduction in function of black liquor content . According to these results, the mortars with different BL dosages always had lower shrinkage than did the mortars without additives (control). The shrinkage decreases when the BL dosage is increased (compared to M_4 to M_6). When comparing M_5 to M_6, it is apparent that mortar that has a BL admixture and water reduction shrinks less than mortar without it, even when the BL dosage is the same.

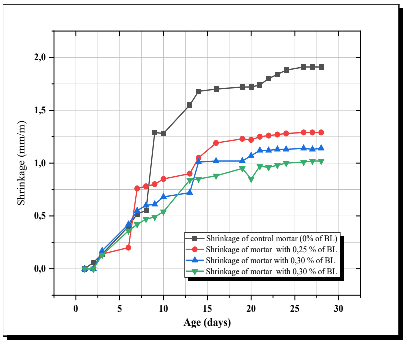


***Figure 9**. Free shrinkage of Mortar in function of time*

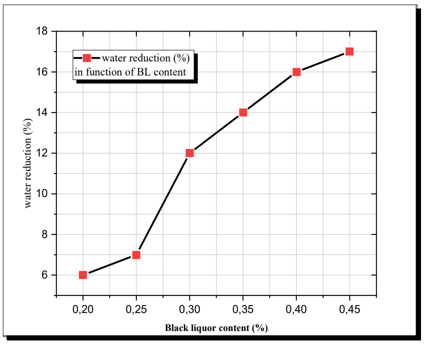


Figure 10 Water reduction in function of

4.3.4. Effect of black liquor on the mechanical properties of mortar.

To determine the mechanical properties (compressive, tensile, and flexural strengths) of the mortar, 14 mortar mixtures were prepared, and from each fresh mixture, 06 specimens with dimensions of 4x4x4x16 cm were obtained. After 24 hours, the specimens were demoulded and kept in a humid place in the laboratory until the testing process, which was carried out for seven days and 28 days. Table. shows the different mortar mixtures used to prepare the tested specimens. The bending test, (three -point method) is carried out with a bending apparatus, and the tensile strength is calculated.. The two parts resulting from the bending process in the bend were subjected to compression using a hydraulic press with a force of 300 kN. The results obtained are illustrated in figures 11 and 12.

From the results obtained, we observe the following:

- The resistance of solid mortars of different proportions to black liquid without water reduction does not vary but rather increases compared to that of typical samples despite their high fluidity.
- The resistance of the solid mortar in different proportions to black liquid with water reduction increases significantly compared to that of the witness sample; the mortar with 0.05% black liquid (M_2) has the greatest strength compared to the witness sample at 28 days with 170%.

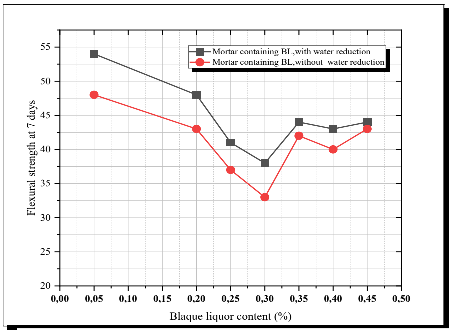


Figure 11. Flexural strength at 28 days in function of black liquor content

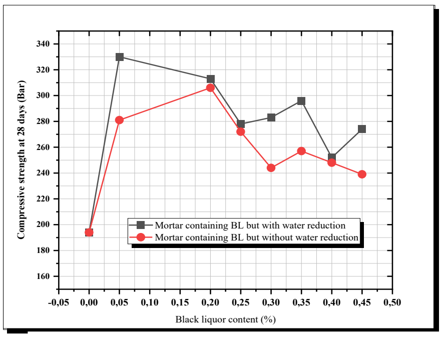


Figure 12. Compressive strength at 28 days in function of black liquor content

4.4. Effect of black liquor on concrete.

The effect of the admixture on the main properties of the concrete was judged by comparing the properties of the concrete without the admixture and with the admixture at different dosages. The composition of the concrete was determined by the SCRAMTAIEV method [10]. The results are presented in the table. On the basis of this concrete composition, 18 mixes were prepared. Samples B_1, B_2, B_4, B_6, B_8, B_{10}, B_{12}, B_{14} and B_{16} are concrete mixes with admixtures. Mixes B_3, B_5, B_7, B_9, B_{11}, B_{13}, B_{15} and B_{17} are concrete mixes with admixtures but with a reduction in water content and almost the same fluidity as the control concrete.

4.4.1. Fresh properties: workability and volumetric weight

The concrete workability was measured using a slump test for each black liquor content. The obtained results are shown in Fig 13. It should be noted that at a low amount of black liquor (less than 2%), the slump remained unchanged because the added quantity was insufficient.

When the amount of black liquor in the mixture changes from 0.2 to 0.5%, a regular increase in slump is observed. For example, the addition of 0.5% black liquor improved the workability by 125%. In this interval (0.2-0.5% of black liquor), it was observed during tests that the density increased slightly. Furthermore, when the black liquor content exceeded 0.5%, the slump increased slightly. In the same figure, it can be seen that the decrease in the w/c ratio in the mix (by decreasing water and increasing black liquor content) remained constant, which confirms that black liquor improves the workability.

As shown in Fig.13, using black liquor in the concrete mix as an admixture allowed the quantity of water to decrease by 12% while maintaining the same level of workability. In the presence of black liquor, the components of the mixture were arranged better and made a denser mixture.

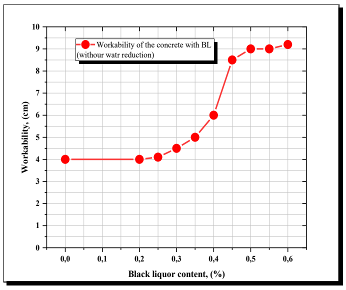


***Figure 13**. concrete workability in function of black*

4.4.2. Compressive strength of concrete with and without an admixture.

To study the effect of using black liquor in the mix on the mechanical properties of the concrete, 15×15×15 cm^3 test specimens were produced. Then, the compressive strengths were measured at 7, 28 and 60 days, with variations in the black liquor content and w/c ratio. The results are illustrated in the figure 14. According to the results obtained, the strength of concrete with different dosages of black liquor does not decrease; but rather increases slightly compared to that of the control concrete (B_0), despite the considerable increase in fluidity. This is due to the more uniform distribution of cement grains throughout the concrete (11).
compared with those of the control concrete with the same fluidity, the strengths of the concrete with black liquor admixtures at different dosages and water reduction at 7 days, 28 days and 60 days increase considerably.
A peak increase in strength (22%) is observed for the concrete with the addition of 0.25% black liquor. Beyond this two-sided dosage, the increase in strength becomes weaker. This shows that the optimum black liquor admixture content can be equal to 0.25% to obtain a maximum increase in strength, while the increase in fluidity increases with increasing black liquor admixture up to 00.5% of the weight of the cement.

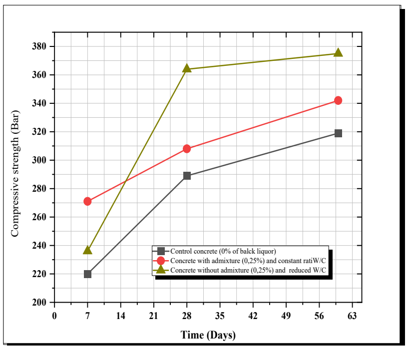


***Figure 14**. Compressive strength of concrete with and without BL addition in function of time*

5. CONCLUSION

By using black liquor as a superplasticizer, it is possible to control the slump of fresh concrete, which means, that the place ability of concrete might be improved. The concrete with black liquor was denser, which means that the durability improved.
Ultimately, the main benefits of this study are to show the possibility of avoiding the danger represented by the enormous quantities of black liquor thrown into rivers and transforming this liquid waste into an efficient ingredient for cementitious materials. The most important points we can take away from this study are as follows:
After treatment ,black liquor is a common plasticizing admixture for mortar and concrete. It has a relatively high lignin content and is superficially active.
✓ The cement paste consistency can be considerably decreased by the addition of 10% or more black liquor.

- ✓ Black liquor drastically shortens the initial setting time of cement but does not affect its final setting time.
- ✓ Black liquor dramatically improves mortar and concrete flow (usually by 4 to 8 cm of cone slump).
- ✓ Concrete with black liquor can have a much lower water content while maintaining the same fluidity as concrete without admixture (control).
- ✓ The mortar with the admixture and water reduction lost significantly less fluidity over time than did the mortar without the admixture.
- ✓ Despite the significant increase in fluidity, black liquor only marginally strengthned the concrete without lowering the water content.
- ✓ The graph in Figure 1 can be used to determine the dry matter content in black liquor and the dosage of liquor in the concrete and mortar.
- ✓ Black liquor significantly reduces the shrinkage of mortar, especially mortar with water reduction; this is important because it can lessen or eliminate the risk of cracks forming in concrete and mortar in the hot, dry climate of Algeria.
- ✓ Black liquor significantly increases the strength of concrete with water reduction (typically by 14 to 22%) at 28 days, by 17 to 26% at 7 days, and by up to 21% at 60 days.

REFERENCES

[1]. A.Maghchiche, H.Abdelkarim,I.Barbara I."Extraction and characterization of algerian alfa grass short fibers " Chemistry & Chemical Technology. vol 7 (3), pp 339-344, September 2013

[2]. H. Aksas, M. Hachemi S. Smaili " Recovery of waste from Algerian raw hides and their development in paper industry based on Alfa "A. J. Env.Sc. and Technology, Vol 6, n°1,pp 1230-1271, (2020).

[3]. *Standard Specification for Chemical admixtures for concrete , ASTM C494-92 ,* decembre 15.2019.

[4]. A.Samar El-Mekkawi, M. Ibrahim Ismail , M.Mohammed El-Attar , A.Alaa.Fahmy,S.Samia " Utilisation of black liquor on concrete admixture and set retarder aid " J. advanced research, Vol 2, pp.162-163, 2011 .

[5] Ajoy Kumar Mullick " *Use Of Lignin-Based Products In Concrete Waste Materials Used In Concrete Manufacturing*" Elsevier edition, book-chapter, pp 329-352, 1966.

[6] A. Irekti1, M. Oualit , H. Siahmed , D. Buncianu , F. Zibouche. " Effect of black liquor from date palm on the workability and compressive strength of Portland Cement and Concrete " advances in materials science journal, Vol 19, n°.3(61) , pp 5-18. sep 2009.

[7] S. Nikkanen "Liquor Heat Treatment And High-Dry-Solid Firing " Bio resource Technology, vol.46, issues1-2, pp 173-176, 1993.

[8] T. Michael Pichler, M.Silvia, K.Marlene " Influence of long-term treatment of kraft black liquor on lignin precipitation and material properties " Journal: Holzforschung, Vol.74, n° 3, pp.286-292, 2020

[9] *liants hydrauliques, ciments courants, composition, spécification critères de conformité.NF 15-301,Juin 1994.*

[10] file:///C:/Users/pc%20maker/Downloads/pdfcoffee.com_methode-des-volumes-absolus-pdf-free.pdf

10TH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL SCIENCE AND TECHNOLOGY